

## A COMPARATIVE STUDY ON THE ROLE OF MODELS AND PROTOTYPES IN HUMAN-CENTERED DESIGN VERSUS DESIGN-DRIVEN INNOVATION APPROACHES

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### Abstract

In search for meaningful and radical innovations, many authors comply with the understanding that User-Centred Design lead to incremental innovation. However, opposing views are prevalent among design researchers, when discussing and comparing the innovation impact between Human-Centred Design and Design-Driven Innovation approaches. Some researchers claim that Human-Centred Design methods contain a significant facilitative value for achieving radical innovation, because of their participatory and design led characteristics. However, this is contested by another group of researchers, who are convinced that to realise breakthrough innovation, user involvement, whether participative or not, is not sufficient. The aim of this article is to discuss on how models and prototypes can be applied in Design-Driven Innovation, as well as how they can facilitate a more explorative and creative approach towards idea and concept generation in a Human-Centred Design. Results indicate that active engagement through models and prototypes enables designers, stakeholders and interpreters to gain first-hand experience with existing or future design contexts.

**Keywords:** Design methods, Design-Driven Innovation, Human-Centred Design

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## **1 INTRODUCTION**

Within the context of design thinking for innovation, Human-Centred Design and Design-Driven Innovation approaches are becoming more popular problem-solving methodologies used by many industrial designers in the past 30 years (Brown, 2009). These methods emphasise visualisation of ideas, observation, collaboration, interpretation, rapid concept prototyping and concurrent business analysis, which ultimately influences how a company strategizes its current product and service portfolio or plan new products for the future. However, a structured Human-Centred Design approach is often silently contested by the more hermeneutic Design-Driven Innovation theories as advocated by Verganti (2008). According to Verganti and Norman (2014), a human-centered approach of iterated observation, ideation, quick prototyping and testing is very well suited for incremental innovation but unlikely leads to radical innovation (Norman and Draper, 1986). To achieve radical innovation, Verganti and Norman (2014) suggested a “Design Driven Research” approach where radical changes in meaning is cross-fertilised with radical changes in technology. However, both authors did not propose a clear methodological approach to achieve technology epiphanies. They merely suggested an approach where interpreters with expert knowledge need to be consulted to help the designer to acquire a deeper and historical understanding of a typical technology or product, so that he or she will gain better insights to “jump the hill”. Adopting a more positivistic worldview, Sanders and Stappers (2008) differentiated between Human-centered and user-centered design approaches. They concur with Verganti and Norman that a user-centered design approach most likely leads to incremental innovation, but advocates the value of human-centred methods to be more facilitative for radical innovation, because they are participatory in nature and design led.

Human-Centred Design and Design Driven Innovation approaches are multi focal and complex processes. These approaches especially suit experienced designers, who are capable of managing design processes. According to Broek (2009), these designers are mature enough to gather information as efficient as possible, select relevant methodologies, and tools, as well as understand company procedures and cultures, presented to them. Operationally, a customised process will depend on the fact whether the design task is to redesign a product, to extend a product family or to develop an entirely new product. This article focusses on how models and prototypes are used as supporting tools in design activities. The aim is to argue how models and prototypes can be used to achieve more impactful Design-Driven Innovation. Furthermore, the article suggests how models and prototypes can facilitate a more explorative and creative approach towards idea and concept generation in a Human-Centred Design approach. This has led to the following research questions: **RQ1:** Can a structured step-by-step methodological approach for Design-Driven Innovation, which involve physical prototyping, be developed? ; **RQ2:** Are there Human-Centred Design methods, which can be adopted in Design-Driven Innovation and vice versa, as defined by Sanders and Stappers (2008)?; **RQ3:** How can models and prototypes contribute in the explorative stages of the (strategic) design process to achieve meaning driven innovation?

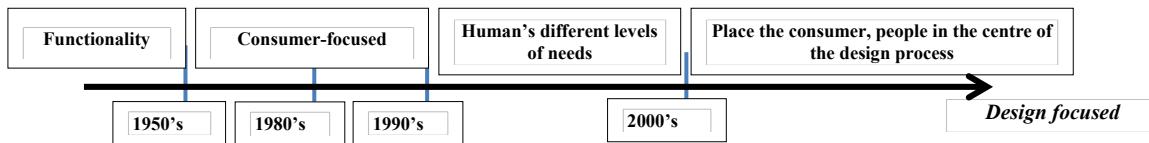
## **2 MODELS AND PROTOTYPES IN DESIGN**

Models and Prototypes are considered to be efficient tools in engineering design as they help to reveal flaws in ideas and concepts, highlighting problems to be solved. In engineering design literature, there is an overload of definitions about models and prototypes. However, no consensus has been found on an overarching unified one. The most inclusive definition is presented by Hallgrímsson (2012). First, he clarified that model making and prototyping are different activities, although they are principally associated. Then, he defined prototyping as a design method that uses physical prototypes to study and test how a new product will be used, and how it will look in a “manufactured state” . Alternatively, he defined model making, as a step by step method for producing the prototype. According to Kelly (2001), prototyping is defined as problem-solving. It is a kind of culture and language. One can prototype just about anything; a new product or service, or a special promotion. Therefore, he strongly recommends that designers should frequently use physical models and prototypes in design processes. Prototypes and models may be defined differently in various fields. In software engineering, prototypes and models are often defined more narrowly as working models. The final prototype is usually the same as the actual application. In architecture, prototypes and models are scale-downed versions of the final construction. It is different with the interactive system, when the designer may produce a fully functional full-scale prototypes to prove a concept, but may not look and feel like the

final product. Designers, who are working in the creative sector, such as fashion or graphic design make use of prototypes to generate and reflect on ideas and concepts from a more intuitive perspective (Lafon and Mackay 2009). The above examples demonstrate that models and prototypes are exploratory and generative in nature. By using models and prototypes in Human-Centered Design and Design Driven processes, designers are not only creating new products but new ways of working, managing and innovating. After reviewing how different designers and researchers have defined models and prototypes, one may say that models are the first sample of representations, which enables designers to demonstrate how their concept works or how valid their theory is. Besides that, prototypes also have the complementary function to enrich respective design processes and activities, with or without the involvement of stakeholders, especially when it concerns designer – client relationships

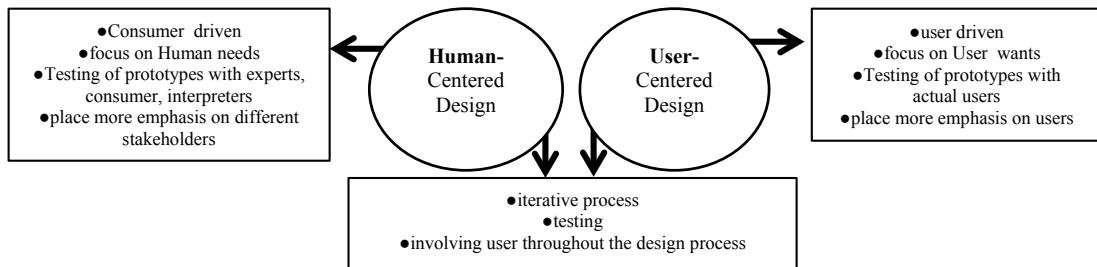
### **3 HUMAN-CENTERED DESIGN PARADIGMS**

Before 1950's, design focused on functionality. From 1950's to 1980's, design appeared to be consumer-focused. After 1990's design pays more attention to human's different levels of needs (Zhang and Dong, 2008). Bartl (2009) mentioned that design practice has experienced significant changes in the last quarter of 20th century. One of the main changes was a focal shift to place the consumer, instead of the product, in the center of the design process (see figure 1). This approach, known as user-focused or user-centered design, requires that user needs, goals and desires need to be satisfied first. In other words, user-centered design is a process that involves users in designing, from the investigation of needs until when the design is finalised. There are four key principles that are emphasised in the framework of user-centered design (Gould and Lewis, 1985) : i) early focus on users and task, ii) prototyping, iii) user testing, and iv) iterative design.



*Figure 1: Time line of design focused in Industrial Design*

Within the focus of this article, the following question arises “What is the difference between user-centered and human-centered design?” Researchers have interpreted, applied and communicated these concepts in different ways. However, it seems that user-centered and human-centered are perceived to be very similar and sometimes used indifferently for the same design context. For example, Zhang and Dong (2008) claimed that Human-Centered Design is similar as “people-centered design”, “user-centered design”, “person-centered design” and “user/client-oriented design”. However, other researchers differentiate “user-centered design” and “human-centered design”. They argued that “human-centered design” place more emphasis on different stakeholders’ variety of needs and broader contexts, while “user-centered design” is a subset of “human-centered design”, focusing on the end-user to contribute with design insights (Steen et. al, 2004). According to Sanders and Stappers, (2008), Human-Centered Design suits designers very well, when they have the freedom and means to facilitate and interpret human’s preferences, values, beliefs and desire in their own way by using specific methods and tools. However, in user-centered design activities, designers are required to make a more conscious effort to understand users, their needs and contexts (Figure 2).



*Figure 2: Comparison of Human-Centered Design Process and User-Centered Design Process*

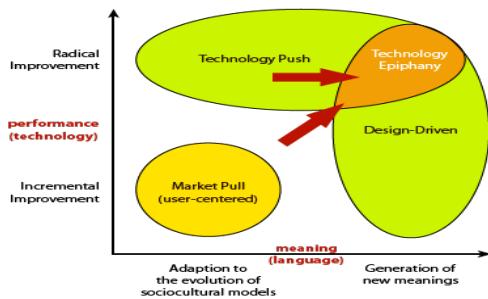
User-centered approaches in conjunction with the implementation of models and prototypes, whether virtual or physical, are often being adopted in the study and design of human computer interaction (HCI) products and interfaces. Referring to Mackay and Fayard (1997), Human-Computer Interaction is a multi-disciplinary field, which combines the elements of science, engineering and design. According to Norman & Draper (1986) HCI is an important field, where explorations of the interactive system between users, and artefacts within a specific environment, centers around the use of “prototypes”. In comparison with Industrial design, HCI prototyping is more embedded in the cognitive and analytical realms of designing activities. For example, models and prototypes are instrumental in the creation of front-end user interaction scenarios, allowing users to see and experience the system before it is realised. Underlined by Lafon and Mackay (2000), the role of prototypes in user-centered design processes is to assist designers to explore real world scenarios and to analyse user needs.

#### **4 HUMAN CENTERED DESIGN VERSUS DESIGN DRIVEN INNOVATION.**

The term Design Thinking is a complex phenomenon, emergent, and diverse in both construct and application. Liem and Sanders (2013) discussed within the context of design thinking for innovation that Human-centered Innovation processes are becoming more popular. These processes and methods emphasise observation, collaboration, interpretation, visualisation of ideas and rapid concept prototyping which ultimately influence how a company strategizes its current product and service portfolio, or plans new products for the future (Liem and Sanders; 2013, Bartl;2009 and Brown;2009). Verganti (2008) stresses that structured Human-Centered approaches should be considered as a market-pull innovation approach, because it starts with user needs and then searches for technology in order to satisfy them. According to him, using Human-Centered Design methods for observation, analysis and ideation, most likely will lead to incremental innovation and not radical innovation (Norman and Verganti, 2014). This questions the value of prototyping to support user-centered or human-centered activities (Norman and Draper 1986). To succeed in terms of radical innovation, Norman and Verganti (2014) suggest a “Design-Driven Research” approach where a radical change in meaning is cross-fertilised with a radical change in technology (Figure 3). They describe the development of competitive advantage and product innovation as historically being the result of product performance enhanced by disruptive technology and advanced through a broad analysis of users’ needs. Radical innovation, on the other hand, is more about infusing more elusive unexpected meanings into the product. Verganti (2008) explained that to create meaning is to create significant value within a product or service to be given to users.

Radical innovation is new to stakeholders; it is not about function or form, but about function and meaning which is never driven by users (Norman and Verganti, 2014). By radically changing meaning, Design-Driven Innovation is differentiated from technology-push and market-pull innovation. Technology-push innovation is often driven by innovators and is not derived from studying users. It usually does not involve market research, but starts with a new innovative technology to be applied in the development of a product and then to be introduced to the user. When technology-push innovation leads to breakthrough technologies to be applied in the development of new products, it is called technology epiphany. Technology epiphany is achieved when new meanings

in prospective products and services are created through technology innovations (Norman and Verganti, 2014). However, both authors did not propose a clear methodological approach to achieve technology epiphanies (Figure 3). They merely suggested an approach where interpreters with expert knowledge need to be consulted to help the designer to acquire a deeper and historical understanding of a typical technology or product, so that he or she will gain better insights to “leapfrog innovation”. From a more positivistic worldview, Sanders and Stappers (2008) differentiated between “human-centered” and “user-centered” design approaches. They concur with Verganti and Norman that “user-centered” design approaches most likely lead to incremental innovation, but advocates another definition and value of “human-centred design”. They claim that human-centred design may have a more significant impact in the development of radical innovations, because they are participatory in nature and design led. Instead of designers designing for people, the structured Human-Centred Design approach will lead designers to design with people (Liem and Sanders, 2013).



*Figure 3: The strategy of Design-Driven Innovation - (Verganti, 2008)*

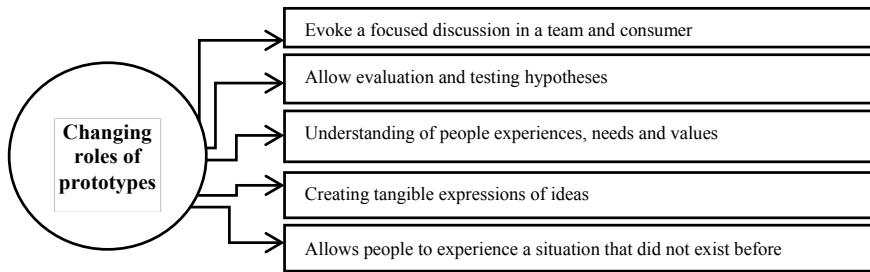
Sanders and Stappers (2008), Bartl (2009), Steen et al. (2004) made it clear that Human-Centred Design is embedded in internal collaborations among product design disciplines, R&D and market research and in external collaborations with consumers and users. Designers value people as co-creators in design process because they believe that people are true experts, when first-hand experiencing typical working, learning and living conditions (Liem and Sanders, 2013). Besides that, Bartl (2009) added that Human-Centred Design approaches ensure that innovation is not solely driven by data reports or technology push. It sets a counter balance, which put human and social requirements first and foremost. Hence, Steen et al. (2004) conclude in their research that Human-Centred Design approaches in market research and product development improve the innovation process.

## 5 CHANGING ROLE OF MODELS AND PROTOTYPES IN DESIGN PROCESS

Presently, designers are challenged to meet or even create the “wants” and “needs” of end users or customers. Bartl (2009) suggests within this new era of open innovation and co-creation that consumers or experts should be encouraged to communicate with each other rather than only with the designer. These multi-directional exchanges and discussions may facilitate the development innovative ideas and concepts. The designer(s) will then adopt a more facilitative role between the different participants (experts, users, suppliers, etc.) in a co-creation process.

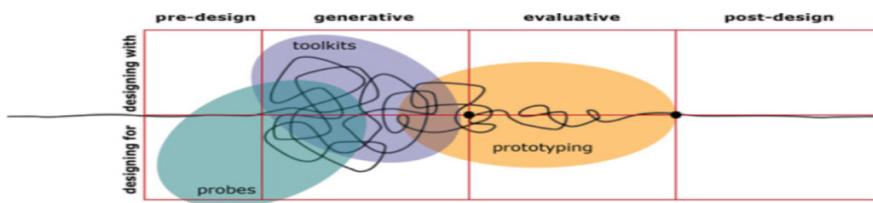
According to Sanders and Stappers (2014), models and prototypes have been instrumental over the past 10 years, in creating advanced representations and forms to connect better with the expectations of the different stakeholders. Hereby, the designer plays a key role in shaping the (physical) representations, which then can be distributed to non-designers to imagine future objects, future experiences and future ways of living.

The implementation of models and prototypes in human-centered design activities underlines a shift in using models and prototypes to become a platform for interaction in all phases of the design process. However, classification is still important even though the role of physical models and prototypes has changed and is categorized differently in different fields of design development. Stappers (2010), Lim et al (2008) and Coughlan et al (2007) underlined the changing role of prototypes in new product development, as shown in figure 4 embodying three primary objectives: i) building to think, ii) learning faster by failing early (and often), and iii) giving permission to explore new behaviours.



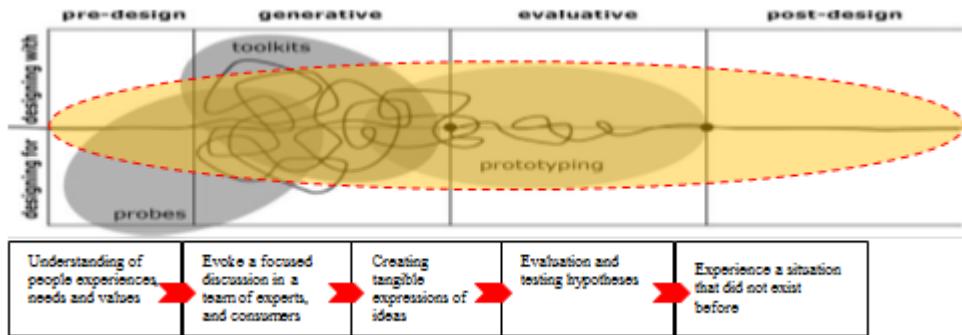
*Figure 4: The changing roles of prototypes adapted from Stappers (2010), Lim et al. (2008) and Coughlan et al. (2007).*

According to Sanders and Stappers (2014), creative designers are involved in creative acts of making when engaged in their research. Creative acts of making deal with the making of probes, toolkits and prototypes to facilitate co-creation activities. A revised framework is being proposed by Sanders and Stappers (Figure 5) illustrating the relationship between probes, toolkits and prototypes within the design process. Probes and generative toolkits are two prominent approaches in the practice of co-creation. Probes are predominantly used in a “designing for” (user as a subject) context, whereas toolkits are applied in a “designing with” (user as a partner) situation, involving different stakeholders as a client and partner. Probes are techniques used to provoke or elicit response from users in the design process. It is an artefact like postcard, camera or diary to record participants’ feelings or interactions in order to gather data about people’s lives, values and thoughts. Toolkits are created from 2D or 3D components, such as button, blocks, phrases and pictures suitable to be used in collaborative activities. With these components it helps designers and non-designers to create new ideas, vision and concepts for the future . On the other hand, prototyping can be conducted equally in both mindsets “designing for” and “designing with” as shown in figure 5. However, as new methods and tools are constantly being developed within the three approaches, the use of probes, toolkits and prototypes will overlap more, across the stages of the design process.



*Figure 5: Framework of three approaches to making are positioned relative to the mindsets and phase in design process adopted from Sanders and Stappers (2014).*

Considering the three co-creation approaches, this study focuses on how to exploit the use of prototyping methods to be iteratively implemented in a design process in conjunction with probes and toolkits in the pre-design and generative stages of the design process (see figure 6). In the early development stages, prototypes act as representations, which may be used by users and experts to probe for confirming and aligning design directions referenced from earlier research. For example, low fidelity prototypes were used to probe appropriate contents, topics and sequence of information from customers, experts and design team members (Hannington, 2003). Representations applied in the pre-design stage are not made for user testing. Instead, they are used as mechanisms to facilitate interpreting user needs and envisioning future products and services. The use of prototypes in parallel with toolkits during generative design stages is meant to assist designers in developing tangible design concepts with continued involvement of stakeholders.

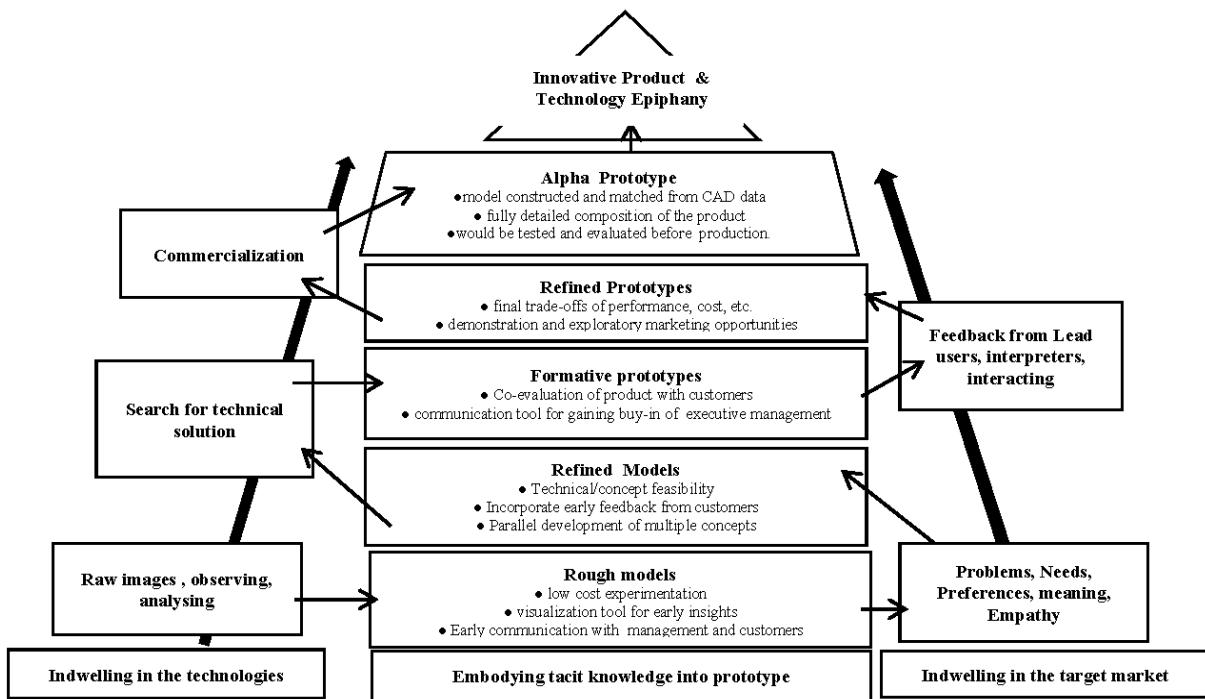


*Figure 6: An expanded usage of prototypes, adapted from Sander and Stappers revised framework*

## 6 MODELS AND PROTOTYPES IN HUMAN CENTERED DESIGN VERSUS DESIGN DRIVEN INNOVATION

The use of models and prototypes are dependent on the needs of the project. Previous research showed that models and prototypes fulfilled different roles throughout the design process (Ulrich and Eppinger; 2012, Sanders and Stappers; 2014, Coughlan et al; 2007, Broek et al; 2009, Hallgrímsson; 2012). Ulrich and Eppinger (2012) classified roles of models and prototypes according to four categories (p.250). These categories are: (i) Learning: Models and prototypes used as learning tools to answer designer questions during product development; (ii) Communication: Models and prototypes as tools for designers to communicate with different stakeholders; (iii) Integration: Models and prototypes used to verify the assembly and integration of components and subsystems of the product; (iv) Demonstration: Models and prototypes used to show the progress of design project to keep track of product development.

The above classification exercised by Ulrich and Eppinger (2012), were used to represent an iterative process of prototyping, which can be applied to Human-Centred design and Design-Driven Innovation. Additionally, the aspect of functionality of each prototype and model, which has been introduced at every stage in the design process, was adapted from Mascitelli (2000) and Ulrich and Eppinger (2012). In order to discuss what type of models or prototypes should be used in Human-Centred Design and Design driven innovation, designers must decide first what the purpose of these models and prototypes should be with respect to solving the design problem, enhancing design experiences and materialising the targeted design outcome. According to Mascitelli (2000) extensive use of models and prototypes throughout the design process provide rich opportunities for individuals to take a physically active approach to learning and experimentation. Within the context of achieving breakthrough innovations, it is important to develop a methodological approach for prototyping within the context of Design-Driven Innovation and Human-Centred Design (fig. 7).



*Figure 7: A conceptual model of continuous prototyping leading to breakthrough innovation, adapted from Mascitelli (2000).*

By making physical models and prototypes at each stage, designers will be able to visualise and solve complexities when designing products and systems. For example in the early conceptualization stages of the design process, “rough models” and “refined models” complement the ambiguity of 2-D sketches and drawings. The advantage is to minimise the chances of overlooking mistakes. However, the creative space may be restricted, typically because ambiguity is being reduced. During this process the physical models need not to be expensive or attractive, it is an appropriate tools for generating ideas in a fast and affordable manner. “Formative prototypes”, “Refined prototypes” (Mascitelli,2000) and “Alpha prototypes” (Ulrich and Epingger,2012) are instrumental for assisting designers and engineers in the engineering development phases to confirm the prototype design for manufacturing and assembly. When gradually transitioning from the generative to the evaluative stages of the design process, qualities of accompanying models are also expected to improve up to the level of a “refined prototypes” (Mascitelli,2000).

“Refined prototypes” will be used in the detailing and materialisation stages of the design process to refine the selected design concept according to specifications as earlier stated in the project. However, refinement depends on what aspects of the design need to be further explored; form, technical or ergonomic functionality. By appropriately using the right prototypes in the final stages of Human-Centred design and Design-Driven Innovation processes, it can help the designers to evaluate and fine-tune their final design as well as confirm certain critical requirements. In this context, Viswanathan and Linsey’s experiment also demonstrated that creating appropriate physical prototypes during final stages of design processes enhances the designer’s innovative and creative capabilities at a micro-level of idea generation and conceptualisation, which may contribute to a more elaborate materialisation and detailing design activities. Unlike for commercialization purposes, “Alpha prototypes” are instrumental for assisting designers and engineers in the engineering development phases to confirm the final design for manufacturing and assembly. However, it should also be mentioned that the final prototype is not the end-goal of a design and development activity. Instead, Computer-aided design (CAD) models or engineering drawings are considered to be the outcome of the design process as it is a medium for design transfer and communication between designers and engineers.

## **7 SELECTED METHODS TO FACILITATE HUMAN-CENTERED DESIGN AND DESIGN DRIVEN INNOVATION APPROACH**

After examining existing co-creation approaches, this paper proposes the implementation of selected methods in Human-Centred Design and Design Driven Innovation activities. The following methods have been selected based upon how effective they are in broadening of the creative space and engaging user participation in co-creation activities.

### **i) Minimum Viable Product (MVP)**

Ries (2011) introduced Minimum Viable Product in “Lean Start-up” method to minimizes the uncertainties on how the product can be accepted by the future market. He defined MVP as “a version of a new product which allows a team to collect the maximum amount of validated learning about customers with the last effort...” (p103, 2011). It emphasizes the “fail fast” concept which means the sooner the designers realize the idea is not working, the faster they can rebuild and retest the idea. It may save much time and resources. Keitsch and Røed (2014) proposed in their study to use MVP in the analysis of user experiences in the early stages when developing innovative or product service. They emphasize that MVP is a valuable method to test different prototypes in a collaborative setting with different stakeholders. The study suggested using MVP techniques in conjunction with models and prototypes in the early stage of design process to modify ideas according to customer's feedback.

### **ii) Experience Prototyping**

Buchenau and Suri, (2000) described experience prototyping as a form of prototyping that allow design team members, users and clients to gain first-hand appreciation of existing future conditions through active engagement with prototypes. It is a valuable method for understanding how to classify prototypes to generate better user feedback, how to communicate ideas to an audience more convincingly, and how to explore and evaluate ideas more effectively. Moreover, Experienced Prototyping is valuable for understanding user experiences, which implies (1) identifying future design opportunities; (2) exploring and evaluating design ideas – (3) directing design team towards more informed developments; and (4) getting users to experience and understand the subjective value of design ideas and concepts.

### **iii) Discovery-Driven Prototyping**

Lim et al. (2012) developed this new prototyping technique for the users to be entirely in control of what they can and would like to do with new technologies. Discovery-Driven Prototyping enables designers to trigger meaningful ways of using proposed product or technologies among potential users. The main objective of this method is to discover human-centered application ideas of new technologies materials and to understand what is truly valued by the users through the careful examination of what has been discovered. When applying discovery-driven prototyping methods in the form of idea-provoking material-like artefacts, it can help the designer to accelerate the creativity and ideation process

## **8 DISCUSSION**

Designers should re-think the functionality of models and prototypes in Human-Centred Design and Design-Driven Innovation processes, as these tools are not only useful for generating design ideas, but in conceptualising and materialising the detailing aspects of the final design. In this discussion chapter, the earlier proposed research questions will be discussed. To answer RQ 1 : Can a structured step-by-step methodological approach for Design-Driven Innovation, which involve physical prototyping, be developed? Within the context of Design –Driven Innovation approach, models and prototypes are used to enrich self-reflection and communication activities, with or without the participation of stakeholders, especially when it concerns designer – client relationships. Furthermore, models and prototypes are appropriate tools for generating ideas in a fast and affordable manner, bringing abstract ideas to a more concrete level. Structured step by step methodological approaches for Design-Driven Innovation can be developed involving physical prototyping especially during the early development process involving interpreters. In the early stages of the design process, models and prototypes activities are mainly applied to predict the future. In that phase the prototyping activities are used for exploring, expressing and testing hypotheses about future ways of living. Models and prototypes may assist in soliciting passive or active participation from designers, experts, potential users and other stakeholders. In terms of active participation, where users and other stakeholders are involved in

design-driven innovation activities, more innovative designs may be generated through the discovery of hidden needs using models and prototypes. In other words, models and prototypes can be perceived as a medium for dialogue between the designers and interpreters, illustrating that ambiguity is one of the key factors to allow partakers in the design process to see new possibilities in the representations, in other words re-interpretations for more radical design solutions.

To answer RQ2: Are there Human-Centred Design methods, which can be adopted in Design-Driven Innovation and vice versa, as defined by Sanders and Stappers (2008)?; This study proposed a selection of Human-Centred Design approaches to be applied in Design-Driven Innovation processes. Discovery-Driven Prototyping and Experiences Prototyping are some examples of Human-Centred Design methods that can be combined, adapted or adopted for Design-Driven Innovation. These methods can be proposed to designers to facilitate their creativity and synthesis activities in the early idea generation, as well as detailing and materialisation stages of the design process. Reference to an agile and interactive designing process, they will facilitate designers and interpreters in the making, telling and enacting of future product and service design. Compared with Design-Driven Innovation approach there are processes that can be adapted in Human-Centred Design process to increase technological innovation and to create a new meaning in product development. Listening, Interpreting and Addressing are processes in Design-Driven Innovation that can be used to understand how people can give meanings to things.

To answer RQ3: How can models and prototypes contribute in the explorative stages of the (strategic) design process to achieve meaning driven innovation? The most important factor, which determines the choice of prototype for Design-Driven Innovation and Human-Centred Design projects is dependent upon the designer's adopted worldview in the project. Instead of developing prototypes for investigating a specific need, construction or context, using them continuously in divergent or convergent design activities may be more valuable. During the explorative stages of the process, prototypes are to assist designers to develop several initial concepts to be evaluated, discussed and debated by interpreters, consumers, experts and designers. Models and prototypes will bring designers and non-designers together for a design dialogue that can lead to innovative concepts with breakthrough in meaning or technology epiphany. Furthermore, the universal use of prototypes and models made explicit in this article, contributes to the designer's awareness of the importance of design thinking processes with respect to managing structured and collaborative design processes. In this early stage a wide variety of low-fidelity models are built to help designers to reflect and answer questions concerning overall shape, volume and proportions as efficiently and effectively as possible. Moving on to the conceptualisation and refinement stages of the design process, Low-fidelity prototypes can be extended to accurate high fidelity prototypes for assessing functionality, geometry and aesthetics. Regarding Human-Centred Design and Design-Driven Innovation, several examples were discussed in this study to show how models and prototypes can be used to support design tasks in all stages of the design process. In particular, figure 7 advocates continuous prototyping as a creative method to develop design solutions, emphasising on improvisation, immediate feedback and rapid learning. Furthermore, Figure 7 shows how the interest of different stakeholders who are involved in co-creating design concepts are represented in the different prototypes, embodying certain directions of exploration and typical qualities, which have been emphasised.

## 9 CONCLUSION

This study provides an insight on how models and prototypes play a significant role in augmenting designers, clients, and other stakeholders involvement in co-creative design process to evaluate and select the most appropriate representations for communicating design ideas and concepts. It shows that existing models and prototypes have different effects on communication and negotiation among designers, experts and stakeholders at different stages of the Human-Centred Design and Design-Driven Innovation processes. However, the absence of specific models and prototypes for Human-Centred Design and Design-Driven Innovation activities have challenged designers to continue the search for alternative methods and tools to analyse design problems, broaden the creative space and to synthesise design concepts within acceptable time frames.

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