Smart Home Product-Service-System (SH-PSS) Innovator Toolkit

Thesis submitted in partial fulfillment for the requirements for the degree of

Doctor of Philosophy
in
Design

by

Leeladhar Ganvir

(Roll No. 196105005)

Under the Supervision of

Prof. Pratul Ch Kalita

Department of Design
Indian Institute of Technology Guwahati
Guwahati -781039
Assam, India

TH-3294_196105005

Department of Design
Indian Institute of Technology Guwahati
Guwahati, Assam – 781 039, India

Declaration

I hereby declare that the work contained in this thesis entitled "**Smart Home Product-Service-System (SH-PSS) Innovator Toolkit**" is my work and done under the guidance of Dr. Pratul Ch Kalita, Professor at the Department of Design, Indian Institute of Technology Guwahati, Assam, India. To the best of my knowledge, it contains no materials previously published or written by another person or substantial properties of the material which has been accepted for the award of any other degree or diploma at Indian Institute of Technology Guwahati or any other educational institution, except where due acknowledgment is made in the thesis. Any contribution made to this research by others, with whom I have worked at Indian Institute of Technology Guwahati or elsewhere, explicitly acknowledge in the thesis. I declare that the intellectual content of this thesis represents my work and words. I have adequately cited and referred to the original work where others' ideas, work, and words have been included. I also declare that I have adhered to all principals of academic honesty and integrity and not misrepresented or fabricated or falsified any idea/ data/ fact/ source in my submission.

Place: Guwahati

Date: 5 October 2023

Leeladhar Ganvir

(Roll no: 196105005)

TH-3294_196105005

Department of Design
Indian Institute of Technology Guwahati
Guwahati, Assam – 781 039, India

Certificate

This is to certify that the work contained in this thesis titled **"Smart Home Product-Service-System (SH-PSS) Innovator Toolkit"** submitted by Mr. Leeladhar Ganvir to the Indian Institute of Technology Guwahati for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

Place: Guwahati

Date: 5 October 2023

....

Prof. Pratul Ch Kalita
Professor
Department of Design
Indian Institute of Technology Guwahati
Guwahati, Assam – 781 039, India

TH-3294_196105005

Acknowledgment

First and foremost, I would like to convey my gratitude to the Department of Design, Indian Institute of Technology Guwahati for providing the opportunity and facilities to pursue my PhD research. I would like to express my sincere gratitude to my supervisor, Prof. Pratul Ch Kalita for his patience, motivation and immense support towards my PhD research and Thesis. His guidance and encouragement throughout the journey of my research are deeply acknowledged. This work would not have been possible without his timely guidance and excellent mentorship.

I would like to express my sincere gratitude to my Doctoral Committee Chairman Dr. Keyur Sorathia, Doctoral Committee Members Dr. Debayan Dhar and Dr. Chandan Karfa, who have been guiding and giving me meaningful insights and valuable feedback since the beginning to the end of my Research Work. My earnest thanks to Prof. Sougata Karmakar, Head of the department, Department of Design for his administrative cooperation.

I convey my gratitude to all the industry experts for providing me with the necessary information required for my Research. I am incredibly thankful to for their valuable feedback and information.

Special thanks to the participants, who are also my colleagues at IIT Guwahati for their contribution and their voluntary participation in my experiments. My sincere gratitude to Prof. Ravi Mokashi Punekar for his guidance and support during the progress of the research. I am forever grateful to the non-teaching staffs of the department for their continuous help and support towards me whenever required.

Last but not the least, I am forever grateful to my friends who have helped me directly or indirectly in completing my thesis, and I would like to convey my special thanks to my family members for their encouragement and support always and my better half Miss. Deep Shikha for walking by my side throughout this journey. I would like to convey my special thanks to my brother Mr. Yogesh Ganvir and my sister-in-law Mrs. Apeksha Kamble for their inspiration. Their unconditional support and encouragement will always be appreciated.

Leeladhar Ganvir

TH-3294_196105005

Abstract

The prime inspiration of this research is to formulate a framework for factors affecting consumers' new technology acceptance and develop an innovator toolkit for idea generation enhancement during the smart home ideation phase of the design process. The effort has been experimented, validated and successfully demonstrated in this study.

The term 'smart' has become widely used to describe advanced products and innovative business strategies, leading to substantial growth in the smart home market in recent years. The expansion has resulted in the launch of a multitude of unique products onto the global market. The appeal and practicality of smart devices lie in their ability to understand a user's surroundings and activities within a certain context, facilitating adaptive responses. The deployment of smart home technology has been found to give several advantages in the long run, hence boosting the quality of life for users, particularly among elderly people. These advantages reach across different domains, including healthcare, security, and entertainment, as highlighted by Marikyan (2019). The growing acceptance of smart homes worldwide can be attributed to the tangible benefits they offer in terms of promoting pleasant and healthy lifestyles. The representation of advanced intelligent technologies in science fiction movies has significantly influenced the level of user engagement and acceptance. In spite of the increasing prevalence of smart technology in household products, there is a conspicuous lack of research focused on user-centric perspectives in this field. The present collection of study has primarily focused on the technological elements, while overlooking the crucial user perspectives. Hence, it is important to incorporate user perspectives in the design and development of smart home technologies, specifically in relation to the acceptance and adoption of these innovative technologies by users.

In the first phase, an integrative review of the available literature was carried out. The four major categories that emerged through the analysis of the shortlisted articles are as follows: 1. The Terminology used in smart home and IoT products, 2. Consumer behaviour and its relationship with the other factors such as benefits, barriers, and socio-cultural aspects in smart homes, 3. New technology acceptance, and 4. Product service system (PSS) design in smart homes. A multi-faceted evaluation of articles of the first two categories proposes a new theoretical framework investigating consumer behaviour related to smart homes and IoT product adoption. The framework illustrates key terms and associations between them with future directions on smart home IoT products.

In the second phase, a comprehensive examination of the characteristics of Smart Home products and services through the lens of the Kano Model offers a complete understanding of the factors that drive customer satisfaction and dissatisfaction within the smart home domain. This phase is a key exploration of the characteristics that shape user perceptions and satisfaction with smart home products and services. The third phase involved developing a conceptual framework for Smart Home Product-Service-System (SH-PSS) design. We examine the current gaps and challenges in SH-PSS design to enhance user satisfaction and improve user experiences. It explores how user needs, preferences, and experiences are integrated into the design process, ensuring that the resulting products and services cater to the end-users effectively.

The fourth and final phase of the study was to Design and Development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit—and validate the proposed Innovator Toolkit by means

TH-3294_196105005

of statistical methods. The study describes card-based toolkit protocols and methods. It describes how to utilize these cards to brainstorm and build Smart Home Product-Service-Systems, emphasizing their importance in creative thinking and problem-solving. It is expected that design practitioners and researchers would find the outcomes of the thesis and developed framework helpful while designing smart homes. Moreover, the 'Conceptual framework for factors affecting consumer's new technology acceptance' presented in the current research is an effective means for suggesting promising future research directions to conduct studies based on specific parts and contributing factors of the framework, which are unexplored previously, and investigate their role in influencing consumer behaviour.

TH-3294_196105005

Table of Content

TH-3294_196105005

TH-3294_196105005

TH-3294_196105005

List of Figures

TH-3294_196105005

List of Table

TH-3294_196105005

Chapter 1: Introduction: Product-Service-System Design in the Context of Smart Home

1.1 Introduction: Smart Home

The term ‘smart’ has become a buzzword for innovative products and revolutionary business models. Smart home products and services have seen tremendous growth in the past decade. Globally, there have been a lot of new innovative products that have entered the market (Khedekar et al., 2017). One of the most important qualities and usage of smart products is the potential to understand the consumer’s environment and their behavior in a particular situation and respond accordingly (Chan et al., 2008; Balta-Ozkan et al., 2014). In the long term, there are many benefits to using smart home technologies for its users to live a comfortable and healthy lifestyle. Marikyan (2019) highlights that these products and services help increase the quality of life, especially for the elderly, and in sectors such as healthcare, security, and entertainment. Due to the benefits of smart homes and their impact on everyday life, it has seen great market penetration globally. A major driver for user adoption has been science fiction movies that have shown us the possibilities of integrating smart technologies in our household. We have seen in the last decade a lot of innovative household products in the market where smart technology has an important direction to work on. However, studies in this field have seen a marked lack of user-centric research (Marikyan et al., 2019; Kim et al., 2019a). The focus of majority research in the field of smart homes has focused on the technology involved. Hence, there is a need for the user’s perspective in designing smart home technologies, in the acceptance and adoption of new technologies by users (Chen et al., 2017; Bhati et al., 2017; Hong et al., 2016; Chiang & Wang et al., 2016; Kim et al., 2019a).

In smart homes, digital and physical services are integrated into household products which involve an exchange of information and communication networks (Balta-Ozkan et al., 2014). When tangible products and intangible services come together in an interactive way to provide a consumer's real needs, it is perceived as a product-service system (PSS). PSS integrates smart home technology, service, and communication networks around the different stakeholders. It is also important to explore different stakeholders involved and their roles (Sakao, T. et al, 2009). The development of product-service systems is continuously improving its perspective from including only consumers to including all the various stakeholders involved in the communication network (Sojung Kim et al., 2019). Generally, a smart home product’s smartness is studied through technical aspects which ultimately results in a gap with what consumers really want from smart home products and services like highly customized and empowering experiences. This shift in focus of research, from technology to users and stakeholders will allow researchers to better understand the user and design products to satisfy their needs and reach a wider user base for their products and services.

1.2 Fundamental Smart Home Design Elements

Smart homes comprise primarily of domestic appliances and products, which form a communication network, using different technologies, devices, and sensors. This network can be remotely accessed, monitored and controlled, and provides us with different services that satisfy the various needs of the user (Marikyan et al., 2019; Kim et al., 2019a).

TH-3294_196105005

In the 1990s, smart homes were mainly used for home automation. The network was built using broadband internet. The 2000s saw the advent of smartphones and applications. This caused smart homes to move towards home networks, whose main function was to control and monitor devices. In the 2010s, smart homes have incorporated Internet of Things (IoT) and Artificial Intelligence (AI) technologies. The main application of smart homes has shifted to context awareness, which arises the need for user-centric research (Yang et al., 2018). Over the years, researchers have defined smart homes, and their characteristics in three distinct perspectives as shown in Table 1, which are 'products', 'services', 'consumer's needs' (Marikyan et al., 2019).

While perusing the literature, we came to know that many researchers have identified various characteristics, that define smart homes in their particular directions (Marikyan et al., 2019). Some of these researchers have attempted to study smart homes from a technological perspective. These studies mainly focus on the sensors and communication networks that form the various smart products and devices, that are comprised in a smart home (Aldrich, 2003; Lutolf, 1992; De Silva et al., 2012; Reinisch et al., 2011; Scott, 2007; Balta-Ozkan et al., 2014; Diegel et al., 2005; Alam et al., 2012).

Many researchers have also studied smart homes from the perspective of the services they provide. Smart home products and technologies are used for a variety of activities and purposes, which are of value to the user. These services may include control and monitoring of remote systems, energy management systems, which use smart technologies to optimize energy consumption (Aldrich, 2003; Lutolf, 1992; De Silva et al., 2012; Reinisch et al., 2011; Scott, 2007; Balta-Ozkan et al., 2014; Diegel et al., 2005; Alam et al., 2012; Chan et al., 2008). Smart homes also provide support and assistance for healthcare and telecare (Alam et al., 2012; Chan et al., 2008). Recent literature also discusses context awareness, which allows smart home systems to anticipate and respond to a user's needs and requirements (Aldrich, 2003).

Table 1 Characteristics of Smart Home

	Characteristics	Themes	Sources
1	Product	• Technology • Sensors • Devices	Aldrich, 2003; Lutolf, 1992; De Silva et al., 2012; Reinisch et al., 2011; Scott, 2007; Balta-Ozkan et al., 2014; Diegel et al., 2005;
2	Service	• Control • Monitor • Energy management • Support and assistance • Anticipation and response	Aldrich, 2003; Lutolf, 1992; De Silve et al., 2012; Reinisch et al., 2011; Scott, 2007; Balta-Ozkan et al., 2014; Diegel et al., 2005; Alam et al., 2012; Chan et al., 2008; Alam et al. 2012; Chan et al., 2008
3	Consumer need	• Cost efficiency • Comfort • Emotional support • Security	Balta-Ozkan et al., 2013a; Kerbler, 2013; Kim & Shcherbakova, 2011; Hu et al., 2003; Yang et al., 2017; Mani & Chouk, 2017; Ram & Sheth 1989; Alam et al., 2011; Kleinberger et al., 2007; Sun et al., 2010; Fuchsberger,

TH-3294_196105005

		• Health • Quality of life • Sustainability	2008; Stringer et al., 2006; Keith Edwards & Grinter, 2001; Hu et al., 2011; Wu & Fu, 2012; Meng & Lee, 2006

1.3 Product-Service-System (PSS) Design

A product-service system (PSS) is a mix of tangible products, intangible services, and the various stakeholders involved. These components combine in a complex communication network to fulfill a consumer's needs (Figure 1). The way smart home products are currently developed, from a technological perspective rather than a user-centric or stakeholder approach, makes it difficult to approach them from a PSS perspective. Currently, it is tough to develop a service, around the product-oriented solutions of problems a consumer faces in their living space. It is important to explore the potential of smart home products and services to enhance the advantages of designing smart homes with a PSS approach. The various qualities of smart homes and how they are integrated with a PSS have to be studied, in order to create a link between the two. While exploring the qualities of smart home products and the advantages of a PSS, we discovered two directions of the "smartness" of smart home products. The first direction is smartness to create custom user experiences. The ability of smart home products and services to collect, process and respond to data from its surroundings is important for a customized user experience, personalized to each user's particular need and requirements. The second direction is the ability of smart home products to communicate and collaborate with one another. Smart home products require communicating their data with other smart home products in their surroundings, to satisfy common goals and provide an enhanced and integrated user experience. Exploring these two directions enabled researchers to integrate the development of smart homes with PSS (Kim et al., 2019).

Figure 1 Traditional Product Service System Design

Consumers expect highly customized and empowering experiences from smart home products. To this end, there is a need to integrate the development of smart home products with PSS. From the literature studied, designers and developers have realized there is a shift in focus required, from technology to consumers, and more importantly, the various stakeholders involved to increase the advantages of a PSS approach (Kim et al., 2019; Watanabe et al., 2020). Smart homes are an umbrella, consisting of various smaller and individual products and services that communicate and function in tandem. As we know, the home is a very private space for its occupant, and it is essential to be sensitive to a user's needs and not invade their privacy (Kim et al., 2019). For this, it is important to build a relationship with the user, in order for them to better connect with the product required and to receive feedback from the user. This will enable service providers to better optimize their offerings and develop flexible solutions. A PSS approach will enable designers to take into account all these factors and design better and personalized solutions that empower their users.

TH-3294_196105005

1.4 Research Gap

There is lack of framework and toolkit for Product-Service-System (PSS) designers for designing technology-based interventions in the context of smart home. We have formulated the research question based on the knowledge gap identified in the literature review. We have observed that there is a knowledge gap of PSS designers for smart home PSS design. We have also found the knowledge gap of technology adoption models in the context of smart home PSS. We identified the need of development of a PSS design toolkit for smart home PSS design which will not only fulfil the knowledge gap in PSS design academia but also will help practising PSS Design.

1.5 Research Questions

Table 2 Research Question

	Research Question
RQ1:	What framework and toolkit Product-Service-System (PSS) designers can use in Smart Home PSS Design to ensure new technology acceptance and adoption by the target consumer?
RQ2:	Can existing technology adoption model be considered as a mean to adapt a new framework and toolkit for PSS designers in context of smart home?
RQ3:	What is the smart home PSS design framework with special emphasis to service dominance?
RQ4:	How to customize the generic PSS design toolkit in context of smart home PSS design considering context awareness, multi-functional, ability to co-operate, personalization, openness.

1.6 Aim and Objectives

Aim The aim of the study is to develop a Smart Home Product-Service-System (SH-PSS) design framework for smart home.

Objectives

Table 3 Objectives

	Objective
O1:	To study technology adoption models with special emphasis to PSS design frameworks and toolkits.
O2:	To identify PSS design frameworks suitable for smart home PSS design.
O3:	To customize the generic PSS design framework incorporating "service dominance" in the context of smart home PSS design projects.
O4:	To develop a specific PSS design toolkit for PSS designers for smart home PSS design projects.

TH-3294_196105005

1.7 Framework of the Thesis

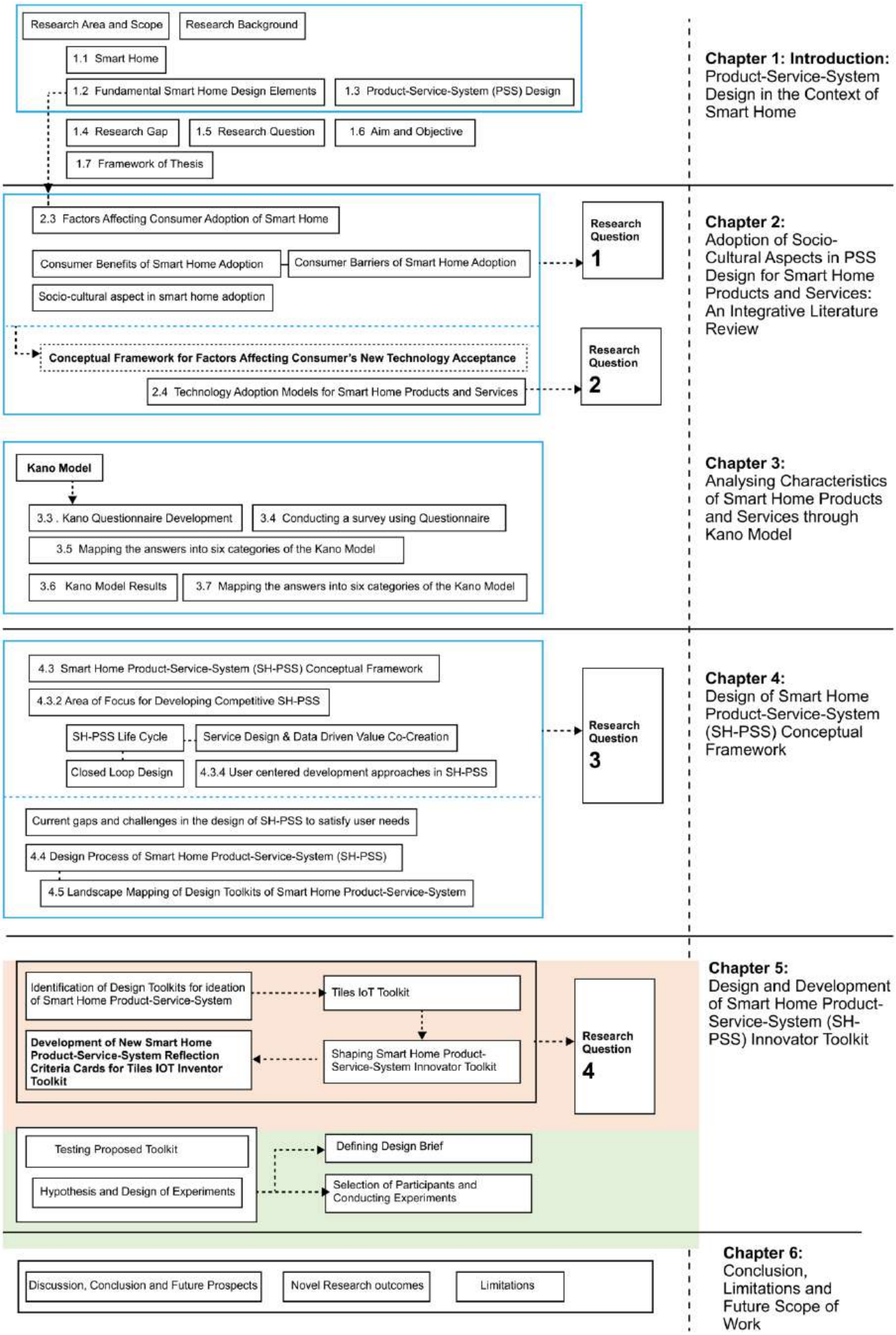


Figure 2 Thesis workflow and content of various chapters

Based on the study workflow, the thesis report is divided into five chapters. Figure 2 illustrates a brief workflow. The research questions, objectives, and hypotheses are addressed in the individual chapters. A brief summary of the study divided into five chapters in the thesis is as follows:

Chapter–1: Introduction (present chapter)

The first chapter focuses on the central themes of the thesis, which frame the context of Product-Service-System (PSS) design within the domain of Smart Homes. Section 1.1 introduces Smart Homes, a transformative domain. Section 1.2 addresses Smart Home design basics, establishing the basis for PSS design talks. Section 1.3 introduces Product-Service-System (PSS) design and its importance in Smart Homes. Section 1.4 highlights the research gap in PSS design in Smart Home contexts, underlining the need for more study. Section 1.5 presents the thesis's research questions, guiding the investigation into this complicated and dynamic topic. Section 1.6 explains the research's goals. The chapter finishes in Section 1.7 with the thesis structure, highlighting the upcoming chapters and their relationships. This chapter sets the stage for the in-depth study of PSS design in Smart Homes.

Chapter–2: Adoption of Socio-Cultural Aspects in PSS Design for Smart Home Products and Services: An Integrative Literature Review

The second chapter describes the multifaceted landscape of adopting socio-cultural aspects in Product-Service-System (PSS) design within Smart Home products and services. Section 2.2 provides insights into the research methodology, offering readers an understanding of the systematic approach used to gather and analyze the relevant literature. The chapter's core lies in Section 2.3, where various factors affecting consumer adoption of Smart Homes are explored. Subsections 2.3.1 and 2.3.2 delve into the benefits and barriers that consumers encounter in adopting Smart Home technologies. Subsection 2.3.3 then delves into the socio-cultural aspects that play a pivotal role in shaping the adoption landscape, providing a deeper understanding of how culture, societal norms, and human behavior influence Smart Home adoption. Section 2.4 shifts the focus to technology adoption models, shedding light on the theoretical frameworks researchers have employed to understand the adoption of Smart Home products and services. Chapter 2 concludes in Section 2.5, summarizing the key takeaways and insights from the comprehensive literature review. This chapter is a foundational reference point for understanding the intricate interplay of socio-cultural factors in adopting PSS design within the Smart Home ecosystem.

Chapter–3: Analyzing Characteristics of Smart Home Products and Services

The third chapter illustrates a comprehensive examination of the characteristics of Smart Home products and services through the lens of the Kano Model, a well-established framework for understanding customer preferences and satisfaction. The chapter unfolds as follows: Section 3.1 introduces the Kano Model and its significance in assessing customer satisfaction and preferences, setting the stage for the following research. Section 3.2 outlines the research methodology employed, providing readers with insights into the study and data collected. The development of the Kano questionnaire is detailed in Section 3.3, shedding light on how the survey tool was created to effectively capture respondents' insights and opinions regarding Smart Home characteristics.

TH-3294_196105005

Section 3.4 provides an overview of the survey process, describing how the questionnaire was administered to gather valuable participant data. The chapter's core resides in Section 3.5, where the collected survey responses are meticulously analyzed and mapped into the six categories of the Kano Model. This section unveils the nuanced insights into the characteristics of Smart Home products and services as perceived by consumers. Section 3.6 presents the results derived from applying the Kano Model, offering a comprehensive understanding of the factors that drive customer satisfaction and dissatisfaction within the Smart Home domain. Chapter 3 wraps up in Section 3.7, summarizing the essential findings and implications drawn from the Kano Model analysis. This chapter is a pivotal exploration of the characteristics that shape user perceptions and satisfaction with Smart Home products and services.

Chapter–4: Design of Smart Home Product-Service-System (SH-PSS) Conceptual Framework

The fourth chapter illustrates the development of a conceptual framework for Smart Home Product-Service-System (SH-PSS) design. Section 4.2 explains the research methodology employed in crafting the SH-PSS conceptual framework. This section outlines the approach, methodologies, and data sources utilized in the framework's creation. The chapter's core, Section 4.3, unveils the conceptual framework of the Smart Home Product-Service-System (SH-PSS). This section offers a detailed breakdown of the framework's components, illustrating how they interconnect to provide a comprehensive design approach for Smart Home products and services. In Section 4.3.1, we examine the current gaps and challenges that exist in the design of SH-PSS to enhance user satisfaction and improve user experiences. Section 4.4 emphasizes the significance of user-centric design principles within the SH-PSS framework. It explores how user needs, preferences, and experiences are integrated into the design process, ensuring that the resulting products and services cater to the end-users effectively. Chapter 4 is a pivotal step in developing a robust design framework for SH-PSS, including innovative concepts with user-centric design principles to create a holistic approach to Smart Home Design.

Chapter–5: Design and Development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit

This chapter develops and validates a new toolkit for designing Smart Home Products-Services. Section 5.2 discusses the SH-PSS Innovator Toolkit and how it aids Smart Home system design. It explains how this toolkit was created to aid SH-PSS innovation and design. Section 5.3 The chapter describes card-based toolkit protocols and methods. It describes how to utilize these cards to brainstorm and build Smart Home Product-Service-Systems, emphasizing their importance in creative thinking and problem-solving. Section 5.4 examines the Smart Home Product-Service-System Cards Tool's architecture and structure. It shows designers, innovators, and stakeholders in the SH-PSS area how to use these cards' significant features and properties. Section 5.5 describes the SH-PSS Innovator Toolkit validation process and experimental design. It describes how experimentation examined the toolkit's effectiveness and usability, laying the groundwork for eventual validation. The chapter reports SH-PSS Innovator Toolkit validation results. It emphasizes how the toolkit improved Smart Home Product-Service-System design and innovation in practical scenarios. In conclusion, Chapter 5 describes the design, development, use, and validation of the

TH-3294_196105005

SH-PSS Innovator Toolkit, a valuable resource for Smart Home Product-Service-System designers and innovators.

Chapter–6: Conclusion, Limitations and Future Scope of Work

The fifth chapter provides the novelties and critical findings of this thesis. The fulfillment of objectives and testing of hypotheses were also depicted here. This chapter covers the recommendations and suggestions for future study

TH-3294_196105005

Chapter 2: Adoption of Socio-Cultural Aspects in PSS Design for Smart Home Products and Services: An Integrative Literature Review

2.1 Introduction

Smart homes are becoming an increasingly integral part of our daily lives. Smart homes consist of domestic Internet of Things (IoT) products that are connected to a communication network and provide various functions and services to their consumers with the purpose of improvement of their quality of life. However previous research suggests there is very limited user- centric research published in this domain. One of the main factors for the success of smart homes is the acceptance and adoption of technology by new users. This report presents a literature review conducted with the aim of exploring smart homes, their characteristics, advantages, and challenges perceived by the consumer. This study investigates various factors influencing the acceptance and adoption of new technologies by consumers and how the design of smart homes can be integrated with a product-service system (PSS), considering socio-cultural aspects. The study is an integrative review of papers from major journals in design, consumer research, management, and marketing on the topic of smart home IoT products from 2000 to 2020 relevant articles were shortlisted and analysed considering the purpose, method, and main findings of the studies. The four major categories that emerged through the analysis of the shortlisted articles are as follows: 1. The Terminology used in smart home and IoT products, 2. Consumer behaviour and its relationship with the other factors such as benefits, barriers, and socio-cultural aspects in smart homes, 3. New technology acceptance, and 4. Product service system (PSS) design in smart homes. A multi-faceted evaluation of articles of the first two categories proposes a new theoretical framework investigating consumer behaviour related to smart homes and IoT product adoption. The framework is described illustrating key terms and associations between them with future directions on smart home IoT products. It is expected that design practitioners and researchers would find the developed framework helpful while designing IoT products.

2.2 Research Methodology

This study is an integrative review, defined as one in which the published research studies are critically analysed and synthesized into a significant contribution to new knowledge about the theme under study. The development of an integrative review includes six steps: the selection of research questions, defining the criteria for literature screening, defining categories or themes that emerged from the existing research articles, analysis, and synthesis, logical and conceptual reasoning, implications for future research (Snyder, 2019).

The questions that this research tries to answer are:

- What are the fundamental terminologies in smart home IoT products?
- Which are the factors affecting consumer adoption of smart home IoT products?

A systematic search was conducted using online databases: Google Scholar, Scopus, and Web of Sciences. The keywords used for this purpose were “Smart home product”, “IoT product”, “Consumer adoption”, “Cultural aspect in smart home” and “PSS in smart home” with limitations to studies conducted in design, consumer research, management, marketing, psychology, cognitive science, philosophy, and technology. The inclusion criteria were: (a) Works written in English language only

TH-3294_196105005

in the timeframe of 2000 to 2020, (b) the presence of the search term in keywords or title, (c) full-text availability, (d) original and relevant articles in the IoT products and smart home adoption.

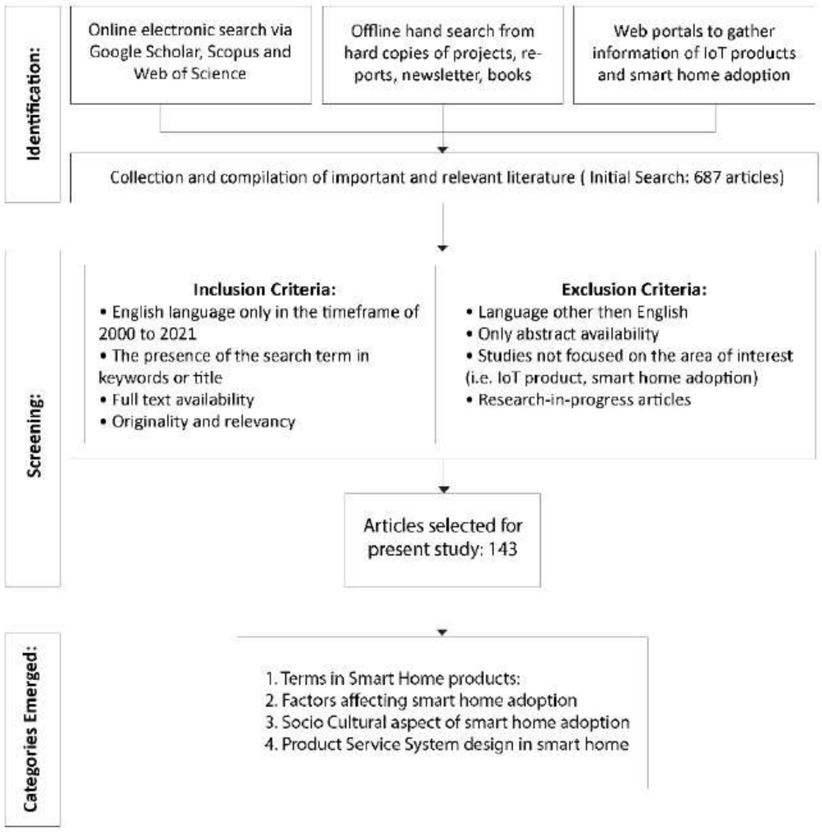


Figure 3 Process and method of research for literature review

Furthermore, additional papers from reference lists of the articles reviewed were also identified. The initial search resulted in the identification of 825 articles. After the application of inclusion and exclusion criteria, 143 articles remained for our review. A systematic approach of indexing and categorising research articles were done. Notes were taken and extracted in a tabular format for future references and thematic coding process. Next, coding or thematic extraction process were carried out by the help of two-three external research scholars including my doctoral supervisor to derive various themes from the notes extracted earlier and categorise them. Coding process were done in two phases: open coding phase and axial coding phase. Open code and axial code were generated as key themes and factors which influenced the acceptance of smart home products and services innovation and implementation by the users. Through the assessment of selected articles and thematic analysis, four main categories emerged, which are represented in Figure 1. The critical analysis of identified literature was conducted phase-wise based on the first two categories. The majority of authors tended to generate theoretical/conceptual papers. Other types of publications included 9 review papers, 32 papers adopting a survey method, 15 case study papers, 2 papers adopting an experimental approach, 10 based on interviews, and only one based on ethnographic study (Figure 3).

The concept map shown in Figure 4 is the visual representation of the categories and sub- categories of the current research topic, created to enhance the understanding and explain the structure of this chapter.

TH-3294_196105005

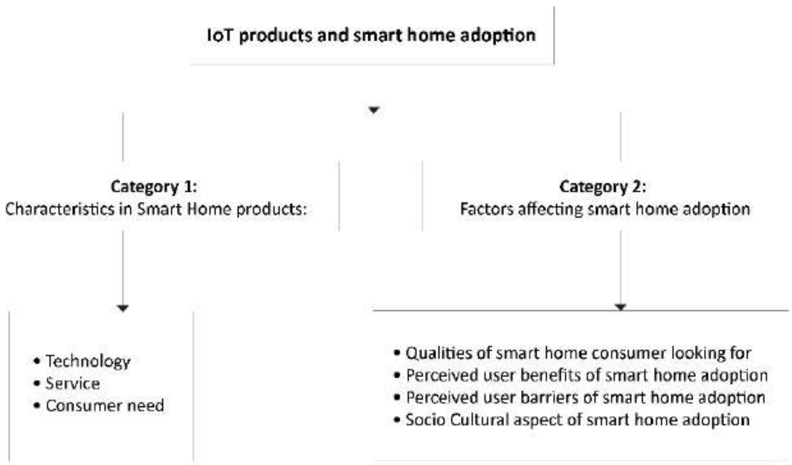


Figure 4 Concept Map of the critical analysis

2.3 Factors Affecting Consumer Adoption of Smart Home

2.3.1 Consumer Benefits of Smart Home Adoption

Various advantages of smart home products that we have observed from the literature include health-related advantages. This includes care for the elderly, telecare, health monitoring, and fitness. This has promoted a healthy lifestyle amongst consumers and earned the trust of consumers, especially in critical or life-threatening situations. There are also environmental benefits of smart home products. Smart products using AI technologies help optimize power consumption and limit carbon emissions. This promotes sustainable living and a sense of responsibility towards the environment. Smart homes also provide monetary gains to consumers, in the form of savings on bills due to optimization of resource consumption. Lastly, there is mental well-being. Smart products provide connectivity, online interactions, and leisure activities that help cope with feelings of isolation. These factors affect consumer behavior in a positive manner and promote smart home acceptance and adoption. The consumer benefits of smart home adoption are summarized in Table 4.

Table 4 Consumer Benefits of Smart Home Adoption

	Consumer benefits	Themes	Sources
1	Health related benefits	• Promoting well-being of ageing and vulnerable people. • Care accessibility and comfort • Monitoring user's safety • Consultancy for social connectivity and communication • Supporting detection of life-threatening events • Therapy for reduction of medical errors	Chan et al., 2008; Demiris et al., 2008; Demiris & Hensel, 2009; Reeder et al., 2013; Courtney et al., 2008; Rantz et al., 2005; Demiris et al., 2004; Finkelstein et al., 2004; Chan et al., 2009; Czaja, 2016; Mynatt et al., 2004; Celler et al., 2003; Finch et al., 2008; Walsh & Callan, 2011; Cavicchi & Vagnoni, 2017; Rahimpour et al., 2008; Matlabi et al., 2012; Kerbler, 2013;

TH-3294_196105005

2	Environmental benefits	• Environmental sustainability • Monitoring and reducing energy usage • Consultancy and feedback on energy and resource consumption • Suggestions on how to use electricity efficiently and comfortably.	Balta-Ozkan et al., 2014; Chen et al., 2017; Elkhorchani & Grayaa, 2016; Zhou et al., 2016; Beaudin & Zareipour, 2015; Kyriakopoulos & Arabatzis, 2016; Kiesling, 2016; Aye & Fujiwara, 2014; El-hawary, 2014; Balta-Ozkan et al., 2013a; Paetz et al., 2011; Paetz et al., 2012
3	Financial benefits	• Affordability of health care • Sustainable consumption • Cheaper consultancy and monitoring cost of virtual visits	Balta-Ozkan et al., 2013a; Darby & McKenna, 2012; Hargreaves et al., 2013; Paetz et al., 2012; Faruqui et al., 2010; Balta-Ozkan et al., 2014; Paetz et al., 2011; Park et al., 2018; Park et al., 2018; Steele et al., 2009; Ehrenhard et al., 2014; Kun, 2001
4	Psychological well-being and social inclusion	• Overcome the feeling of isolation • Support • Entertainment • Virtual interaction	Chan et al., 2008; Percival & Hanson, 2006; Demiris et al., 2004; Brandt et al., 2011; Damodaran & Olphert, 2010; Gaul & Ziefle, 2009; Kim et al., 2013; Balta-Ozkan et al., 2013a; Balta-Ozkan et al., 2013b; Khedekar et al., 2017

2.3.2 Consumer Barriers of Smart Home Adoption

On the other hand, various researchers' discuses challenges towards smart home acceptance and adoption, which influence consumer behavior negatively. These include technological barriers, which consists of security and privacy issues, where a user feels that their private data is not secured. This makes consumers feel that smart home systems are not reliable. Another dimension of challenges includes usability issues, where users find smart home products complex and challenging to use. The overhead costs of using smart home products are also a deterrent for consumers. The initial investment, installation, and running cost of maintenance and repair might make smart home products not be economically viable for consumers. According to the researchers, the most influencing challenge in using smart home products is a lack of proficiency and psychological resistance. This causes people to resist the adoption of new technologies, mainly due to a lack of knowledge and exposure to such technologies. The consumer barriers of smart home adoption are summarized in Table 5.

Table 5 Consumer Barrier to Smart Home Adoption

	Consumer barriers	Themes	Sources
1	Technological barriers	• Security • Usability	Balta-Ozkan et al., 2013a; Park et al., 2018; Yang et al., 2017; Alsulami &

TH-3294_196105005

		• Privacy intrusion • Reliability	Atkins, 2016; Czaja, 2016; Diegel, 2005; Kim & Shcherbakova, 2011
2	Financial, ethical and legal barriers	• Price • Cost of installation • Cost of repair and maintenance • Concern about misuse of private data	Balta-Ozkan et al., 2013a; Steele et al., 2009; Chan et al., 2012; Chan et al., 2008; Wells, 2003; Chan et al., 2009; Jacobsson et al., 2016; Friedewald et al., 2005; Kotz et al., 2009; Sundström et al., 2002; Coughlan et al., 2013; Hanson et al., 2007; Paetz et al., 2011; Yang et al., 2017; Wilson et al., 2017; Theoharidou et al., 2016; Paetz et al., 2012; Chung et al., 2016; Zwijsen et al., 2011; Courtney, 2008; Lorenzen-Huber et al., 2011; Chan & Perrig, 2003; Chiang & Wang, 2016; Anderson, 2007; Harkke et al., 2003; Balta-Ozkan et al., 2014
3	Knowledge gap and psychological resistance	• Human barrier • Resistance to using innovative technology • Lack of prior knowledge and/or experience	Balta-Ozkan et al., 2013a; Kerbler, 2013; Kim & Shcherbakova, 2011; Hu et al., 2003; Yang et al., 2017; Mani & Chouk, 2017; Ram & Sheth 1989; Alam et al., 2011; Kleinberger et al., 2007; Sun et al., 2010; Fuchsberger, 2008; Stringer et al., 2006; Keith Edwards & Grinter, 2001; Hu et al., 2011; Wu & Fu, 2012; Meng & Lee, 2006;

2.3.3 Socio-cultural aspect in smart home adoption

In our systematic study of literature, although there is limited study on how individual cultures affect the adoption of new technologies, there is not a lot of prior research on the differences in culture between user demographics and how these differences affect user adoptions. As seen in the case of the USA and Japan, the primary factor affecting a user's smart home acceptance is trust, in the fact that these products and services will complete their intended goals and tasks. A user's satisfaction and trust increase when they connect with the product emotionally. Users begin to have moral concerns as they start using a product or service with an emotional attachment (Dylan et al., 2021). For example, in Japan, owners of robots start to get emotionally attached to them and are left with a void when these robots reach the end of their life cycle. There have been cases of users conducting funerals for their defunct robots (James, 2018). While studying literature, we discovered researchers shedding light on how local social practices, beliefs, behavioral routines, and socio-technical expressions affect new technology adoption (B Lee et al., 2017). Studies on the link between usage of smart home products and culture show that there is a risk of cultural values and behaviors being compromised. Hence, researchers argue that for the growth and development of smart home products it is essential to be empathetic towards a user's culture, their experiences, and expectations. It is also observed that a user's adoption of smart homes is affected by their respective country's socio-economic status (Dylan et al.,

TH-3294_196105005

2021).

By studying how cultures of different countries affect user behavior, researchers have observed various perceptions of smart homes by users of different demographics (Demiris et al., 2008; LN Lee et al., 2020). Literature elaborates how consumers in the USA and Japan both mainly bought smart homes to assist the elderly population, whereas in the UAE smart homes are mainly used to connect with friends and families. Meanwhile, in the UK and UAE, smart homes are perceived with social standing, which is not the case with the USA and Japan (Dylan et al., 2021; Gram-Hanssen et al., 2004; Foye et al., 2018; Sovacool et al., 2018; Aljomaa et al., 2016; Tsetsi et al., 2017). Using smart products to make homes more resilient is an important factor in Japan due to the frequent occurrence of natural disasters in the country, however, this is not a key factor in other countries such as the USA and UK (Ton et al., 2015; Dylan et al., 2021). UAE and USA have a comparatively young user base, who are very technologically enthusiastic. These users actively seek to use the latest and best technology available in the market (Van, 2020; Galperin, 2017; Dylan et al., 2021).

In the way difference in culture affects the applications and uses of smart home products, it also leads to cultural barriers to the adoption of smart homes (Figure 5). In order for smart homes to function, they collect a lot of data regarding the usage patterns and behaviors of their users. There is a potential for such private data to be misused (Sovacool et al., 2021). For example, in the UAE, homes are perceived as sacred places. Their users are skeptical about sharing their private data as they feel it is an invasion of their private space. In comparison, users in Asia are more willing to share their private data in exchange for good service (Dylan et al., 2021). The level of effort and skill required to use a smart home product can be perceived as a barrier. Consumers who are not technically proficient may find it hard to use a smart product to its full potential. The majority of younger users will be able to use smart products with greater ease, as they are more exposed to technology compared to elderly users (Dylan et al., 2021). The incompatibility of smart products with its user's lifestyles is another cultural barrier. The functionality of a smart product may not be harmonious with the needs and gaps in a user's lifestyle. For example, smart home products that automate certain tasks, may not be desirable by elderly people, who wish to perform these tasks manually on their own (Dylan et al., 2021). Also, consumers may not want to relinquish control and become dependent on smart home products (Sovacool et al., 2021). Service providers seek to limit consumers to their proprietary ecosystems, which are not compatible with products and services offered by other providers. The willingness of service providers to work together will encourage greater development in home automation (Wilson et al., 2017). Religious practices and gender roles may also hinder the adoption of smart homes (West et al., 2019). For example, cultures in the middle east which require their women to hide their faces in public, may not be comfortable with the presence of cameras on smart devices inside their homes (Dylan et al., 2021). Language challenges are also a cultural barrier. Certain services do not support a wide variety of languages, which leads to certain user groups not being able to use their services and products. The naming of products and services may also cause a gap in users of different cultures connecting with the service or product. Certain functions and features can get lost in translation, which will result in users not appreciating the function of these technologies (Koenecke et al., 2020; Carrie et al., 2021; Lopez-Lloreda, 2020; Buolamwini et al., 2018, Dylan et al., 2021).

TH-3294_196105005

2.4 Technology Adoption Models for Smart Home Products and Services

Researchers have delved into the complexity of technology adoption through various theoretical models in smart home products and services. These models serve as foundational frameworks for understanding how users embrace and integrate new technologies into their lives (Figure 6). Adopting smart home innovations has been a subject of keen interest, leading to the exploration of multiple theoretical models. Often combined, these models provide valuable insights into the factors that influence users' acceptance of new technology. Among these, one model has emerged as particularly prominent, serving as an essential for comprehending the dynamics of technology adoption in the context of smart homes. This study explores these theoretical models, shedding light on their unique characteristics and their collective impact on the adoption of innovative smart home solutions.

Table 6 Technology Adoption Model

	Technology Adoption Model	**Attributes**	**Source**
1	Consumer Perceived Innovativeness (CPI)	• Perceived Concept Newness • Perceived Technology Newness • Perceived Relative Advantage • Excitement	Nikou, 2019
2	Cognitive Dissonance Model/Theory (CDM)	• Action • Belief	Marikyan et al., 2020
3	Diffusion of Innovation Theory (DOI)	• Relative Advantage • Compatibility • Complexity • Trialability • Observability	Shih et al., 2013; Toft et al., 2014
4	Expectation Confirmation Model (ECM)	• Perceived Usefulness • Confirmation • Satisfaction	Marikyan et al., 2020;
5	Eco-friendly Smart Home Objects (ESHO)	• Environmental Beliefs • Environmental Concern • Perceived Usefulness • Happiness • Success	Schill et al., 2019;
6	Elaboration Likelihood Model (ELM)	• Motivation • Ability • Opportunity	Kim. Y. et al., 2017;
7	Innovation Diffusion Theory (IDT)	• Relative Advantage • Compatibility • Complexity	Alaiad & Zhou, 2017; Hubert et al., 2018; Nikou, 2019;

TH-3294_196105005

		• Trialability • Observability	Marikyan et al., 2020
8	Kano Model	• Must-be Features • One dimensional Features • Attractive Features • Reverse Features • Questionable Features • Indifferent Features	Luor et al., 2015;
9	Motivational Model (MM)	• Perceived Usefulness • Perceived Ease of Use • Perceived Enjoyment	Alaiad & Zhou, 2017
10	Model of Personal Computer Utilization	• Social Factors • Complexity • Job-fit • Long-term Consequence • Affects Towards Use • Facilitating Conditions	Alaiad & Zhou, 2017
11	Net Valance Model (NVM)	• Perceived Benefits • Perceived Risks	Wang et al., 2020
12	Norm Activation Model (NAM)	Personal Norms: • Awareness of consequences • Situational Responsibility • Efficacy • Ability • Denial of responsibility	Toft et al., 2014
13	PAD Theory	• Pleasure • Arousal • Dominance	Alaiad & Zhou, 2017
14	Perceived Risk Theory (PRT)	• Consumer Perceived Risk • Consumer Trust	Hubert et al., 2018
15	Responsible Technology Acceptance Model (RTAM)	• Perceived Usefulness • Perceived Ease of Use • Personal Norms	Toft et al., 2014
16	Social Cognitive Theory (SCT)	• Reciprocal Determinism • Behavioral Capability • Observational Learning • Reinforcements • Expectations	Alaiad & Zhou, 2017

TH-3294_196105005

		• Self-efficacy	
17	Technology Reediness Index (TRI)	• Optimism • Innovativeness • Discomfort • Insecurity	Mulcahy et al., 2019
18	Technology Acceptance Model (TAM)	• Perceived Usefulness • Perceived Ease of Use	Shih et al., 2013; Alaiad & Zhou, 2017; Kim. Y. et al., 2017; Yang. H. et al., 2017; Shin et al., 2018; Hubert et al., 2018; Yang. H. et al., 2018; Pal et al., 2018; Park et al., 2018; Mashal et al., 2018; Mulcahy et al., 2019; Shuhaiber & Mashal, 2019; Nikou, 2019; Schill et al., 2019; Ji et al., 2019; Aldossari et al., 2020; Wang et al., 2020; Hong et al., 2020; Liu et al., 2020; Mamonov et al., 2020
19	Theory of Reasoned Action (TRA)	• Behavioural beliefs and attitudes • Normative beliefs and subjective norms • Control beliefs and perceived behavioural control	Toft et al., 2014; Luor et al., 2015; Alaiad & Zhou, 2017; Yang. H. et al., 2017
20	Theory of Planned Behavior (TPB)	• Attitude towards the Behaviour • Subjective Norms • Perceived Behavioral Control	Toft et al., 2014; Luor et al., 2015; Alaiad & Zhou, 2017; Yang et al., 2017; Mashal et al., 2018; Shuhaiber & Mashal, 2019; Wang et al., 2020; Hong et al., 2020;
21	Task-Technology Fit Chain	• Task Characteristics • Technology Characteristics • Individual Characteristics	Alaiad & Zhou, 2017;
22	Unified Theory of Acceptance and Use of Technology (UTAUT)	• Performance Expectancy • Effort Expectancy • Social Influence • Facilitating Conditions	Alaiad & Zhou, 2017; Kim. Y. et al., 2017; Mashal et al., 2018; Shuhaiber & Mashal, 2019; Wang et al., 2020; Hong et al., 2020
23	Value -based Adoption Model (VAM)	Benefits: • Usefulness • Enjoyment Sacrifice:	Kim. Y. et al., 2017; Shuhaiber & Mashal, 2019; Wang et al., 2020;

TH-3294_196105005

		• Technicality • Perceived Fee	

In the rapidly evolving landscape of smart home products and services, understanding the factors that influence their adoption is of paramount importance. To shed light on this subject, we have examined 29 case studies, employing various theoretical models to analyze and dissect the adoption patterns of new technology in smart homes. These studies have often combined multiple models to conduct comprehensive quantitative analyses, engaging users of smart homes in experimental settings. The overarching goal has been to discern the characteristics and variables within these theoretical models that significantly impact the acceptance of novel technologies within the smart home domain. Among the multitude of models explored, the Technology Acceptance Model (TAM) emerges as a central and frequently employed framework, underlining its paramount relevance in comprehending the dynamics of new technology adoption in this context. This investigation navigates through an extensive understanding of theories, offering valuable insights into the complex interplay of factors influencing the adoption of smart home innovations.

2.5 Chapter Conclusion

Despite numerous advantages observed in various studies, there is very limited user centric study pertaining to smart products and services. A lot of researchers have highlighted this shortcoming in research published so far and the need for it. Prominent research articles published so far in the domain primarily discuss only the technological aspects of smart homes. The research gaps and future research directions were summarized by Marikyan et al. (2019) which we have outlined in Table 4, where researchers suggest the need for adopting a user-centric approach by understanding user perception of smart home technology and change in demographics and geography for focusing on smart home technology benefits for users while keeping in mind the ageing population. A limited number of articles that we studied which incorporate a user-centric approach discuss only about certain user groups, such as the elderly while ignoring other demographics (Khedekar et al., 2017; Peek et al., 2014; Czaja, 2016; Ehrenhard et al., 2014; Morris et al., 2014; Cassarino & Setti, 2016). It is important to explore and understand the various stakeholders involved who influence a user's acceptance and adoption of smart homes. This shift in focus from technology to the user's perspective will lead to better development of smart home products and enable service providers to deliver better service to their users.

Understanding the pre-adoption and post-adoption user behavior will shed light on the consumer's cognitive process of adopting new technology. Studying this behavioral change will help with the better implementation of new products in the market. User-centric studies on the perceived advantages and challenges of smart homes, and how they relate to the adoption of smart homes by users have been contradictory across different geographical locations and demographics. These contradictions suggest that there should be further studies conducted that examine factors that influence user adoption in greater detail (Ehrenhard et al., 2014; Kerbler, 2013; Alsulami & Atkins, 2016). The emotional, psychological, symbolic, social, functional, and financial factors that affect a user's decision on the acceptance or rejection of new technology, and how differences in culture and geography affect these factors should be examined further. (Balta-Ozkan et al., 2014) Psychological resistance is another important factor and studying variables that influence a user's cognitive state of mind and a user's impression of the usefulness of the technology will enable us to overcome this resistance to adopting technology (Mani et al., 2017). The above gaps identified from the literature suggest that there is an increasing need to conduct studies on a user's perception towards smart home products and adopt new technologies (Amiribesheli et al., 2015; Peek et al., 2014; Czaja, 2016; Chen et al., 2017; Bhati et al., 2017; Chiang & Wang, 2016; Hong et al., 2016).

Table 7 Future Research Suggestions

Area of gaps	Future research suggestions		Sources
1	User centric research of smart home products	• User perception of smart home technology • Demographics and geographic change • Smart home technology benefits for users • Focus on ageing population	Chan et al., 2008; Coughlan et al., 2013; Chan et al., 2009; Amiribesheli et al.,2015; Kim et al., 2013; Demiris & Hensel, 2008; Alam et al., 2012; Peek et al., 2014; Czaja, 2016; Balta-Ozkan et al., 2013a; Diegel et al., 2005; Bowes et al., 2012; Chen et al., 2017; Bhati et al., 2017; Balta-Ozkan et al., 2013b; Paetz et al., 2011; Demiris et al., 2008; Brandt et al., 2011; Stringer etal.,2006; Wu & Fu, 2012; Chan et al., 2012; Chiang & Wang, 2016; Matlabi et al., 2012; Paetz et al., 2012; Demiris et al., 2004; Gaul & Ziefle, 2009; Courtney et al., 2008; Yamazaki, 2006; Hong et al., 2016; Vilas et al., 2010;
2	Smart home acceptance and adoption	• Smart home technology acceptance factors	Chan et al., 2008; Dawid et al., 2017; Khedekar et al., 2017; Chan et al., 2009; Peetoom et al., 2015; Kim et al., 2013; Peek et al., 2014; Balta-Ozkan et al., 2013a; Diegel et al., 2005; Ehrenhard et al., 2014; Bowes et al., 2012; Balta-Ozkan et al., 2013b; Kleinberger et al., 2007; Demiris et al., 2008; Park et al., 2018; Yang et al., 2017; Alsulami & Atkins, 2016; Steele et al., 2009; Mayer et al., 2011; Paetz et al., 2012; Gaul & Ziefle, 2009; Courtney et al., 2008; Mani & Chouk, 2017; Chung et al., 2016

The design and development of smart homes will greatly benefit by approaching it from a product-service system (PSS) perspective. However, designers and developers lack a systematic approach to smart products, which will help in integration with PSS. In this data-driven market, the focus is shifting

TH-3294_196105005

from only consumers to including all stakeholders involved as the consumer is part of a larger interconnected network. In this network, individual smart products and services will collaborate and function in tandem to fulfill common goals and provide value to the user. Hence it is essential to study and understand interconnected socio-technical systems with the goal of shifting smart home development towards a PSS approach. There is limited prior research on the integration of smart homes with PSS.

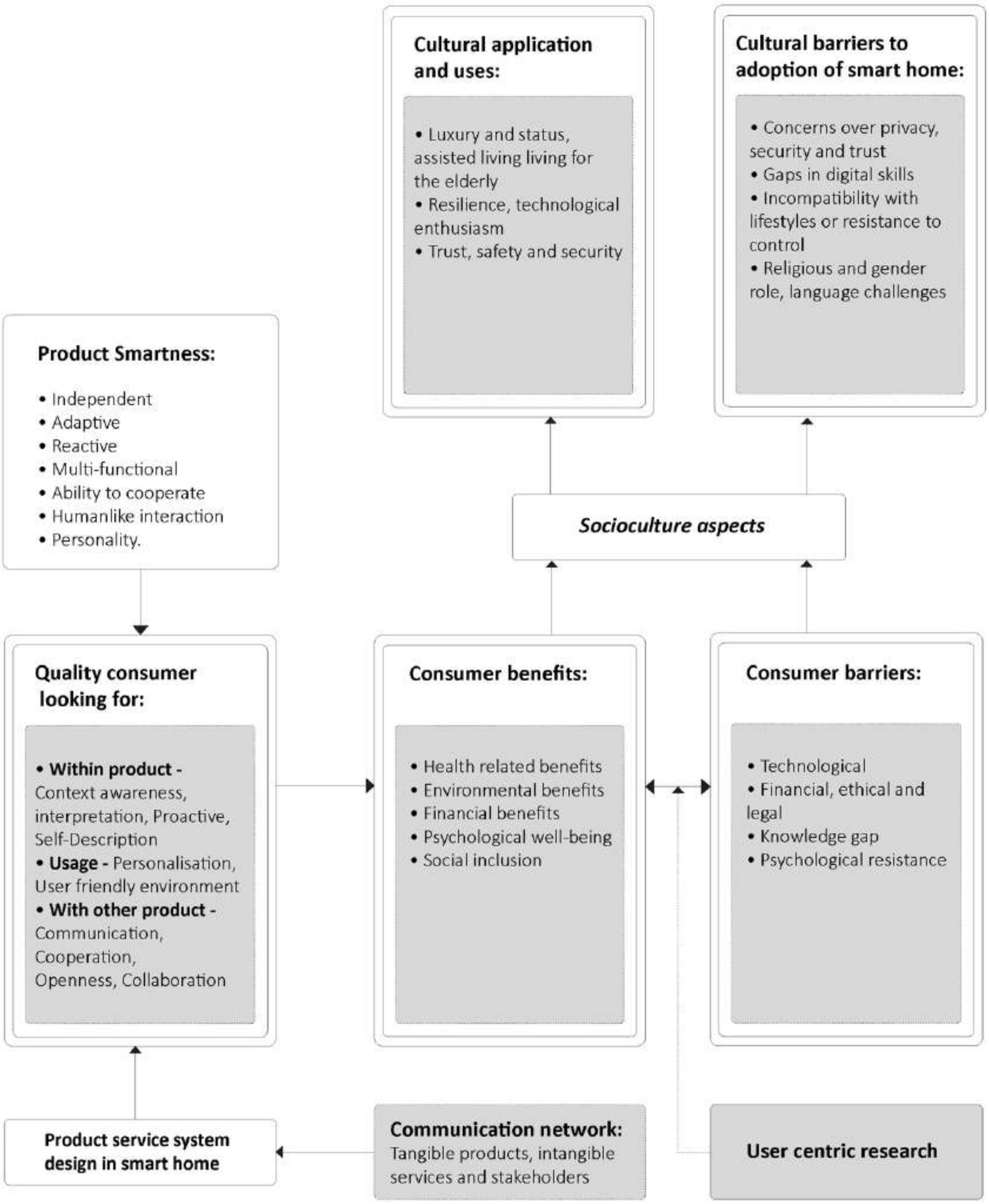


Figure 5 Conceptual framework for factors affecting consumer's new technology acceptance

Continuous research in this direction is required to approach the design of smart homes by taking into consideration the various systems and subsystems involved, accounting for the diverse cultures and varied demographics (Figure 5).

In the proposed framework, initially, we focused on the factors which define any product as a "smart" product and qualities that consumers look for within the product, while using it in cooperation with other products and using smart products. Secondly, we focused on consumer benefits and barriers which influence the new technology acceptance. Also, we have identified consumer behaviour and its relation to socio-cultural aspects of smart home products. At last, we have determined a need for user-centric research and a product service system design (PSS) perspective in smart homes, which includes a communication network between tangible products, intangible services and all the stakeholders involved in the system.

In this study, we conducted an integrative review of 143 articles relevant to smart home and IoT products. Through the critical analysis of these articles, four main themes or categories emerged:

1. The Terminology used in smart home and IoT products,
2. Consumer behaviour and its relation with other factors such as benefits, barriers, and socio-cultural aspects in smart homes.
3. New technology acceptance, and
4. Product service system (PSS) design in smart homes.

The integration of valuable insights drawn from the review of the first two categories has resulted in developing a conceptual framework (Figure 5) for fundamental smart home product design elements affecting consumer new technology acceptance. A key contribution of this study is that the insights gained from the review of the available literature provide an overview of the range of socio-cultural factors and PSS design factors that are most likely to influence consumer adoption to smart homes and IoT products.

TH-3294_196105005

Chapter 3: Analyzing Characteristics of Smart Home Products and Services

3.1 Introduction

The Kano model explains the relationship between the degree of sufficiency and customer satisfaction/dissatisfaction with respect to an attribute of customer requirement (Figure 6). The customer requirements can be classified into six categories: attractive, one-dimensional, must be, indifferent, reverse and questionable.

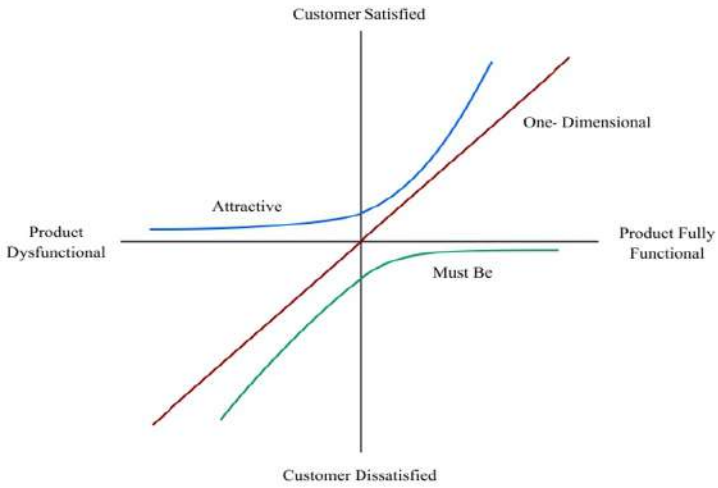


Figure 6 Kano Model

The model can be represented graphically as a combination of two axes – the x-axis and the y-axis – where the x-axis defines whether and to what extent customer needs were met (the x-axis can be interpreted as the product's performance or function) and the y axis is the level of customer response to the product: Was the consumer satisfied or dissatisfied? The consumer reaction and the extent to which expectations are met are separated into three areas (Chen & Chuang, 2008)

- Basic needs or, as we can call them, the "must-be requirements". The criteria in this category are fundamental; if they are satisfied, there will be no special delight for the consumer; their performance will be relatively neutral. However, if these standards are not fulfilled, users will be dissatisfied, and the product will likely not sell.
- Performance requirements. These are requirements that the user and manufacturer may negotiate. The requirements are subject to the maxim "more is better." These demands are the ones that distinguish one product or service from another. This is the category that differentiates between competitors. In this area, the product or service answers queries such as "What degree of service is provided?" What is the performance of the price? What characteristics does a product acquire?
- Attractive (pleasure) needs. Typically, they are unstated needs that the consumer cannot describe. These wants are not anticipated by the user; thus, if the product or service does not fulfil them, the customers are indifferent since they were not anticipating them to begin with. However, if the product or service offers them, users are enthusiastic.

TH-3294_196105005

3.2 Research Methodology

Non-probability purposive sampling is a sampling technique in which participants are selected based on specific criteria or characteristics that are relevant to the research objective. In the context of using the Kano Model for participant selection, purposive sampling can be employed to ensure that individuals who have knowledge and experience related to the smart home products and services (SH-PSS) being evaluated are included in the study.

To conduct purposive sampling for the Kano Model participants, we have followed these steps:

- **Define the target population:** Determine the specific group of individuals who possess the relevant knowledge and experience regarding SH-PSS.
- **Determine the criteria:** Identify the specific criteria or characteristics that participants must meet to be considered eligible for the study. These criteria should align with the research objective and the expertise required to evaluate the characteristics of the SH-PSS.
- **Select participants:** Using the defined criteria, purposefully select individuals who meet the criteria and have the necessary knowledge and experience. This could involve reaching out to experts in the field, professionals working in the smart home industry, or individuals who have extensive experience with using SH-PSS.
- **Sample size determination:** Decide on the appropriate sample size based on the resources available and the depth of analysis required. The sample size should be sufficient to capture diverse perspectives and provide meaningful insights into the characteristics being evaluated.
- **Data collection:** Conduct interviews, surveys, or other data collection methods to gather participants' opinions and feedback on the characteristics of the SH-PSS. Utilize the Kano Model questionnaire or other suitable tools to assess participant satisfaction and dissatisfaction with the characteristics.
- **Data analysis:** Analyse the collected data using appropriate statistical techniques, such as calculating satisfaction and dissatisfaction coefficients, to categorize the characteristics into different Kano Model categories.

Mapping the results into a graphical form of the Kano Model based on the coefficient of satisfaction and coefficient of dissatisfaction

Potential for customer satisfaction and potential for customer dissatisfaction can be calculated using the following formulae (Matzler et al. 1998, Berger et al. 1993):

$$\text{Potential for customer satisfaction} = \frac{(\textit{Attractive} + \textit{One Dimensional}) \times 100}{\textit{Attractive} + \textit{One Dimensional} + \textit{Must be} + \textit{Reverse} + \textit{Indifferent}}$$

$$\text{Potential for customer dissatisfaction} = \frac{(\textit{One Dimensional} + \textit{Must be} + \textit{Reverse}) \times 100}{\textit{Attractive} + \textit{One Dimensional} + \textit{Must be} + \textit{Reverse} + \textit{Indifferent}}$$

TH-3294_196105005

3.3 Kano Questionnaire Development

Regarding data collecting, we used a quantitative strategy based on two questionnaires, and the first two themes were covered in the first questionnaire. The third theme was covered in the second questionnaire. Respondents were randomly chosen from a database of end-user service interventions for whom information on their desire to engage in such activities was available. Participants were encouraged to complete the survey. They were provided with the online application URL. In situations where no email address was supplied, however, the paper survey form was sent. On a five-point ordinal scale, respondents' perceptions of the significance and the relative performance of each home appliance trait were assessed with respect to 22 characteristics of SH-PSS. Respondents' general satisfaction with household appliances was also examined on a five-point Likert scale. We collected 126 valid questionnaires. In 126 valid polls, 81 were male, and 45 were female. More than half of the respondents had a bachelor's degree or above. Approximately 34 of the respondents were above 40 years old. The majority of respondents were working on a permanent basis, and the median salary range was between 5 and 10 lakhs Indian rupees per annum. The most common family size was four or five people, followed by three or two family members.

Example of **functional questions** for characteristics *C.1.1*:
What will be your response when the smart products help you in tasks like washing clothes, dishes, cooking etc. ?

Example of **dysfunctional question** for characteristics *C.1.1*:
What will be your response when the smart products does not help you in tasks like washing clothes, dishes, cooking etc.?

Choice of answer:
1) Like (I like it this way);
2) Must (I expect it this way);
3) Neutral (I am neutral);
4) Can live with it (I can live with it this way);
5) Dislike (I don't like it this way);

3.4 Conducting a survey using Questionnaire

Smart home functions (Table 8) are the services and enabling technology in smart homes which are: *comfort, monitoring, health therapy, support, and consultancy*. (Appendix A)

Table 8 Defining characteristic of smart home functions and their justification

	Characteristics	Justification
C.1	Comfort	*C.1.1:* SH-PSS helps you in a daily task like washing clothes, dishes, cooking etc.
		C.1.2: SH-PSS allows you to manage your home even if you are outside.
C.2	Monitor	*C.2.1:* SH-PSS allows you to analyze your health data like blood pressure, heart rate, ECG etc. and act.
		C.2.2: SH-PSS allow you to monitor air quality parameters like PM 2.5, NO2, VOC, relative humidity, ventilation and act.

TH-3294_196105005

C.3	Health therapy	*C.3.1:* SH-PSS detects potential injuries or diseases and provide suggestions.
		C.3.2: SH-PSS smoke detector ringing alarm as well as showing a warning on the mobile app for people with hearing issues.
C.4	Support	*C.4.1:* SH-PSS smoke detector ringing alarm as well as showing a warning on the mobile app for people with hearing issues.
		C.4.2: Smart glasses guiding the way for the visual disable or blind person.
C.5	Consultancy	*C.5.1:* SH-PSS notifying you about real time information about wash cycle status
		C.5.2: SH-PSS suggesting how to avoid extreme weather conditions

Product Smartness: (Table 9) The literature discusses qualities that define a product as smart: *independent, adaptive, reactive, multi-functional, ability to cooperate, humanlike interaction, and personality*. (Appendix A)

Table 9 Defining product smartness characteristics and their justification

	Characteristics	Justification
C.6	Independent	*C.6.1:* SH-PSS fridge detects that there is no milk, so it automatically orders milk
		C.6.2: SH-PSS vacuum cleaner avoid obstruction on their own while completing cleaning task
C.7	Adaptive	*C.7.1:* SH-PSS air conditioner reacting to the hot weather and turning the temperature down; and vice versa
		C.7.2: SH-PSS lights automatically adapt to its environment and adjust lighting
C.8	Reactive	*C.8.1:* Smart Watch reminding the runner to take some rest as their heart rate is up.
		C.8.2: The smart locker recognizes the owner's voice and opens itself.
C.9	Multi-functional	*C.9.1:* Smart Fridge that can play music, show the weather, show recipes, order food, show the items inside the fridge and a lot more.
		C.9.2: SH-PSS television giving updates of surrounding and who is on door apart from their main purpose
C.10	Ability to cooperate	*C.10.1:* Smartphone automatically sharing the Wi-Fi password with the smart speaker
		C.10.2: SH-PSS cooperate with each other to provide a personalized experience
C.11	Humanlike interaction	*C.11.1:* Alexa knows that the resident is angry, so she tries to talk calmly
		C.11.2: SH-PSS communicating with native accent

TH-3294_196105005

C.12	Personality	*C.12.1:* Smart Thermostat being funny and joking about the weather
		C.12.2: SH-PSS changing its mood based on the status of product

Quality consumer looking for in SH-PSS: In previous studies various qualities, that a consumer looks for in a smart home product. These qualities are categorized as 'within the product', 'related to the usage of the product' and 'related to other products' (Table 10). These qualities are crucial as they will affect consumer behavior, on the decision to adopt smart home products. (a) Within product: *Context awareness, Interpretation, Proactive, Self-description*; (b) Usage: *Personalization, User friendly interaction*; (c) With other products: *Communication, Cooperation, Openness, Collaboration.* (Appendix A)

Table 10 Defining quality consumer looking for in SH-PSS and their justification

	Characteristics	Justification
C.13	Context Awareness	C.13.1: SH-PSS are aware about their surrounding; e.g.: smart home door welcomes the owner and alerts when it detects unauthorized entry.
		C.13.2: SH-PSS automatically perform a function based on their surroundings; e.g.: garage door opens up when it detects car coming.
C.14	Interpretation	C.14.1: SH-PSS are able to understand local languages.
		C.14.2: SH-PSS are able to interpret accidents as emergency situations; e.g.: smart watch interprets fall as an emergency situation.
C.15	Proactive	C.15.1: SH-PSS notify you about certain updates that could be important to you like flight schedule.
		C.16.2 SH-PSS provide you with suggestions on their own; e.g.: smart speaker suggest user to leave early for work to avoid traffic.
C.16	Self-description	C.16.1:SH-PSS guide you through their usage.
		C.16.2: SH-PSS provide you with information on how they function; e.g.: user ask how often smart speaker sync email to smart speaker.
C.17	Personalization	C.17.1: If user is able to customize your smart products.
		C.17.2: SH-PSS recommend you apparel based on your choices; e.g.: smart shoe rack recommends footwear.
C.18	User friendly interaction.	C.18.1: SH-PSS greets you and have conversation with you.
		C.18.2: SH-PSS detect the time and set mood accordingly; e.g.: smart speaker automatically plays ambient music when it is dinner time.
C.19	Communication	C.19.1: SH-PSS communicate with each other to solve problems; e.g.: smart camera detects dust on floor and tells smart vacuum cleaner to clean.
		C.19.2: SH-PSS communicate to get updates from each

TH-3294_196105005

		other.
C.20	Co-operation	C.20.1: SH-PSS cooperate with each other like smart speaker shares WIFI password to new devices by voice confirmation.
		C.20.2: SH-PSS works together to give user best experience; e.g.: smart headphones get connected with multiple device and switch between them seamlessly.
C.21	Openness	C.21.1: SH-PSS transfer Movies, TV shows or music with each other seamlessly.
		C.21.2: SH-PSS share your open data with other smart products.
C.22	Collaboration	C.22.1: SH-PSS collaborate with each other to provide extra features; e.g.: two smart speakers connected with each other to provide stereo sound.
		C.22.2: SH-PSS collaborate with each other to provide extra comfort; e.g.: smart curtains automatically close after sunset and smart lamps lights up.

3.5 Mapping the answers into six categories of the Kano Model

Table 11 Kano Evaluation Table

Respondents answer		Dysfunctional Question				
		Like	Must	Neutral	Can live with it	Dislike
Functional Question	Like	Q	A	A	A	O
	Must	R	I	I	I	M
	Neutral	R	I	I	I	M
	Can live with it	R	I	I	I	M
	Dislike	R	R	R	R	Q

The definition of each category is as follows (Table 11):

M = Must-be, means when a characteristic underperforms, residents are dissatisfied; meanwhile, when a characteristic performs well, residents' satisfaction is just slightly above neutral. When satisfied, must-have characteristics are taken for granted, while their absence leads in discontent. Residents anticipate these characteristics and therefore view them as fundamentals and basics.

O = One dimensional, means there is a linear relationship between resident's satisfaction and performance level, with satisfaction increasing as performance parameters increase and vice versa.

A = Attractive, means that resident's satisfaction will improve dramatically with rising characteristic performance, but will not drop with decreasing characteristic performance.

R = Reverse, means that user satisfaction is inversely proportional to the characteristic performance. Reverse requirements bring more satisfaction if absent then if present.

TH-3294_196105005

Q = Questionable, means that user satisfaction cannot be defined, i.e., when the user's reaction to the contested characteristic contradicts itself. These requirements do not fall under any of the aforesaid five categories.

I = Indifferent, means that the outcomes of the performance criteria have no impact on resident's satisfaction. Residents do not care if these characteristic is present or not.

3.6 Kano Model Results

This study has identified several features that need to be improved in the SH-PSS implemented in India. We utilized the Kano Model by testing 22 characteristics representing features and recommended improvements for the future development of SH-PSS.

The results and categorization for each characteristic are presented in Table 12, 13, 14. It includes the percentages for the categories Attractive, Must-be, One-dimensional, and Indifferent, but there are no categories for Reverse and Questionable. We use calculations to determine the potential of customer satisfaction (x-axis) and dissatisfaction (y-axis). The negative value of the dissatisfaction coefficient just describes dissatisfaction and has no effect on the graph's mapping.

Table 12 Result and categorization for characteristic of smart home functions

Characteristics and its category A= Attractive; M= Must be; O= One Dimensional; I=Indifferent					x-axis	y-axis	Result
C.1: Comfort	*C.1.1:*	A=34.51%	M=38.05%	O=10.18%	47.20	54.67	Must Be
		I=8.41%	R=3.54%	Q=5.31%			
	C.1.2:	A=31.42%	M=42.48%	O=11.06%	44.44	59.26	Must Be
		I=7.52%	R=3.10%	Q=4.42%			
C.2: Monitor	*C.2.1:*	A=36.28%	M=36.28%	O=10.18%	48.62	51.37	Must Be
		I=10.62%	R=3.10%	Q=3.54%			
	C.2.2:	A=22.12%	M=24.78%	O=40.27%	65.27	70.83	One Dimensional
		I=5.75%	R=2.65%	Q=4.42%			
C.3: Health therapy	*C.3.1:*	A=56.64%	M=4.87%	O=15.93%	86.17	22.58	Attractive
		I=17.70%	R=0.88%	Q=3.98%			
	C.3.2:	A=30.09%	M=11.06%	O=11.95%	43.77	27.65	Indifferent
		I=39.38%	R=3.54%	Q=3.98%			
C.4: Support	*C.4.1:*	A=38.05%	M=13.72%	O=34.07%	74.77	52.29	One Dimensional
		I=7.96%	R=2.65%	Q=3.54%			
	C.4.2:	A=37.61%	M=19.03%	O=32.30%	72.81	56.22	One Dimensional
		I=4.42%	R=2.65%	Q=3.98%			
C.5: Consultancy	*C.5.1:*	A=27.43%	M=37.61%	O=19.03%	48.61	62.96	Must Be
		I=7.96%	R=3.54%	Q=4.42%			
	C.5.2:	A=65.04%	M=10.18%	O=7.08%	75.46	20.83	Attractive
		I=10.62%	R=2.65%	Q=4.42%			

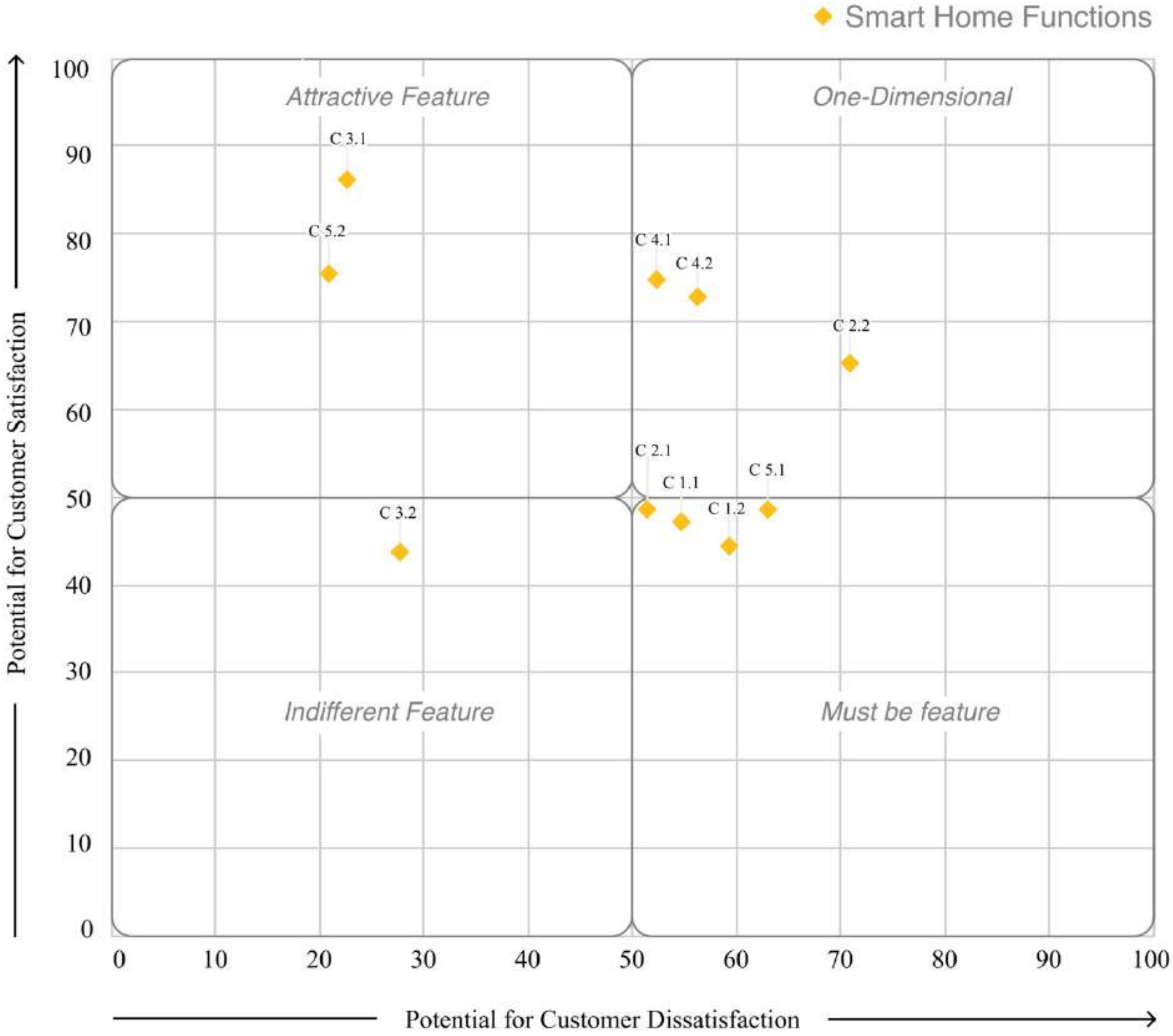


Figure 7 Kano Graph for characteristic of smart home functions

Figure 7 depicts the Kano Model's subsequent graphical representation in which yellow notation denotes smart home functions and in Figure 8 green denotes product smartness.

Table 13 Result and categorization for product smartness characteristic

Characteristics and its category A= Attractive; M= Must be; O= One Dimensional; I=Indifferent					x-axis	y-axis	Result
C.6: Independent	*C.6.1:*	A=36.28%	M=10.62%	O=8.41%	46.97	22.32	Indifferent
		I=37.61%	R=2.21%	Q=4.87%			
	C.6.2:	A=43.36%	M=19.47%	O=12.83%	58.52	36.40	Attractive
		I=17.70%	R=2.65%	Q=3.98%			
C.7: Adaptive	*C.7.1:*	A=26.99%	M=19.47%	O=38.94%	68.98	62.03	One Dimensional
		I=9.29%	R=0.88%	Q=4.42%			
	C.7.2:	A=16.37%	M=12.39%	O=56.64%	76.38	75.46	One Dimensional
		I=7.08%	R=3.10%	Q=4.42%			
C.8: Reactive	*C.8.1:*	A=30.53%	M=23.01%	O=38.50%	71.88	67.28	One Dimensional
		I=0.88%	R=3.10%	Q=3.98%			

	C.8.2:	A=27.43%	M=20.35%	O=30.97%	61.11	57.40	One Dimensional
		I=13.27%	R=3.54%	Q=4.42%			
C.9: Multi-functional	*C.9.1:*	A=55.31%	M=6.19%	O=7.52%	65.13	15.13	Attractive
		I=26.55%	R=0.88%	Q=3.54%			
	C.9.2:	A=49.56%	M=9.73%	O=6.19%	58.25	17.43	Attractive
		I=30.09%	R=0.88%	Q=3.54%			
C.10: Ability to cooperate	*C.10.1:*	A=38.05%	M=20.35%	O=17.26%	57.33	42.20	Attractive
		I=17.70%	R=3.10%	Q=3.54%			
	C.10.2:	A=51.77%	M=8.41%	O=11.50%	65.59	22.93	Attractive
		I=22.57%	R=2.21%	Q=3.54%			
C.11: Humanlike interaction	*C.11.1:*	A=22.57%	M=19.47%	O=10.62%	34.88	34.41	Indifferent
		I=39.82%	R=2.65%	Q=4.87%			
	C.11.2:	A=51.77%	M=15.93%	O=17.26%	71.88	38.24	Attractive
		I=7.52%	R=3.54%	Q=3.98%			
C.12: Personality	*C.12.1:*	A=30.09%	M=16.37%	O=6.19%	38.31	47.66	Indifferent
		I=19.47%	R=22.57%	Q=5.31%			
	C.12.2:	A=27.43%	M=8.41%	O=11.95%	41.58	42.52	Indifferent
		I=26.99%	R=19.91%	Q=5.31%			

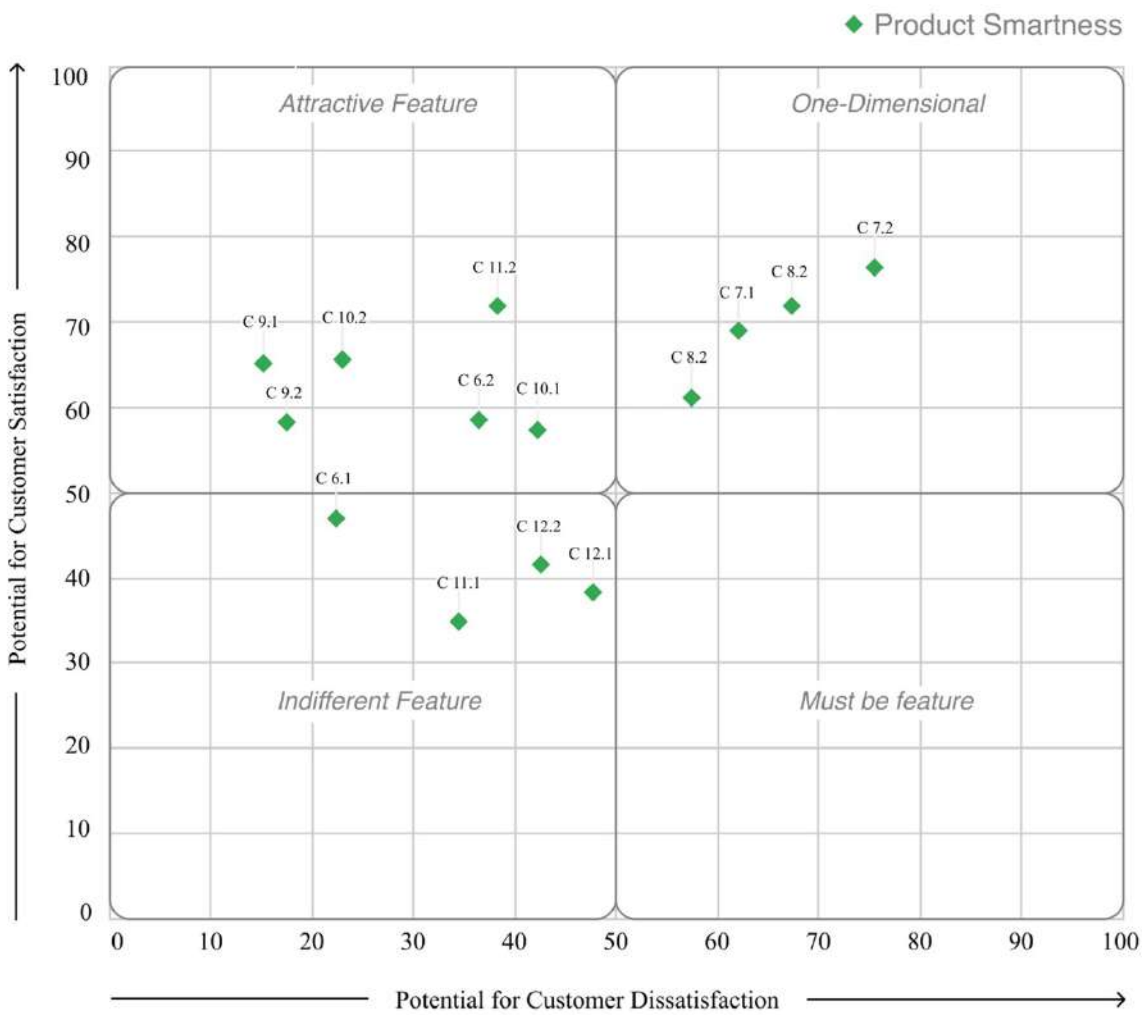


Figure 8 Kano Graph for product smartness characteristic

Figure 9 depicts the Kano Model's subsequent graphical representation denotes quality consumer looking for in SH-PSS.

Table 14 Result and categorization for quality consumer looking for in SH-PSS

Characteristics and its category A= Attractive; M= Must be; O= One Dimensional; I=Indifferent					x-axis	y-axis	Result
C.13: Context Awareness	C.13.1:	A=42.78%	M=9.79%	O=33.51%	77.49	47.12	Attractive
		I=9.28%	R=3.09%	Q=1.55%			
	C.13.2:	A=36.08%	M=9.28%	O=32.47%	70.37	44.44	Attractive
		I=18.04%	R=1.55%	Q=2.58%			
C.14: Interpretation	C.14.1:	A=27.84%	M=14.95%	O=36.60%	66.49	55.85	One Dimensional
		I=14.95%	R=2.58%	Q=3.09%			
	C.14.2:	A=31.96%	M=35.05%	O=13.40%	46.81	52.66	Indifferent
		I=13.92%	R=2.58%	Q=3.09%			
C.15: Proactive	C.15.1:	A=23.71%	M=39.69%	O=13.92%	38.62	57.14	Indifferent
		I=18.04%	R=2.06%	Q=2.58%			
	C.15.2:	A=27.32%	M=18.56%	O=40.21%	69.68	64.36	One Dimensional
		I=7.22%	R=3.61%	Q=3.09%			
C.16: Self-description	C.16.1:	A=35.05%	M=9.28%	O=10.82%	46.84	21.58	Indifferent
		I=41.75%	R=1.03%	Q=2.06%			
	C.16.2:	A=32.99%	M=12.89%	O=9.28%	42.49	26.18	Indifferent
		I=39.69%	R=3.61%	Q=1.55%			
C.17: Personalization	C.17.1:	A=44.85%	M=11.86%	O=15.98%	62.11	31.05	Attractive
		I=22.68%	R=2.58%	Q=2.06%			
	C.17.2:	A=58.25%	M=5.67%	O=13.92%	74.07	21.16	Attractive
		I=18.56%	R=1.03%	Q=2.58%			
C.18: User friendly interaction	C.18.1:	A=26.29%	M=6.70%	O=12.37%	39.68	22.22	Indifferent
		I=49.48%	R=2.58%	Q=2.58%			
	C.18.2:	A=32.47%	M=15.98%	O=14.43%	48.40	34.57	Indifferent
		I=30.93%	R=3.09%	Q=3.09%			
C.19: Communication	C.19.1:	A=36.60%	M=22.68%	O=20.10%	57.89	47.37	Attractive
		I=14.95%	R=3.61%	Q=2.06%			
	C.19.2:	A=35.57%	M=27.32%	O=18.56%	54.97	52.88	One Dimensional
		I=10.82%	R=6.19%	Q=1.58%			
C.20: Co-operation	C.20.1:	A=31.96%	M=40.21%	O=13.92%	46.84	61.05	Must-Be
		I=6.19%	R=5.67%	Q=2.06%			
	C.20.2:	A=23.20%	M=24.74%	O=32.47%	57.45	63.83	One Dimensional
		I=11.86%	R=4.64%	Q=3.09%			
C.21: Openness	C.21.1:	A=44.85%	M=8.76%	O=11.86%	57.89	23.16	Attractive
		I=30.41%	R=2.06%	Q=2.06%			
	C.21.2:	A=55.15%	M=8.25%	O=7.73%	64.21	17.37	Attractive
		I=25.77%	R=1.03%	Q=2.06%			
C.22: Collaboration	C.22.1:	A=34.02%	M=11.34%	O=38.66%	73.82	52.88	One Dimensional
		I=12.37%	R=2.06%	Q=1.55%			

	C.22.2:	A=46.91%	M=12.37%	O=20.62%	69.31	35.45	Attractive
		I=15.98%	R=1.55%	Q=2.58%			

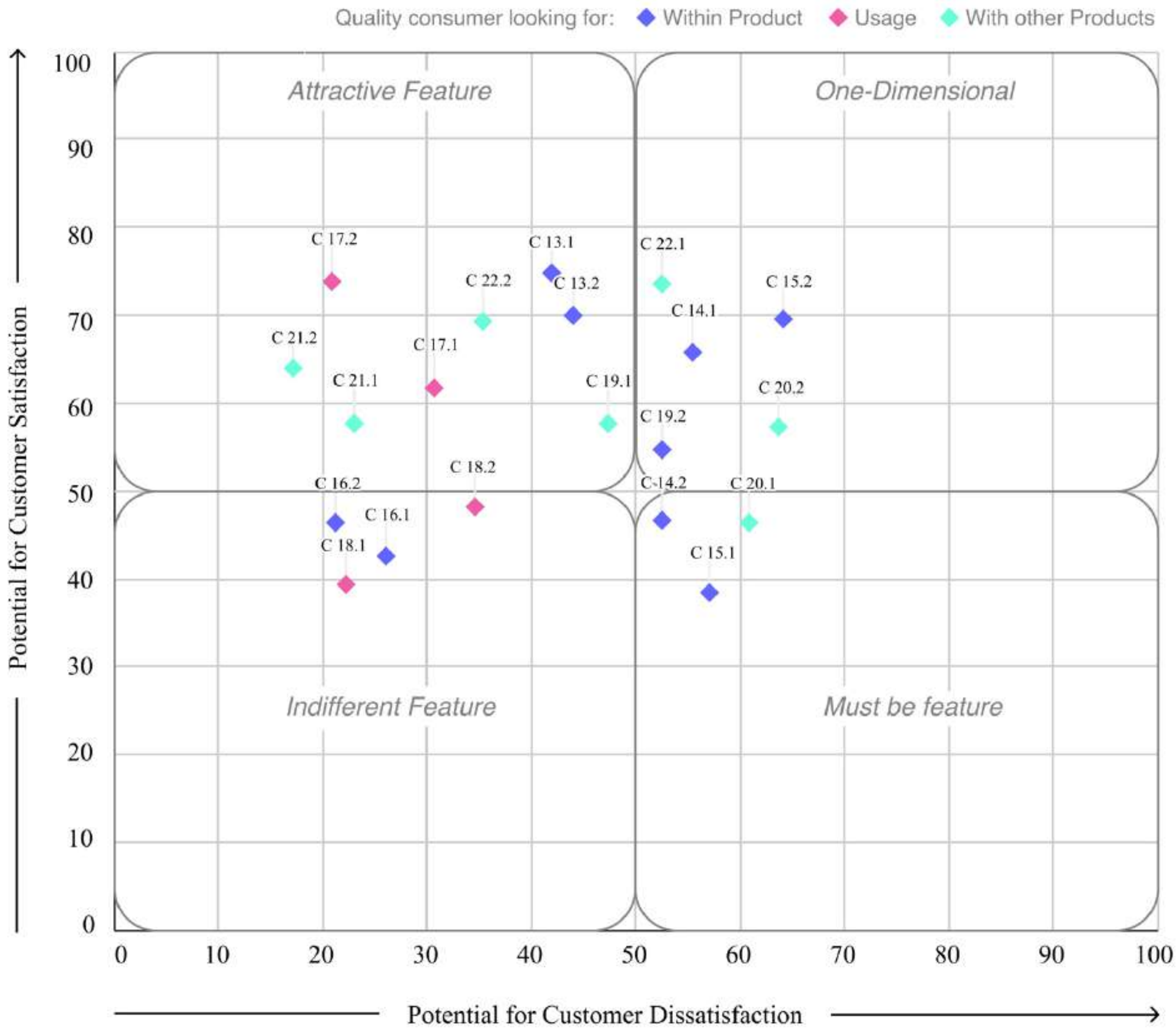


Figure 9 Kano Graph for quality consumer looking for in SH-PSS

3.7 Chapter Conclusion

The characteristics that are in the category of "**Must be**": The results indicate that six characteristics come into the "Must Be" category, in which customers are dissatisfied when the performance of the characteristics is poor. However, their satisfaction is not significantly higher than neutral when the characteristic performs well. In smart home functions: comfort, monitoring, and consulting services (*C.1.1, C.1.2, C.2.1, C.5.1*); and in qualities consumer looking for in SH-PSS: interpretation, proactive, co-operation (*C.14.2, C.15.1, C.20.1*) are the features which suggest that future enhancements will increase the productivity and efficiency of residents. According to the graphs, the position of the all six characteristics is in the Must-be quadrant but starts approaching the One-dimensional quadrant. Thus, these characteristics must be provided to enhance users' satisfaction. If future improvement does not provide better features, it will reduce users' satisfaction (Table 17).

The characteristics that are in the category of “**Attractive**”: Two characteristics of smart home functions: health therapy and consultancy (*C.3.1, C.5.2*); four characteristics of product smartness: independent, multi-functional, ability to cooperate, and humanlike interaction (*C.6.2, C.9.1, C.9.2, C.10.1, C.10.2, C.11.2*); and five characteristics of qualities consumer looking for in SH-PSS: context awareness, personalization, communication, openness, collaboration (*C.13.1, C.13.2, C.17.1, C.17.2, C.19.1, C.21.1, C.21.2, C.22.2*) fall into the category of "Attractive". These characteristics will definitely result in customer satisfaction. However, if this element is not obtained, it will not result in dissatisfaction. Attractive characteristics of smart home function include one of the use cases of providing health therapy and providing consultancy services. In the case of product smartness, attractive characteristics include one use case of independence of SH-PSS and humanlike interaction with users, and both the use cases of multi-functional SH-PSS and the ability to cooperate with other SH-PSS. In the case of qualities consumers are looking for in SH-PSS, attractive characteristics include one use case of communication; and both the use cases of context awareness, personalization, and openness.

The characteristics that are in the category of “**One dimensional**”: Two characteristics of smart home functions: monitor and support (*C.2.1, C.4.1, C.4.2*); two characteristics of product smartness: adaptive, reactive (*C.7.1, C.7.2, C.8.1, C.8.2*); and five characteristics of qualities consumer looking for in SH-PSS: interpretation, proactive, communication, co-operation, collaboration (*C.14.1, C.15.2, C.19.2, C.20.2, C.22.1*) fall into the category of "One dimensional". As for these requirements, satisfaction is proportional to performance level. The higher the performance, the higher the customer satisfaction and vice-versa. One-dimensional features of smart home functions and product smartness include one of the use cases of monitoring, and both the use cases of providing a support system to the consumers, the ability to adapt to the surrounding and reactive SH-PSS. Regarding qualities consumers are looking for in SH-PSS, one-dimensional characteristics include one use case of interpretation, proactive, communication, co-operation, collaboration.

The characteristics that are in the category of “**Indifferent**”: Meanwhile, the six other characteristics: health therapy, independent, humanlike interaction, personality, self-description, and user-friendly interaction (*C.3.2, C.6.1, C.11.1, C.12.1, C.12.2, C.16.1, C.16.2, C.18.1, C.18.2*) fall into the category of "Indifferent", which users do not consider as significant in affecting their future satisfaction. These features include one use of health therapy, independence of smart products and services, humanlike interaction, and both the use cases of smart product personality, self-description, and user-friendly interaction.

Table 15 Kano Result and categorization

Category		Characteristics
Must be	*C.1.1; C.1.2*	Comfort
	C.2.1	Monitor
	C.5.1	Consultancy
	C.14.2	Interpretation
	C.15.1	Proactive
	C.20.1	Co-operation
Attractive	*C.3.1*	Health therapy

	C.5.2	Consultancy
	C.6.2	Independent
	C.9.1; C.9.2	**Multi-functional**
	C.10.1; C.10.2	**Ability to cooperate**
	C.11.2	Humanlike interaction
	C.13.1; C.13.2	**Context Awareness**
	C.17.1; C.17.2	**Personalization**
	C.19.1	Communication
	C.21.1; C.21.2	**Openness**
	C.22.2	Collaboration
One dimensional	*C.2.2*	Monitor
	C.4.1; C.4.2	Support
	C.7.1; C.7.2	Adaptive
	C.8.1; C.8.2	Reactive
	C.14.1	Interpretation
	C.15.2	Proactive
	C.19.2	Communication
	C.20.2	Co-operation
	C.22.1	Collaboration
Indifferent	*C.3.2*	Health therapy
	C.6.1	Independent
	C.11.1	Humanlike interaction
	C.12.1; C.12.2	Personality
	C.16.1; C.16.2	Self-description
	C.18.1; C.18.2	User friendly interaction

TH-3294_196105005

Chapter 4: Design of Smart Home Product-Service-System (SH-PSS) Conceptual Framework

4.1 Introduction

Advancements in home appliance technology have fueled the smart home industry. This shows that the success of a smart home system is dependent on the availability of useful, valuable, and desirable smart home products and related services. In practice, however, success stories are uncommon since manufacturers prioritise technical developments that may or may not align with customer expectations (Valencia et al., 2015). In a smart home, physical and digital services are integrated with household appliances through information and communication technologies (ICTs). Introducing new services into an existing product's lifetime and developing complementary products are two approaches to integrating products and services. For instance, a smart refrigerator may provide recipes depending on its contents, or a smart door lock could be included in a home security service. Since products and services may interact with each other, every smart home is a product-service system (PSS). Product Service Systems (PSS) integrate products with specific applicable services to fulfil customer requirements. An increasing number of businesses are using PSS to maximise product value and boost profits (Hallstedt et al., 2020). A PSS provides consumers value through integrated products and services, often resulting in various stakeholder collaborations. Consequently, a PSS method is effective for building smart homes, typically consisting of products, services, and a network of many stakeholders.

Smart Home Product-Service Systems (SH-PSS) is a new term that authors introduced as "smart home products and their associated e-services into a single solution by embracing disruptive ICT." SH-PSS are realizable because of the current improvements in digital home appliance technology, commonly known as "digitization" (Frank et al., 2019). Digital technologies may be used to construct intelligent and networked services capable of interacting with the physical world (IoT devices, sensors, etc.) and carrying out activities such as data analytics, big data processing, etc. Several studies (Kuhlenkotter et al., 2017; Liu et al., 2018; Pirola et al., 2020) have referred to smarts PSS as a "digital ecosystem that comprises stakeholders, devices, and platforms and is characterized by its high complexity. In order to build value via co-creation, smart PSS must collaboratively capture the needs of various stakeholders (Zheng et al., 2019b). User experience (UX) is a competitive differentiator that must respond to several usage scenarios in varied situations and build a lifetime connection between service providers of smart homes and residents via the services provided (Valencia et al., 2015).

4.2 Research Methodology

This study is an integrative review, defined as one in which the published research studies are critically analysed and synthesized into a significant contribution to new knowledge about the theme under study. The development of an integrative review includes six steps: the selection of research questions, defining the criteria for literature screening, defining categories or themes that emerged from the existing research articles, analysis, and synthesis, logical and conceptual reasoning, implications for future research (Snyder, 2019). This research aims to answer the following questions:

1. What are the fundamental characteristics of a Smart Home Product Service System?
2. What is the connection between user-centric design and the user experience of Smart

TH-3294_196105005

Home Product Service System (SH-PSS)?

3. What are the current gaps and challenges in the design of SH-PSS to meet user's requirements and enhance the user's experience?
4. What are the tool and methods toolkits for ideation of IoT and Smart Home products?

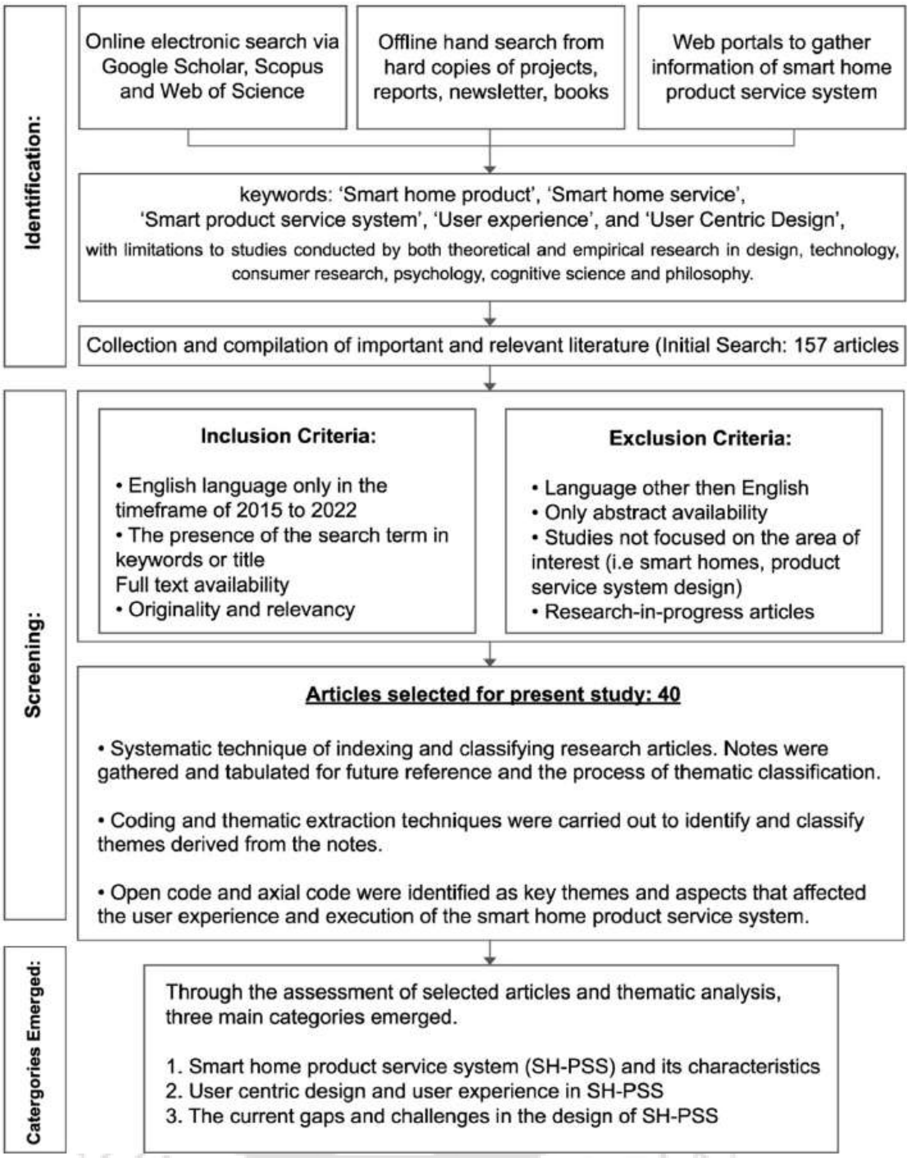


Figure 10 Process and method of research for the study

A systematic search was conducted using online databases: Google Scholar, Scopus, and Web of Sciences. The keywords used for this purpose were "Smart home product ", "Smart home service", "Smart home product service system", "User experience", and "User Centric Design", with limitations to studies conducted by both theoretical and empirical research in design, technology, consumer research, psychology, cognitive science and philosophy. The inclusion criteria were: (a) Works written in the English language only in the timeframe of 2013 to 2022, (b) the presence of the search term in keywords or title, (c) full-text availability, (d) original and relevant articles in the smart home and product service system design. Furthermore, additional papers from reference lists of the articles reviewed were also identified.

TH-3294_196105005

The initial search resulted in the identification of 157 articles. After applying inclusion and exclusion criteria, 40 articles remained for our review. There was a systematic technique for indexing and classifying research articles. Notes were gathered and tabulated for future reference and the process of thematic classification. Furthermore, coding or thematic extraction techniques were carried out to identify and classify themes derived from the notes. The coding methods consisted of two phases: open coding and axial coding. Open code and axial code were identified as key themes and aspects that affected the user experience and execution of the smart home products service system. Through the assessment of selected articles and thematic analysis, three main categories emerged, which are represented in Figure 10.

4.3 Smart Home Product-Service-System Conceptual Framework

Smart Product-Service System (S-PSS) is defined as "smart products and their generated e-services including their interactions with numerous stakeholders into a unified solution by embracing disruptive ICT." In this study, we define Smart Home Product-Service Systems as follows: "SH-PSS is an IT-driven value co-creation business strategy consisting of various stakeholders as the players and residents, smart systems as the infrastructure and home, smart and connected products as the media and tools, and their generated e-services as the key values delivered that continuously strives to meet individual consumer needs sustainably within the context of residence."

Consequently, SH-PSS are developed at the intersection of highly digitized products that enable user-centric business processes and associated services. Digital capabilities are one of the significant distinctive qualities between standard PSS and Smart PSS, according to Zheng et al. (2019b). This is the first step toward digitalization, starting with intelligence capabilities, which include the capacity to configure hardware components to detect and record information via embedded systems and sensors placed into products to collect data and respond to their environment.

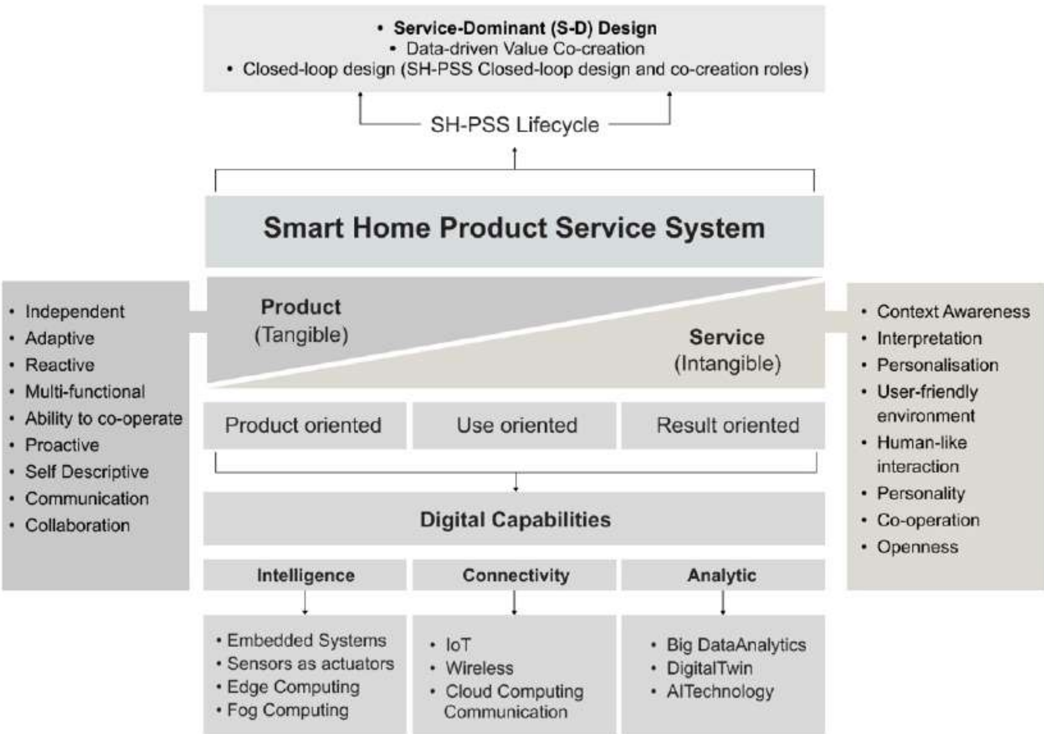


Figure 11 Smart Home Product-Service-System Conceptual Framework

In addition, the ubiquitous connection of smart products made possible by IoT technology and wireless communications, which is necessary for service providers to gather data and optimize processing using cloud computing, allows multiple devices to interact. Last but not least, the analytic capacity is responsible for translating data from deployed smart and connected products into valuable service design insights supported by technologies such as big data analytics, digital twins, and artificial intelligence (Lenka et al., 2017). Smart PSS (Figure 11) preserves the essential business foundations of conventional PSS, which may be classified into three major categories (Figure 1): product-oriented, use-oriented, and result-oriented (Tukker, 2004).

Smart products have the potential to sense what is happening around them and adjust to provide personalized experiences, which can give them an edge in competitive Product-Service Systems (PSSs). This involves aspects like context awareness, knowledge collection, inference, proactivity, personalization, and user-friendly interaction. It is essential to consider how much personalization is needed, whether treating a family as a group or as individuals. The correct information about individuals, their situations, and the environment is critical to increasing the user experience. After all, the same user may react differently in different situations, so it is about being flexible and responsive. In addition, combining user data with expert knowledge can lead to valuable services. For example, using user data on nutrition and physical activity in combination with medical and healthcare information, a service that assists users in living a healthy lifestyle may be developed. The key is to make these services valuable and easy to use so that people can appreciate their value. Therefore, personalized experiences must be user-friendly.

Developing and operating a smart home involves many partners working together within a collaborative ecosystem. They range from large corporations that develop smart home platforms and systems to small and medium-sized businesses that supply appliances and components. As the demand for seamless and dependable user experiences across a wide range of activities in smart homes continues to grow, it becomes clear that these services and products must be developed as integral parts of a more comprehensive system. In the context of smart homes, strategic partnerships are necessary and encouraged, facilitated by intelligent product features like machine-to-machine communication, semantic self-description, and an emphasis on openness and collaboration. Within these collaborative settings, unique partnerships can emerge, crossing industry boundaries – for instance, a partnership between a grocery store, a refrigerator manufacturer, a detergent company, and a washing machine producer. This cross-sector cooperation represents a strategic approach for smart home manufacturers seeking fresh business opportunities and a distinct market presence in the highly competitive realm of household appliances.

Personalization, user-friendly interaction, and the accumulation of information may inspire users to fully embrace smart homes if they are provided with several alternatives for reducing environmental impacts. Context awareness keeps track of smart products' status to extend their lifespan, along with proactive methods that optimize energy efficiency and machine-to-machine communication that encourages eco-friendly behaviors. However, compared to other advantages of Smart Home Product-Service Systems (SH-PSS), the "reduced environmental impact" aspect showed a weaker connection with smart product attributes. This suggests that, at present, environmental impact might not be a top priority for smart home businesses. New smart products must replace obsolete household equipment

TH-3294_196105005

to build a smart home system. Researchers have also suggested that government intervention could reduce the environmental impact of economic activities. From such controversial statements, we can only conclude that environmental concerns are not presently a top priority for smart home businesses.

The concept of "smartness" is increasingly evident in smart homes, focusing on delivering personalized user experiences and promoting collaboration among devices. An examination of smart products in early 2019 reveals various features falling into two primary categories. The more commonly observed features include Machine-to-Machine (M2M) communication, which enables devices like hubs to communicate with appliances like vacuum cleaners, and context awareness, exemplified by features like air quality sensing and floor mapping. Less frequently observed are attributes like openness and cooperation, where devices like microwaves cooperate with food manufacturers, and multifunctionality, such as combining an air purifier with a heater and cooler. Notably, relatively few products offered truly personalized user experiences, like thermostats that learn user preferences or refrigerators that generate shopping lists based on inventory. However, the broader smart home system has a clear trend toward customization. At the core of this ecosystem are artificial intelligence-operated hubs, often equipped with voice-activated virtual assistants, providing users access to the full range of smart home functionalities.

4.4 User centric Design in SH-PSS

For New Technology Adoption, there is a need to imply user-centered development (UCD). This means we put the needs of the people who will use the product at the center of our design process. We do this because it helps improve the product and gives us an advantage over others. UCD consists of four stages ISO 9241–210 (ISO, 2010): Research: understanding and identifying the context of usage; Analysis: establishing user needs; Design: generating design solutions that fulfil these criteria; and Evaluation: assessment. The whole process is iterative and repeated until the desired outcomes are achieved (Figure 12).

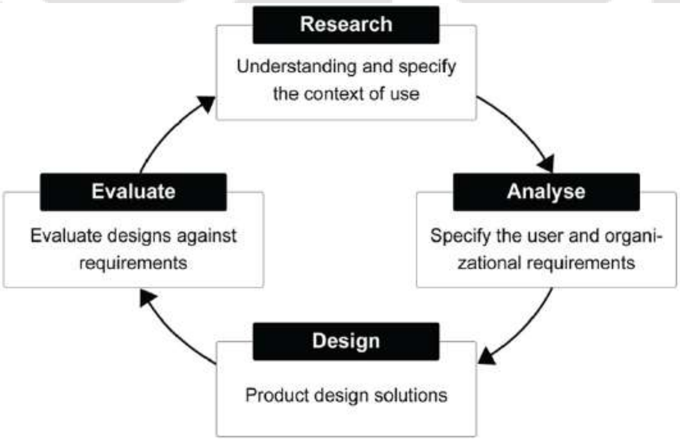


Figure 12 User-centered development (UCD) process

Context awareness is any piece of information that describes the current circumstances of a person, location, or surrounding product (Perera et al., 2013). Multiple scholars have emphasized the significance of context in smart PSS (Cong et al., 2020b; Valencia Cardona et al., 2015; Zheng et al., 2019b) since it helps to ensure that services and products can adapt to a wide range of scenarios and

TH-3294_196105005

cater to the needs of diverse stakeholders (Table 19).

Table 16 Importance of Context awareness

	Entity	*Content Relationship*	*Reference*
1	Smart PSS	"highly **context** dependant" "Smart PSS **context** should be primarily collected to enable real understanding of user behaviour and trigger development"	Valencia Cardona et al., 2015; Cong et al., 2020
2	Context Awareness	"A system is context-aware if it uses **context** to provide relevant information and/or services to the user, where relevancy depends on the user's task"	Perera et al., 2013
3	SD-Logic	"value co-creation" view that uses experiences, **context** and participation from stakeholders to innovate"	Wetter-Edman et al., 2014
4	User Centric Design	"Understand and specify the **context** of use..."	ISO, 2010
5	User Experience	"...is a result of ...user's state., and the **context** features within which the interaction occurs"	Hassenzahl and Tractinsky, 2006

Smart PSS Life Cycle: Smart PSS can be analyzed using the traditional product life cycle, although there are significant distinctions in this case. Kiritsis (2011) categorized the stages of the product life cycle into three basic epochs (Figure 13): Beginning-of-Life (BoL), Middle-of-Life (MoL), and End-of-Life (EoL) (EoL). The BoL starts with the designing phase, during which a product is created in accordance with established requirements before being built. The MoL pertains to the product's usage, maintenance, and repair. Reverse logistics strategies, such as recycling, reuse, remanufacturing, and disposal, comprise the conclusion of the EoL. The design phase starts with the requirement elicitation process, during which customers' requirements are identified; however, unlike traditional procedures, designers may depend on data from user behavior and demands that can be gathered throughout the manufacturing and use stages. Services may be separated into product-independent services (e-services) and digitized services (e-services) that rely on the smart capabilities of the physical product, including monitoring, control, optimization, and autonomy. Digital twins or augmented reality may be a game-changer for digitalized services to make more accurate decisions (Zheng et al., 2019b).

As a result of the smart capabilities of connected products and associated services, the PSS use phase changes significantly from conventional PSS. Beginning with smart operation and maintenance, smart PSS performance is evaluated, and operations are monitored. Smart reconfiguration, on the other hand, includes modifying a product to satisfy new requirements while simultaneously adapting to a changing environment.

TH-3294_196105005

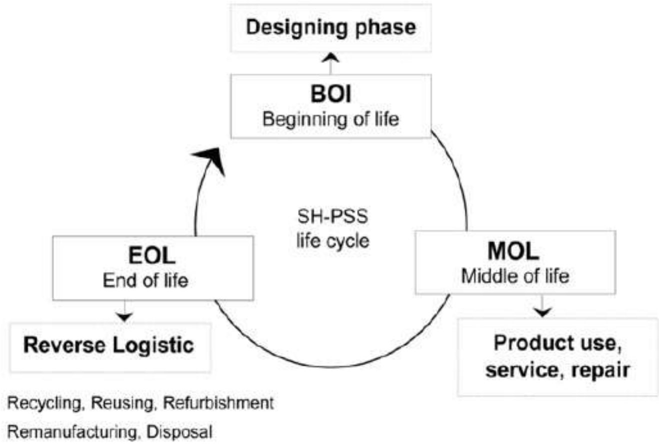


Figure 13 Smart PSS Life Cycle

Lastly, the EoL comprises numerous circumstances, such as product reuse via refurbishing, remanufacturing, recycling, and disposal. Following the transaction, information loops are avoided in conventional product sales. Smart PSS can retrieve the information, delivering data to manufacturers and designers (Kiritsis, 2011). Alcayaga et al. (2019) coined the term "smart-circular system" to describe the combination of the Smart home-PSS and circular economy. Smart PSS enables enhancing processes that result in more effective utilization of resources at the EoL.

4.4.1 Current gaps and challenges in the design of SH-PSS to satisfy user needs and improve user experience

Designing Smart Home Product-Service-Systems (SH-PSS) presents a unique set of challenges and opportunities in the ever-evolving landscape of technology and user expectations. To meet user needs and enhance the overall user experience, several emerging concepts and approaches have gained prominence in recent years. In this context, three significant paradigms have emerged as focal points for design: Service Dominant Design, Data-Driven Value Co-Creation, and Closed-Loop Design. By addressing these gaps and overcoming challenges, designers can unlock the full potential of SH-PSS, delivering innovative, user-centric solutions that cater to the ever-evolving demands of modern living.

- **Service Dominant Design**

Service Dominant Design (SDD) plays a pivotal role in shaping the success of Smart Home Product-Service-Systems (SH-PSS). It has emerged as one of the most critical factors in the design and implementation of SH-PSS due to its multidisciplinary and user-centered approach, which focuses on understanding the intricate interactions between people, institutions, and technological systems. At the core of Service Dominant Design is "value co-creation," a fundamental principle in Service Design (Wetter-Edman et al., 2014). This principle underscores the idea that the user experience (UX), context, and collaboration among multiple stakeholders are critical drivers for crafting new business value propositions within SH-PSS. In essence, SD Design recognizes that value is not merely embedded within products but results from a dynamic and collaborative process involving users, service providers, and technology. The application of SD Design in SH-PSS is underpinned by the Service-Dominant (S-D) logic, which provides a conceptual framework for understanding the shift towards a more service-centric approach in modern businesses. This approach signifies a departure from traditional product-centric models and embraces a holistic perspective that places users at the

TH-3294_196105005

center of the design process.

Several studies have emphasized integrating service design principles and S-D logic into SH-PSS development. For instance, Costa et al. (2018) demonstrated service design's significance in bringing innovative service concepts to fruition. They emphasized the need to comprehend user interactions, institutional dynamics, and technological systems to create SH-PSS that align with evolving user needs. Additionally, researchers like Wetter-Edman et al. (2014) have advocated for a unified strategy combining service design and S-D logic throughout various stages of SH-PSS development, from exploration and production to testing and planned implementation. Such an approach ensures that the resulting SH-PSS meets functional requirements and delivers a superior user experience. Liu et al. (2018) further expounded on the value co-creation paradigm within SH-PSS, emphasizing personalization and value creation across the entire life cycle of these systems. This approach recognizes that SH-PSS are not static entities but dynamic ecosystems that evolve with user needs and technological advancements. In summary, Service Dominant Design, guided by the principles of Service-Dominant logic, is instrumental in shaping the success of SH-PSS. By prioritizing value co-creation, contextual understanding, and multi-stakeholder collaboration, designers can create SH-PSS that meet user needs and adapt and evolve in tandem with the changing landscape of smart home technologies and user expectations.

- **Data Driven Value Co-Creation**

Data-driven value Co-Creation is a critical factor for success in Smart Home Product-Service-Systems (SH-PSS). This approach, which emphasizes the symbiotic relationship between data-driven insights and value creation, has become increasingly indispensable in designing and implementing effective SH-PSS. Several essential aspects underscore the significance of Data-Driven Value Co-Creation in this context (Liu et al., 2018). To comprehend the importance of Data-Driven Value Co-Creation, one can refer to the four-stage framework: co-design, co-implement, and co-evaluate. Developed by Cong et al. (2020b), this framework provides a structured approach to understanding the interplay between data-driven processes and value creation within SH-PSS.

Integral Role of Real-Time Data: Data collection from real-time user-generated sources takes centre stage in the design process of smart PSS. This emphasis on real-time data is crucial because it enables designers and developers to identify and continually evaluate user requirements. In a rapidly evolving smart home landscape, the ability to harness real-time data empowers designers to adapt and refine SH-PSS in response to changing user needs and preferences.

Diverse Co-Creator Roles: Within the SH-PSS ecosystem, consumers are active co-creators who assume various roles at different stages of the product-service life cycle. These roles encompass co-ideators, co-innovators, co-evaluators, co-testers, and even customers as experience designers. This multiplicity of roles reflects the dynamic nature of value co-creation, where users actively participate in shaping the SH-PSS landscape. This approach is in line with the insights presented by Pezzotta et al. (2017).

User-Centric Roles and Responsibilities: The spectrum of user-centric roles and their corresponding responsibilities. These roles range from ideation and innovation to evaluation and testing. Users are not passive consumers but dynamic contributors who actively influence the direction and features of

TH-3294_196105005

smart PSS. As such, their involvement in data-driven processes ensures that the resulting systems are tailored to their needs and expectations.

In essence, Data-Driven Value Co-Creation is a linchpin in the successful development and deployment of SH-PSS. By integrating real-time user-generated data, fostering diverse co-creator roles, and recognizing the user-centric nature of SH-PSS design, this approach ensures that smart home systems remain agile, responsive, and finely tuned to the ever-evolving demands of users. In an era where data is king, Data-Driven Value Co-Creation emerges as a guiding principle that enhances user experiences and drives innovation and competitiveness within the SH-PSS domain.

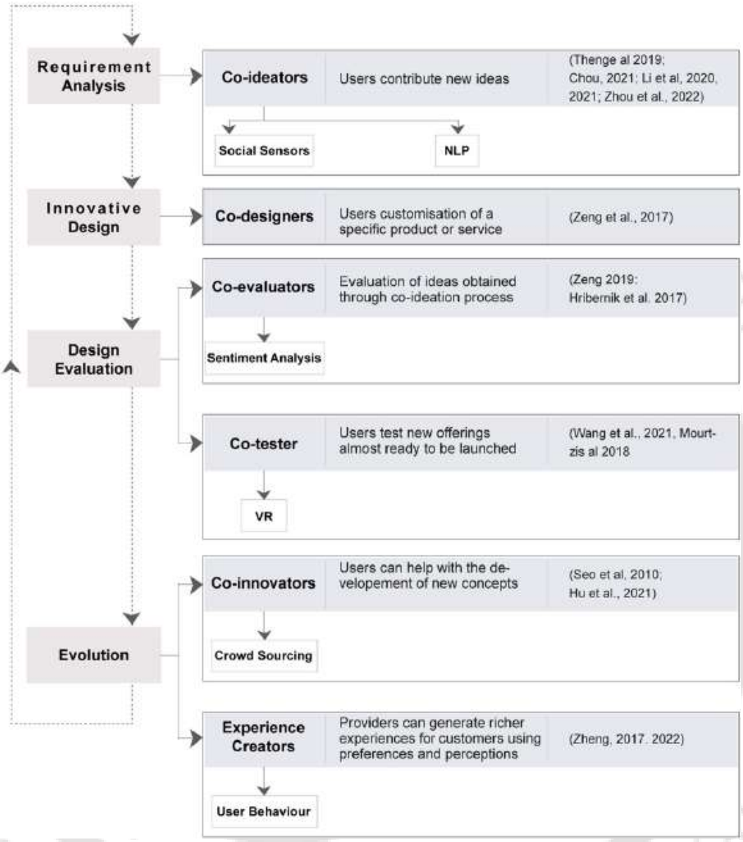


Figure 14 SH-PSS Closed-loop design and co-creation roles

- **Closed Loop Design**

Closed-loop design is a pivotal aspect of Smart Home Product-Service-System (SH-PSS) development, signifying its continuous evolution. However, effectively managing user feedback and behavior within this framework presents notable challenges (Pirola et al., 2020). Despite the significance of user experience (UX) in smart PSS, few studies address it comprehensively, with most concentrating solely on evaluating UX during the design phase, rather than considering the entire smart PSS life cycle. This gap becomes more pronounced when contemplating the capabilities of data-driven customization and self-adaptive design, which can dynamically respond to diverse contextual cues (device, user, and environmental contexts). Cong et al. (2020b) underscored the importance of aligning user preferences with specific smart PSS design elements and usage contexts. However, this aspect is often limited to isolated user-specific settings during smart PSS use. Given the prevalence of digital service platforms in smart PSS, there is a compelling opportunity for personalized user experiences,

TH-3294_196105005

potentially leading to higher satisfaction. A data-driven approach can empower users as "experience designers" and "co-designers," facilitating tailor-made SH-PSS solutions. The closed-loop design has been identified as a distinctive feature of SH-PSS (Wang et al., 2019b; Cong et al., 2020b) since it can be extended to all life cycle phases for a more holistic approach. In addition, as noted by Valencia Cardona et al. (2015), SH-PSS developers must be ready for lifelong evolution. Four steps of "closed-loop design" were outlined by Cong et al. (2020b). In each step, possibilities for users and customers to co-create value from a data-driven viewpoint were recognized, as seen in Figure 14. It operates as a dynamic, iterative approach that spans the entire life cycle of SH-PSS development, ensuring adaptability and relevance. Crucially, Closed Loop Design includes four essential phases: requirements analysis, innovative design, design evaluation, and evolution.

Requirements analysis phase: User requirements need to be collected and identified. Customers may play the role of co-ideators at this phase. Studies have alluded to the co-ideator's involvement in service design via the automated identification of needs. For example, this has been achieved by analysing natural language descriptions of user experiences (Li et al., 2020a, 2021). When behaviour and cognitive aspects are incorporated into the analysis, it is also feasible for users to contribute as experience designers.

Innovative design phase: Developing creative prototypes allows for further analysis of the fulfilment of requirements and consumer needs.

Design evaluation: This evaluation should consider multiple perspectives, sustainability issues, value propositions, and consumer value. Customers might engage as co-evaluators. Here, Wang et al. (2020) provide a method for evaluating the concept of service bundles by analysing customer sentiments. An assessment of usability and UX is also required, with users acting as co-testers in cases where virtual or augmented reality may generate more immersive and realistic experiences.

Evolution phase: This phase illustrates the iterative and self-adaptive nature of SH-PSS, in which the unique situation may trigger service model or product modifications (Cong et al., 2020b). During this phase, users may act as co-innovators. Zheng et al. (2019) developed a hybrid crowdsensing method that uses user-generated and product-sensed data to forecast design actions and incentives for smart-water dispenser users. In a data-driven way, the position of experience designer emphasizes the utilization of data behaviours for smart PSS personalization.

Smart home design requires transitioning from a PSS to a sociotechnical system composed of interconnected social and technical subsystems. Several scholars are already expanding the concept of PSS to include more significant (socio)technical systems, which is rather intriguing (Kanda & Matschewsky, 2018). Therefore, efforts to incorporate systems thinking and design into the development of smart homes must continue (Kim et al., 2019). The current study includes several limitations. Our findings are temporally restricted and susceptible to cultural biases. Continuous research is necessary in this field to develop smart home service systems that consider the numerous features and subsystems involved. We focused on the characteristics that identify smart products and services in the suggested framework. Second, we focused on the PSS benefits that impact user adoption of smart homes. In addition, SH-PSS-related digital capabilities have been found (Figure 7). In building a smart home which involves a communication network between tangible products, intangible

TH-3294_196105005

services, and all system stakeholders, we have recognized the need for user-centric research and a smart product-service-system design perspective.

In the case of S-D logic as part of service design, consumer value generation is prioritized, indicating that it is a co-creation process and that a significant amount of the value depends on the context, indicating that the process must be able to grasp the user's environment and resources (Wetter- Edman et al., 2014). UX focuses on the part of user interface design that will interact with the SH-PSS. Its context is influenced by a mix of people, resources, and user environment components. Consequently, the value of the SH-context-aware PSS's capabilities and the significance of gathering context for customers and users are readily apparent. Most engineering design methodologies concentrate on smart products as compared to smart services (Cong et al., 2020b). In order to allow the smart service part of S-PSS, additional frameworks or techniques are necessary.

4.5 Design methods and toolkits for ideation of IoT and Smart Home products

4.5.1 Card 'n' Dice

Cards'n'Dice is a unique design method that combines Loaded Dice and a set of cards to facilitate scenario creation for Internet of Things (IoT) devices and services (Arne Berger; 2019). The method leverages the functionality of Loaded Dice, a pair of cubical IoT devices. One cube has different sensors on its face, while the other has various actuators. By rolling the Loaded Dice, different combinations of sensors and actuators are generated, providing a random yet structured starting point for ideation and scenario development. These combinations serve as prompts and constraints for the design process, sparking creativity and exploring possibilities. The set of cards that accompanies the Loaded Dice complements the scenario creation process. Different card sets are available, such as scenario development, scenario specification, micro-interaction exploration, and idiosyncratic ideation. These cards provide additional prompts, concepts, and guidelines to help users frame their ideas and design concepts within the functional possibilities offered by the sensors and actuators of the Loaded Dice. One of the key advantages of the Cards'n'Dice method is its playful and accessible nature. It allows individuals without technical expertise to engage in the design process and explore the fundamental principles of IoT. By focusing on functional possibilities rather than technical details, the method enables laypeople to generate ideas and design scenarios in a user-friendly and non-intimidating manner. The Cards'n'Dice method offers a creative and engaging approach to ideation and scenario creation for IoT devices and services. Combining Loaded Dice and a set of cards, it provides a structured yet flexible framework for exploring the potential of IoT and designing concepts within its functional scope. Whether for educational purposes or generating innovative ideas, this method allows users to delve into the world of IoT design without getting overly involved in technical complexities.

4.5.2 Co-create the IoT

Co-create the IoT is a comprehensive method that facilitates collaboration between expert groups and end-users in workshops, aiming to foster a deep understanding of user needs and preferences. While the method is suitable for large-scale projects, it can also be adapted for smaller commercial contexts. The approach incorporates various methodologies and tools to create an interactive and engaging environment for participants (Nathalie Stembe; 2017). One of the key components of Co-create the IoT is the use of contextual packages, which provide a structured framework for the workshop activities. These packages include canvases, which serve as visual maps or frameworks, helping participants to navigate the complexities of IoT networks. The canvases provide a visual representation of the relationships, interactions, and components within the IoT ecosystem, aiding in the understanding and visualization of the network. Additionally, tangible objects are used in the method to represent metaphorical sensors, symbolizing the various senses (Nathalie Stembe; 2019). These tangible objects serve as interactive tools that participants can physically engage with, enhancing the experiential aspect of the workshop. By associating IoT concepts with sensory experiences, the method facilitates a deeper understanding and empathy for end-users' perspectives. The primary goal of Co-create the IoT is to foster collaboration and empathy between expert groups and end-users. Participants are encouraged to discuss, share insights, and co-create solutions that align with user needs and preferences using canvases and tangible objects. The method helps bridge the gap between technical expertise and user-centered design, ensuring that IoT solutions are not only technologically sound but also meet the real-world requirements of the end users. Co-create the IoT offers a holistic and interactive approach to workshop facilitation, enabling experts and end-users to explore and visualize IoT networks collaboratively (Rob; 2014). By incorporating visual canvases and tangible objects, the method fosters empathy, understanding, and meaningful dialogue, ultimately developing more user-centered and impactful IoT solutions.

4.5.3 IoT Design Deck

The IoT Design Deck is a comprehensive method designed to support teams throughout the entire design process of an IoT product or service. It provides a common language that enables experts from diverse disciplines to collaborate effectively (Massimiliano,; 2017, 2019). The facilitator plays a crucial role in guiding the team and ensuring that each step of the process is executed correctly. One of the key features of the IoT Design Deck is its versatility and adaptability to different contexts. The method can be applied in various settings and projects, accommodating each situation's specific needs and requirements. This flexibility allows teams to tailor the method to their design challenges and goals. The method includes a set of cards that serve as tools for idea generation, concept development, and prototyping. These cards provide prompts, prompts, and prompts that stimulate creativity and assist in exploring different design possibilities. The facilitator can leverage these cards to provide additional guidance and support, distributing unique cards to address specific challenges or adjusting the process based on the context. Moreover, the IoT Design Deck is a comprehensive resource that can be utilized throughout the design process. The included card sets, such as the reference cards, can be used independently as a library of knowledge or a source of inspiration. This allows users to access relevant information and insights at any stage of the design process, enhancing their understanding and informing their decision-making. The IoT Design Deck offers a comprehensive and flexible approach to IoT product and service design. It facilitates effective collaboration among multidisciplinary teams by providing a common language and a range of supporting tools. With the facilitator's guidance, teams can navigate the design process, generate innovative ideas, and create prototypes that align with their specific objectives.

4.5.4 IoT Ideation Design Kit

The IoT Design Kit and accompanying canvases are specifically designed for companies seeking to incorporate IoT into their business operations. This method acknowledges that ideation is just one aspect of a broader process and emphasizes the importance of considering company strategy and

TH-3294_196105005

positioning within the context of the IoT (Dries; 2014, 2019). The method offers a collection of elements that can be completed as individual exercises, allowing teams to explore different starting points and user journeys. These exercises are typically conducted in workshops, with the creators of the method guiding participants through the process. By using the IoT Design Kit, companies can effectively navigate the complexities of IoT integration and make informed decisions based on their specific goals and objectives. During the workshop, the method was utilized as a pre-final prototype, meaning it served as a means to refine and iterate on ideas before reaching the final stage. The IoT ideation cards, which likely provide prompts or inspiration for generating ideas, were used in conjunction with the IoT Design Kit to facilitate the ideation process and stimulate creative thinking. Overall, the IoT Design Kit and its associated canvases offer a structured approach for companies to explore and integrate IoT into their business strategies. By considering not only ideation but also company positioning and strategy, this method provides a comprehensive framework for leveraging the potential of IoT technologies in a meaningful and impactful way (Studio Dott; 2019).

4.5.5 KnowCards

KnowCards are designed to simplify understanding the technical aspects of IoT functionality and interaction. These cards act as a visual dictionary, providing descriptions of various components that can be utilized in the design of IoT products. The primary focus is on the technical aspects rather than the business considerations associated with IoT (Tina et al.; 2019). The purpose of KnowCards is to assist both technical and non-technical users, enabling them to comprehend the workings of different components and better understand IoT products in general. By using these cards, users can familiarize themselves with the functionalities and interactions of various features in a simplified manner. During brainstorming sessions, KnowCards serve as a valuable tool. Users can employ the cards to generate new ideas by starting with a specific component and exploring its potential applications. Additionally, the cards can aid in determining the most suitable element for implementing a particular idea, helping users make informed decisions about component selection and integration. Overall, KnowCards provide a user-friendly approach to understanding the technical aspects of IoT. Individuals, including non-experts, can use these cards to enhance their knowledge of IoT components and foster innovative thinking when brainstorming IoT product ideas (Tina et al.; 2019).

4.5.6 Mapping the IoT

Mapping the IoT is a comprehensive method that incorporates three key tools to support the design process (Ilaria Vitali; 2016): (1) Main Deck: The main deck consists of a set of cards containing questions and prompts related to the product-to-be. These cards encourage discussions among team members and stakeholders, helping them delve into critical aspects of the IoT product or service. The main deck serves as a guide to explore and address important considerations during the design process. (2) Analysis Cards and Features Map: This component includes analysis cards and a features map. The analysis cards are used to examine and evaluate existing IoT products in the market, allowing teams to gain insights into competitive offerings and identify potential areas for improvement or differentiation. The features map helps visualize and compare the features and functionalities of different products, facilitating a comprehensive analysis of the competitive landscape. (3) Activity Guides: The method also includes activity guides that provide instructions on how to use the tools effectively based on specific goals. These guides offer structured approaches to problem-framing, concept development, and evaluation within the context of the IoT design process. They serve as a

TH-3294_196105005

roadmap for conducting activities and guide teams through the various stages of refinement and iteration (Ilaria Vitali; 2019).

Mapping the IoT primarily focuses on refining pre-existing ideas. It is particularly useful for problem-framing, concept development, and evaluation stages of the design process. The method is flexible and can be utilized without the need for a dedicated facilitator. It can be used individually or in a team setting, allowing for both structured and unstructured approaches depending on the specific needs and preferences of the design team (Ilaria Vitali; 2016). Overall, Mapping the IoT provides a comprehensive framework and toolset to support the refinement and evaluation of IoT product ideas, enabling teams to systematically analyze and iterate upon their designs.

4.5.7 Tiles IoT Toolkit

The Tiles IoT Toolkit is designed to empower non-experts in generating ideas and inventing IoT products quickly, even without extensive technical knowledge. The toolkit consists of Tiles of IoT Cards, a canvas, and a playbook that provides instructions on how to use the cards effectively (Simone Mora et al.; 2017). The method is designed to be user-friendly and does not require a facilitator to guide the process. The Tiles IoT Cards serve as ideation prompts, helping users spark creative thinking and generate innovative concepts for IoT products. The accompanying canvas provides a visual space for arranging and organizing ideas, allowing users to visually map out their thoughts and concepts. The playbook offers guidance on how to utilize the cards and canvas effectively, providing instructions and suggestions for different exercises and activities. It is important to note that the Tiles IoT Toolkit does not delve into detailed design aspects of IoT products. Instead, its primary focus is on fostering a basic understanding of IoT principles and facilitating idea generation. The method aims to provide a user-friendly and accessible approach for individuals who may not have the deep technical expertise to explore and invent IoT solutions. By using the Tiles IoT Toolkit, non-experts can quickly engage in the ideation process, generate ideas, and gain a foundational understanding of IoT concepts. It offers a streamlined and simplified approach, making it easier for individuals without extensive technical backgrounds to participate in IoT product design and innovation.

4.6 Landscape Mapping of Design Toolkits of Smart Product-Service-System

Through a comprehensive literature review and collaborative workshops involving smart home product designers, we have engaged in the landscape mapping of design toolkits relevant to Smart Product-Service-System (SH-PSS) development (Figure 15). Seven distinct toolkits, namely Card 'n' Dice, Co-create the IoT, IoT Design Deck, IoT Ideation Design Kit, Know Cards, Mapping the IoT, and Mapping the IoT, emerged as noteworthy contributors to the landscape of SH-PSS design methodologies (Table 21). During semi-structured interviews and open discussions with these designers, we sought to understand their design processes, challenges faced, and the role of these toolkits in their work. Subsequently, we applied a double diamond method to map these toolkits into a design process model. This mapping revealed the specific dimensions in which each toolkit facilitates designers, such as technical capabilities, idea generation, problem-solving, and planning implementation. As a result, we propose that a collaborative approach to understanding and utilizing these methods can benefit the design research community in selecting the most suitable SH-PSS design method for specific tasks within distinct contexts. This landscape mapping sheds light on the diverse capabilities and applications of these toolkits, offering valuable insights for future smart home product

TH-3294_196105005

design endeavors.

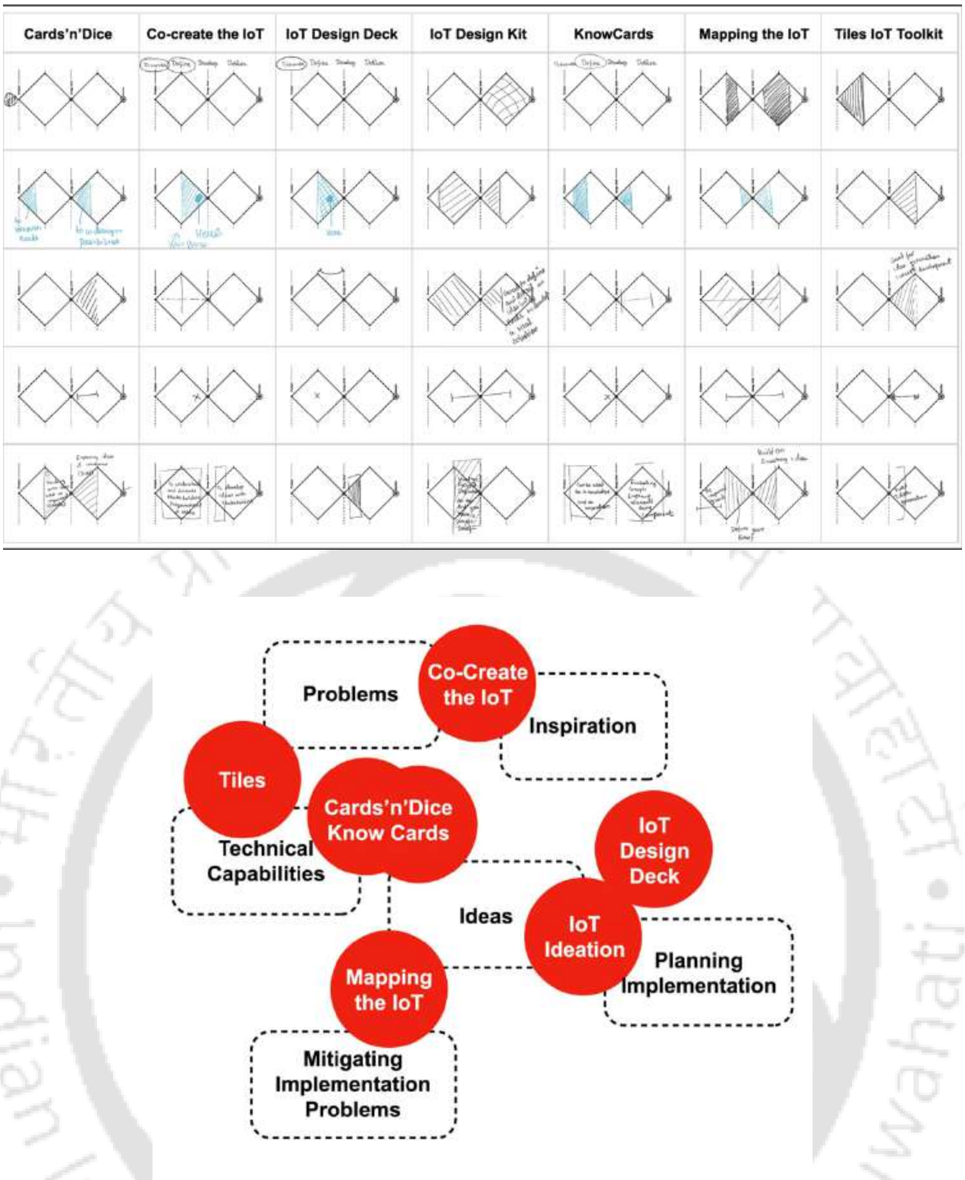


Figure 15 Landscape Mapping of Design Toolkits through Double Diamond Method

Table 17 Design Toolkits of Smart IoT products

	Design Method	Context
1	Card ‘n’ Dice	• Technical Capabilities • Ideas
2	Co-create the IoT	• Problems • Inspiration
3	IoT Design Deck	• Ideas • Planning Implementation
4	IoT Ideation Design Kit	• Ideas • Planning Implementation
5	Know Cards	• Technical Capabilities • Ideas
6	Mapping the IoT	• Ideas

TH-3294_196105005

		• Mitigating Implementation Problem
7	Tiles IoT Toolkit	• Problems • Ideas • Technical Capabilities

4.7 Chapter Conclusion

The chapter's core resides where the Smart Home Product-Service-System (SH-PSS) conceptual framework is meticulously developed. This section provides a comprehensive model encompassing SH-PSS design's key elements and principles. It serves as a valuable guide for researchers, designers, and stakeholders in the Smart Home industry. The current gaps and challenges in SH-PSS design to meet user needs and enhance user experience are addressed. Three critical aspects are explored: Service Dominant Design, Data-Driven Value Co-Creation, and Closed Loop Design. These elements represent critical considerations in the creation of effective and user-centric SH-PSS solutions. One of the sections delves into the pivotal concept of user-centric design within SH-PSS. It underscores the crucial role of user-centeredness in the design process, ensuring that Smart Home solutions seamlessly align with user needs and preferences. Various design methods and toolkits for ideating IoT and Smart Home products are introduced. These include Card ‘n' Dice, Co-create the IoT, IoT Design Deck, IoT Ideation Design Kit, Know Cards, Mapping the IoT, and Tiles IoT Toolkit. Each of these tools plays a vital role in stimulating creativity and generating innovative ideas in the context of Smart Home design. Next, comprehensive landscape mapping of design toolkits for Smart Product-Service-System. This mapping is a valuable resource for designers and researchers, offering a structured overview of the available design tools and their specific applications in SH-PSS. This chapter forms the cornerstone of the thesis, offering a robust framework and a rich toolkit for researchers, designers, and stakeholders in the Smart Home domain. It lays the foundation for subsequent chapters, guiding the exploration of SH-PSS design principles and practices.

TH-3294_196105005

Chapter 5: Design and Development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit

5.1 Introduction

The smart home design and development field is continuously evolving, driven by the increasing demand for innovative and user-centric solutions. To meet these evolving needs, we present the "Design and Development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit," a novel and specialized toolkit designed to facilitate the ideation and development of smart home products and services. Building upon the foundation of a previous generic toolkit, we have tailored this new Innovator Toolkit specifically for the unique challenges and opportunities the smart home ecosystem presents. In this upgraded toolkit, we introduce two significant enhancements: the inclusion of "Benefits" and "Barriers" cards and improvements to the ideation and storyboard generation process. These additions enable designers, developers, and innovators to comprehensively explore their smart home concepts' potential advantages and challenges. The enhanced toolkit provides a holistic approach to smart home innovation, fostering creativity while addressing critical considerations.

Additionally, the new toolkit streamlines the process of sketching and generating ideas, allowing participants to visualize their concepts quickly. It also introduces a structured framework for elevator pitches and the evaluation of ideation sheets, promoting effective communication and assessment of smart home ideas. In upcoming sections, we will delve into the critical features of the SH-PSS Innovator Toolkit, emphasizing how it empowers designers to navigate the complex landscape of smart home development and create solutions that resonate with end-users.

5.2 Design and Development of Smart Home Product-Service-System Innovator Toolkit

The Smart Home Product-Service-System Innovator Toolkit is a modular, hands-on learning system designed to teach product designers, interaction and user experience designers about the smart home, which are Internet of Things (IoT) enabled smart products (Figure 16). This toolkit is a fun and educational way to learn about the ideation of smart home products and services. It can be an excellent tool for identifying and learning the consumer's problems and exploring the technical capabilities of the design brief while ideating. The toolkit consists of a variety of physical tiles or cards that can be connected together to create various ideas. These decks in the toolkit are scenario, persona, missions, things, human actions, sensors, services, benefits, barriers, feedback and reflection criteria. These tiles are created to inspire ideas for smart home user experiences by fostering both divergent and convergent thinking. The playbook guides the participants in designing IoT-enabled smart products in a seven-step process (Table 22). Although the ideation technique is meant to be supervised by professionals, the playbook helps keep the design process visible and minimizes the need for supervision.

Innovator Toolkit, a dynamic game design approach that reimagines how innovation happens in the realm of smart home technology. This toolkit transforms ideation into an engaging and collaborative journey, empowering participants to craft inventive solutions tailored to the needs of real users in specific scenarios. At its core, the SH-PSS Innovator Toolkit revolves around a set of protocols that guide participants through a structured process of ideation and refinement. It all begins with the selection of a Persona and a Scenario, setting the stage for a deep dive into addressing user needs and

TH-3294_196105005

challenges. With the Mission cards, participants are encouraged to think creatively about the purpose and mission of their ideas. The toolkit also introduces the concept of Things, which serve as central objects in users' lives, and Triggers, exploring the actions that activate these objects. Responses, whether direct feedback or data transmission, enrich the interaction between users and objects. The real magic happens in the Storyboard section, where participants can illustrate their ideas, envisioning how their concepts work and feel in real-world scenarios. Finally, the toolkit offers a reflective phase, allowing participants to assess their concept against various criteria, identify strengths and weaknesses, and refine their ideas for optimal impact. The culmination of this creative journey is an Elevator Pitch that encapsulates the essence of the final idea. With the SH-PSS Innovator Toolkit, innovation in the smart home domain becomes an exciting and collaborative endeavor, promising groundbreaking solutions that resonate with users and address real-world challenges.

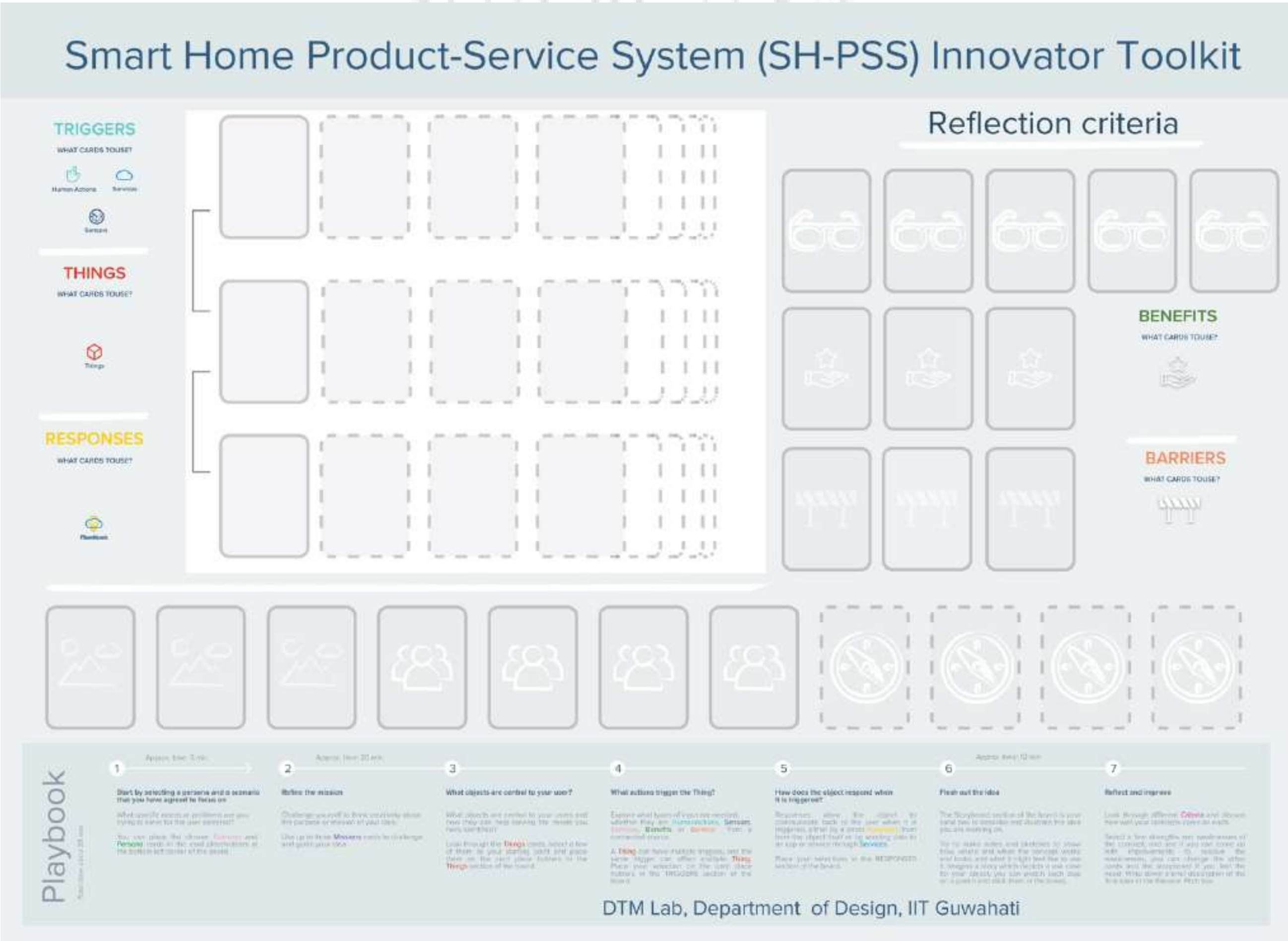


Figure 16 Canvas of Smart Home Product-Service-System Innovator Toolkit

The new ideation sheet (Figure 17) is a pivotal addition to the Smart Home Product-Service-System (SH-PSS) Innovator Toolkit, enhancing the ideation process by seamlessly integrating cards and creative thinking. This innovative sheet provides a structured framework for participants to bring their ideas to life. At the outset, it encourages a clear understanding of the challenge by dedicating space to define a Design Brief, ensuring that participants fully grasp the problem to be solved and the direction for their solutions. The Sketch section is where the magic truly happens, allowing participants to unleash their creativity and illustrate the storyline of their ideation. This visual storytelling brings concepts to life, helping creators and collaborators envision the user experience. The Elevator Pitch section distils the essence of the ideas into concise descriptions, fostering clarity and communicability. Lastly, the inclusion of an ordinal scale for evaluating ideations through ratings adds a valuable dimension to the ideation process, allowing for a structured assessment of each concept's merits and weaknesses. In essence, this ideation sheet serves as a versatile canvas for participants to craft, refine, and evaluate their innovative ideas, making the ideation journey within the SH-PSS Innovator Toolkit even more dynamic and impactful.

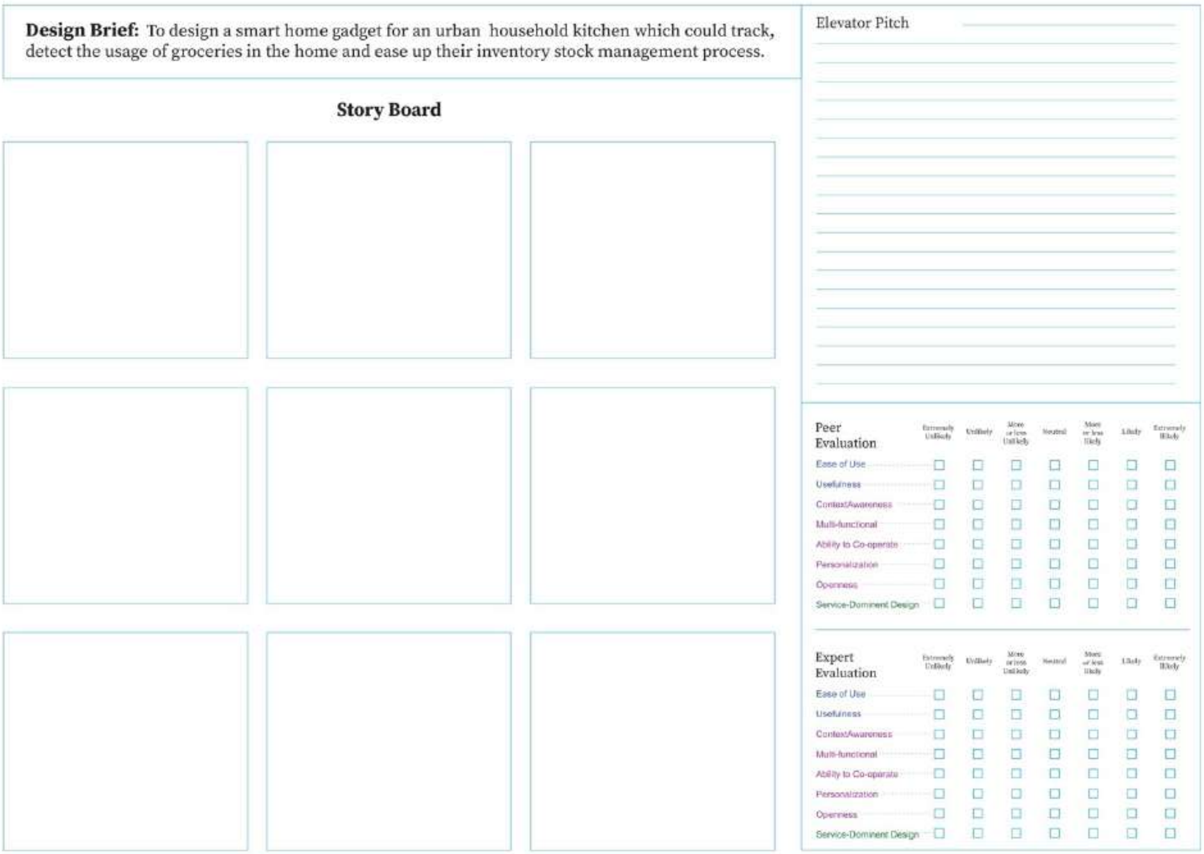


Figure 17 Ideation sheet of SH-PSS Innovator Toolkit

Table 18 Protocol for playing the SH-PSS Innovator Toolkit

	Activities
1	Start by selecting a **Persona** and a **Scenario** that you have agreed to focus on: What specific needs or problems are you trying to solve for the user selected? You can place the chosen Scenario and Persona cards in the card placeholders at the bottom left corner of the board
2	Refine the **Mission**: Challenge yourself to think creatively about the purpose or mission of your idea. Use up to three Missions cards to challenge and guide your idea.
3	What objects are central to your user? What objects are central to your users and how they can help solving the needs you have identified? Look through the **Things** cards, select a few of them as your starting point and place them on the card placeholders in the THINGS section of the board.
4	What actions trigger the Thing? Explore what types of input are needed, whether they are

	Human Actions, Sensors, Services, Benefits or Barriers from a connected source. A **thing** can have multiple triggers, and the same trigger can affect multiple things. Place your selections on the card placeholders in the TRIGGERS section of the board.
5	How does the object respond when it is triggered? Responses allow the object to communicate back to the user when it is triggered, either by a direct **Feedback** from the object itself or by sending data to an app or service through **Services**. (RESPONSES section of the board)
6	Flesh out the idea: The Storyboard section of the board is your sandbox to describe and illustrate the idea you are working on. Try to make notes and sketches to show how, where and when the concept works and looks, and what it might feel like to use it. Imagine a story which depicts a use case for your object, you can sketch each step on a post-it and stick them in the boxes.
7	Reflect and improve: Look through different **Criteria** and discuss how well your concept scores on each. Select a few strengths and weaknesses of the concept, and see if you can come up with improvements to resolve the weaknesses, you can change the other cards and the storyboard if you feel the need. Write down a brief description of the final idea in the Elevator Pitch box.

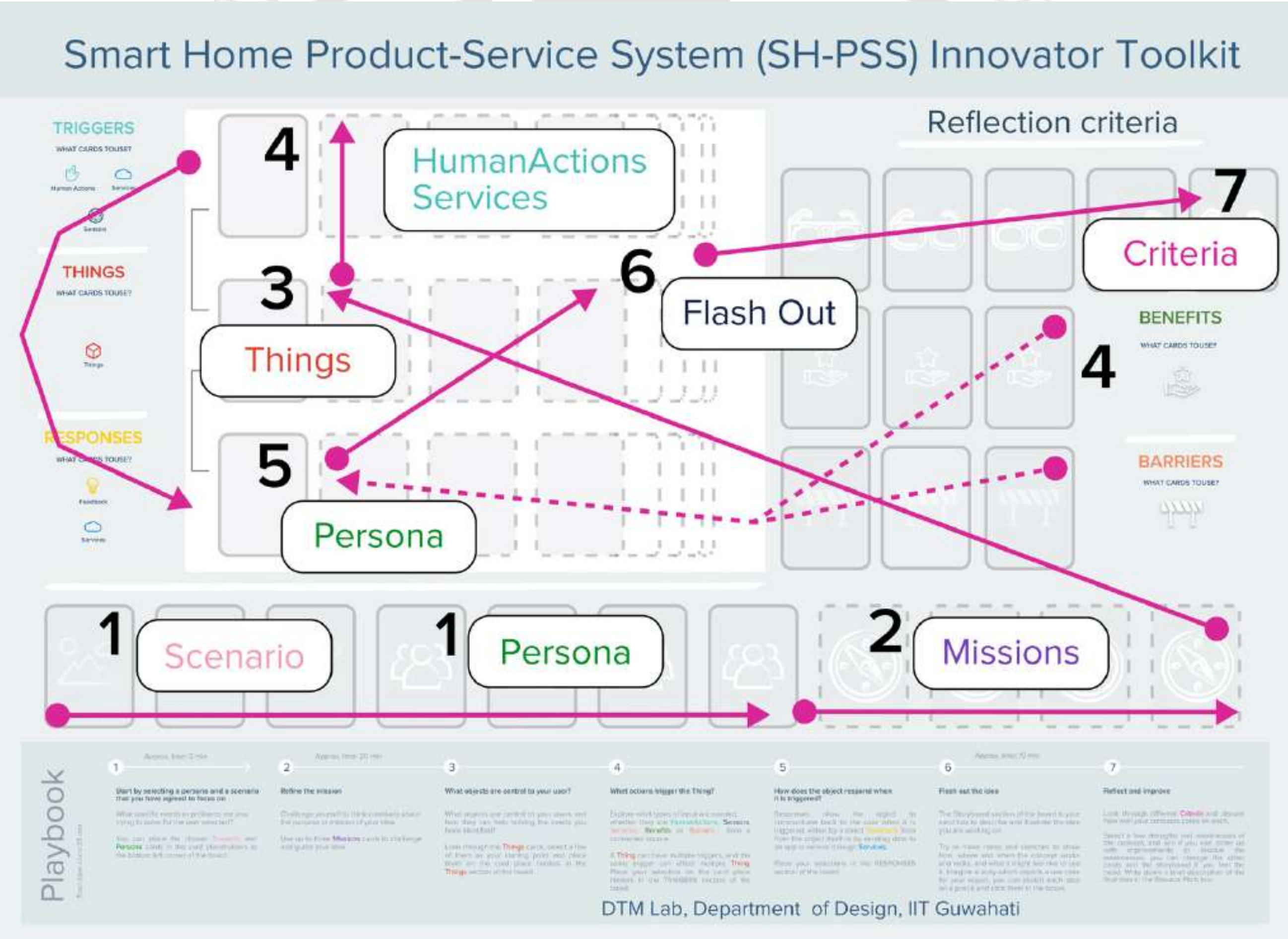


Figure 18 Step by step protocol on canvas of SH-PSS Innovator Toolkit

Playing the Smart Home Product-Service-System (SH-PSS) Innovator Toolkit (Figure 18) involves a structured process that guides designers and innovators in creating innovative concepts for Smart Home scenarios. The design manager instructs the designers on the protocols for using the toolkit. Start by choosing a Persona and a Scenario that align with the specific user needs or problems you intend to address in the Smart Home context. Place the selected Persona and Scenario cards in the designated placeholders at the bottom left corner of the board. This initial selection provides a clear focus for your ideation process. Next is refining the Mission by challenging yourself to think creatively about the purpose or mission of your concept. Use up to three Mission cards to guide and inspire your idea. These missions serve as guiding principles for your concept, ensuring it aligns with the desired objectives. Then, identify Central Objects. Explore the Things cards to identify objects central to your chosen Persona and Scenario. Consider how these objects can play a role in addressing the identified user needs. Select a few of these objects as your starting points and place them on the card placeholders in the Things section of the board. After that, Determine Triggers. Delve into what actions or events trigger these selected objects. These triggers can encompass Human Actions, Sensors, Services, Benefits, or Barriers from connected sources. Objects may have multiple triggers, and the same trigger can affect multiple objects. Position your trigger selections on the card placeholders in the Triggers section of the board. Consider how the selected objects respond when triggered. Responses can take the form of direct feedback from the object itself or by transmitting data to an app or service through Services. Place your response selections in the Responses section of the board. Flesh Out the Idea by utilizing the Storyboard section of the board as your creative canvas. Describe and illustrate your concept, showing how, where, and when it operates. Use notes and sketches to depict the concept's functionality, appearance, and user experience. Craft a narrative that outlines a use case for your object, breaking it down into steps that can be sketched and placed in the provided boxes. Reflect and improve by evaluating your concept against different Criteria provided in the toolkit. Discuss the strengths and weaknesses of your concept and brainstorm potential improvements to address any weaknesses. You have the flexibility to adjust other cards and modify the storyboard if needed. Summarize your final concept by writing a brief description in the Elevator Pitch box. By following these structured steps and protocols, designers and innovators can effectively use the SH-PSS Innovator Toolkit to generate creative and user-centered Smart Home Product-Service-System concepts that address specific user needs and enhance the overall Smart Home experience.

5.3 Shaping Smart Home Product-Service-System Cards Tool

A classic definition of analogy is "the illustration of an idea with another idea that is similar or analogous to it in some significant features (Leclercq 2002). Design by analogy is a problem-solving technique involving using a familiar solution from one context as a model or inspiration for solving a problem in another context and developing innovative design, particularly during the ideation phase (Christensen et al., 2007; Wood et al., 2008). Designers use this method to produce creative designs. In product design, George Mestral's invention of Velcro and automobile design of the VW Beetle automobile form are some of the most cited examples of Design by analogy. Similarly, in product service system design, Design by analogy can be a valuable method to develop novel ideation.

Meanwhile, Smith et al. (1993) demonstrated that analogous design might have a restricting influence on idea generation (fewer ideas are generated) and that unintentional transfer of negative design features may occur (Jansson et al.,1991; Smith et al., 1993). Therefore, it is essential to choose analogies wisely to avoid hindering effects in innovative design ideation and demonstrate the methods that keep the designer in charge of selecting analogies that may only be beneficial, as finding relevant analogies is often tricky. Taking inspiration from previous studies, we identified technology adoption characteristics of SH-PSS. These characteristics were analyzed using the Kano model approach to

TH-3294_196105005

identify the attractive features. These attractive features are analogies introduced as SH-PSS reflection criteria cards in the Tiles IoT Inventor Toolkit. This method helps select relevant analogies systematically over random selection.

Card-based tools are a popular method in design thinking and innovation processes. These proposed tools are essentially sets of cards, each containing specific prompts or information related to the design challenge. They are used to facilitate brainstorming, ideation, and problem-solving by providing structured guidance to participants. Here's an explanation of the card tools you mentioned:

Reflection Criteria Card Tool: This tool consists of cards that help individuals or teams assess and reflect on the criteria they should consider when making decisions. These criteria could relate to various aspects of a design, such as Context Awareness, Multi-functional, Ability to Co-operate, Personalization, Openness (Figure 19). By using these cards, designers can systematically evaluate their design options against predefined criteria, ensuring that the final product or solution aligns with the desired goals.

Mission Card Tool: Mission cards are used to define the purpose or mission of a design project. They often contain prompts or questions that help clarify the project's objectives, target audience, scope, and expected outcomes. This mission card could relate to various aspects of a design, such as call Independent, Adaptive, Reactive, Humanlike Interaction, Personality, Interpretation, Proactive, Self-Descriptive and Collaboration (Figure 20). Mission cards are valuable for aligning team members' understanding of the project's goals and ensuring that everyone is working towards a common mission. (Appendix E)

Benefit Card Tool: Benefit cards focus on identifying and elaborating on the potential benefits or advantages of a design concept or solution. Each card might describe a specific benefit, such as health related benefits, environment benefits, financial benefits, psychological benefits, social inclusion, luxury, status, resilience, technological enthusiasm, trust, safety and security (Figure 21). Designers can use these cards to brainstorm and communicate the positive aspects of their ideas, which can be valuable when pitching or presenting concepts to stakeholders. (Appendix F)

Barrier Card Tool: Barrier cards address potential obstacles or challenges that may hinder the successful implementation of a design solution. These cards typically list common barriers or problems that teams might encounter during a ideation such as technological barrier, Financial barrier, Ethical barrier, Legal barrier, Knowledge gap, Psychological resistance, Language challenges, Lifestyle, Resistance to control (Figure 22). By considering these barriers early in the design process, teams can develop strategies to overcome or mitigate them, ultimately leading to more robust and effective solutions. (Appendix G)

TH-3294_196105005

Figure 19 Proposed Reflection Criteria Card Tool

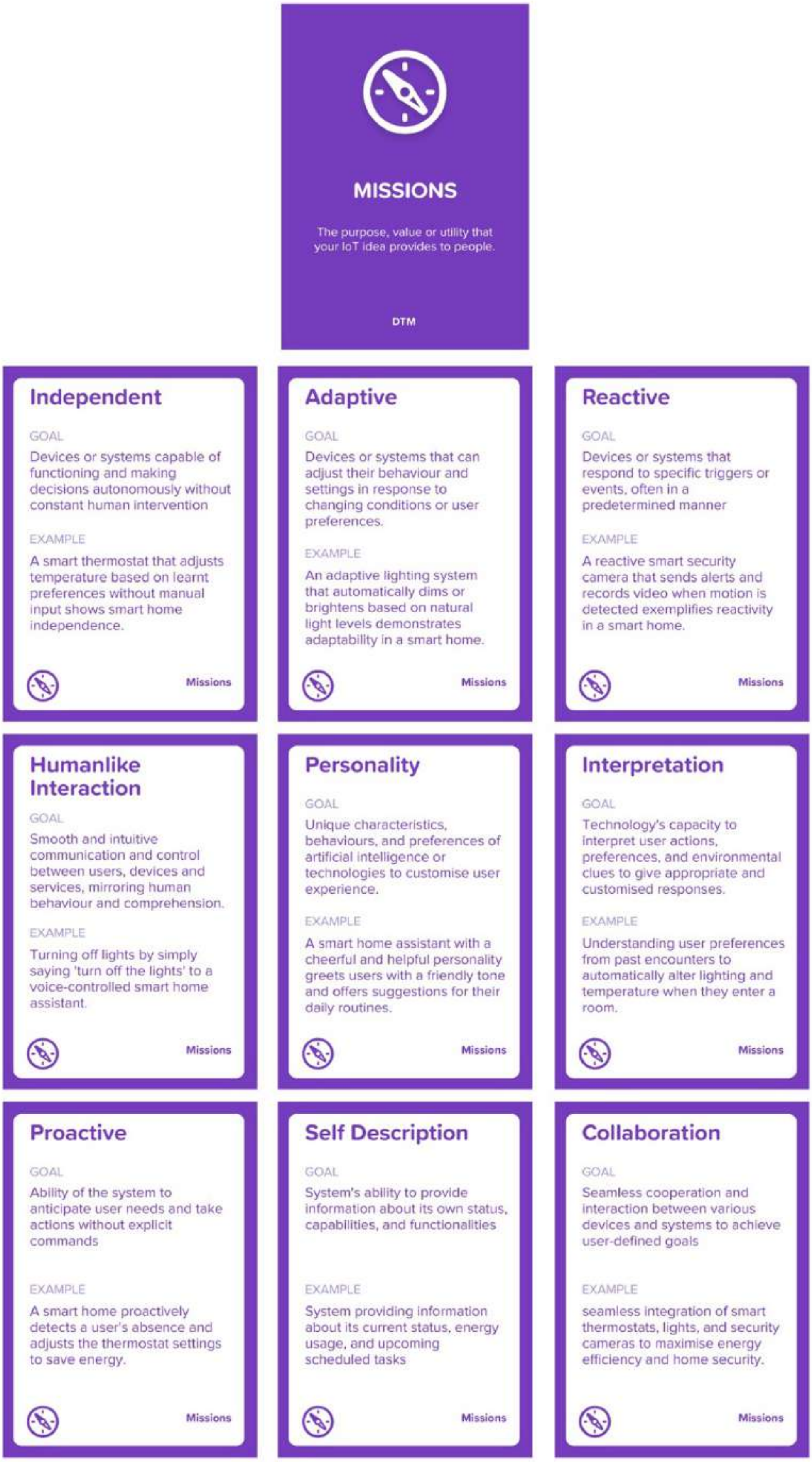


Figure 20 Proposed Mission Card Tool

Figure 21 Proposed Benefit Card Tool

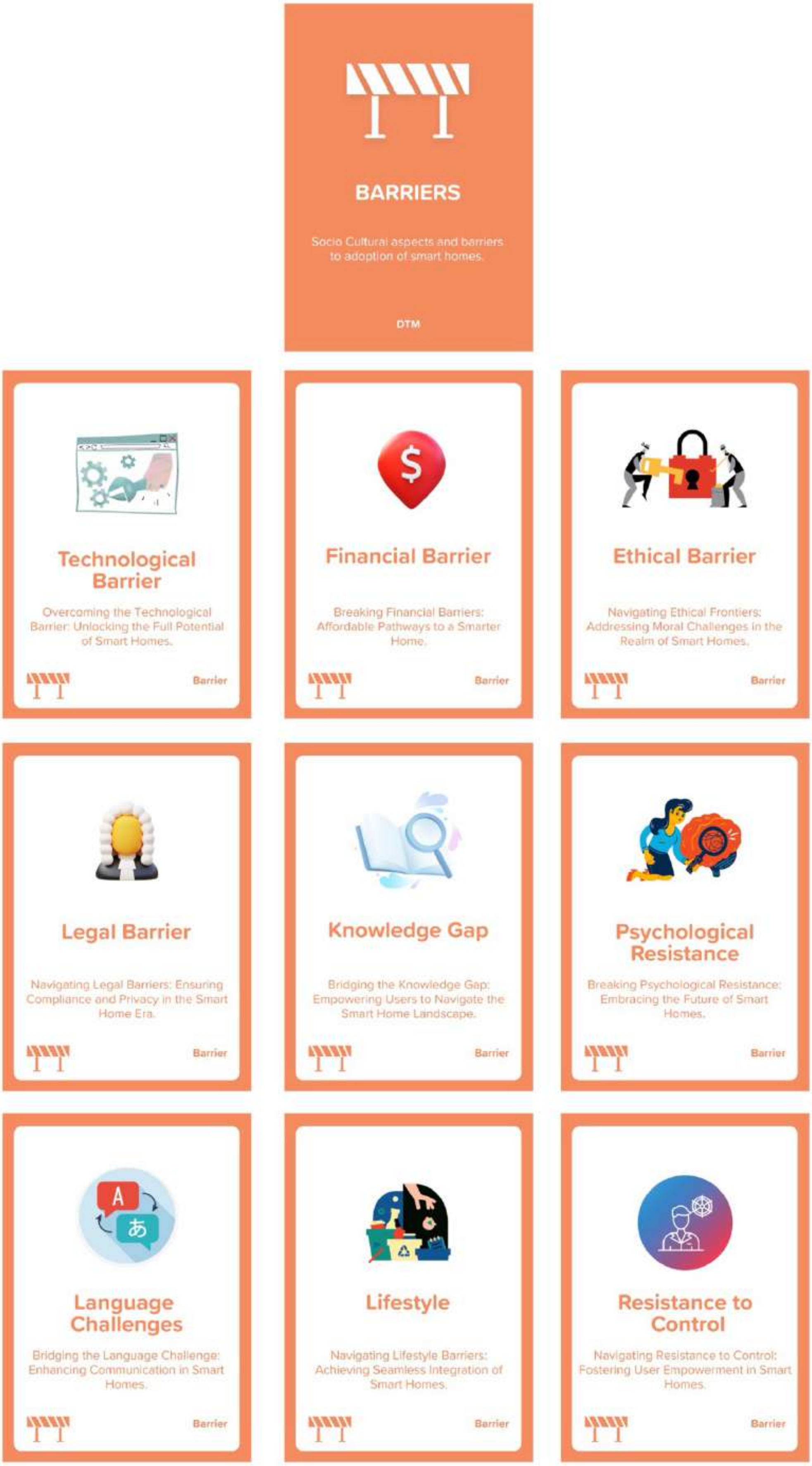


Figure 22 Proposed Barrier Card Tool

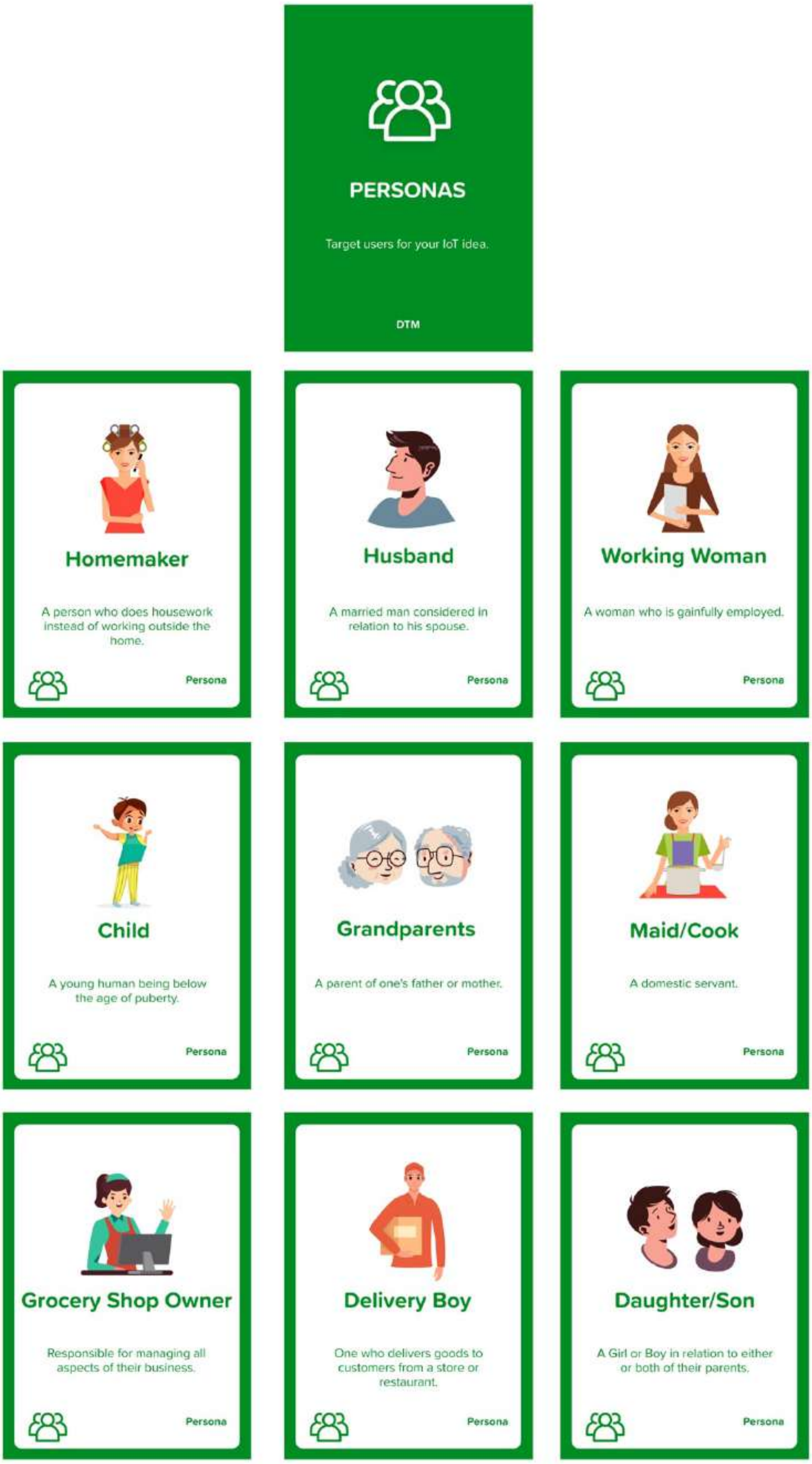


Figure 23 Proposed Persona Card Tool

Figure 24 Proposed Things Card Tool

Persona Card Tool: Persona cards help designers create detailed user personas, which are fictional representations of target users. These cards may include information such as the persona's name, age, background, goals, and pain points of smart home users. These cards typically list members of a family such as Homemaker, Husband, working women, Child, Grandparents, maid, Cook etc (Figure 23). Designers use persona cards to humanize the design process, ensuring that the final product is tailored to the needs and preferences of specific user groups. (Appendix H)

Things Card Tool: Things cards are used to brainstorm and explore physical or digital components that could be part of a design solution (Figure 24). These components, often referred to as "things," can include devices, interfaces, equipment, or any tangible elements relevant to the design challenge. By using these cards, designers can generate ideas for the physical aspects of their solution. (Appendix I)

These card tools are valuable resources for designers and teams working on various ideation process, as they provide structure, guidance, and a systematic approach to the design process. They encourage creativity, collaboration, and thoughtful consideration of different aspects of a design challenge.

5.4 Experiment Design

The primary objective of this experiment is to validate the effectiveness and usability of the newly proposed Smart Home Product-Service-System (SH-PSS) Innovator Toolkit for ideation and concept development in the context of smart home products and services. In this experiment, we will employ a controlled design to assess the impact of the SH-PSS Innovator Toolkit on ideation outcomes. Participants will be asked to ideate into two treatment groups: Treatment T1, the Control Group T1, consisting of 15 participants who will engage in the ideation process without the SH-PSS Toolkit, and Treatment T2, the Experimental Group T2, also comprising the same 15 participants, who will utilize the SH-PSS Toolkit during the ideation session. The experiment will involve a pre-defined SH-PSS challenge as the basis for idea generation. Both groups will be given a set amount of time to brainstorm and develop their ideas. Subsequently, the ideas generated by each group will be evaluated based on

TH-3294_196105005

criteria such as technology adoption, idea generation capability, and service dominance. The collected data will be analyzed to determine if the Experimental Group, with access to the SH-PSS Toolkit, outperforms the Control Group regarding the quality and efficiency of ideation. This controlled experiment will provide valuable insights into the toolkit's effectiveness in enhancing ideation for Smart Home Product-Service-Systems.

Participants:

- **Sample Size:** 15 participants will be recruited for this experiment.
- **Criteria:** Participants will include individuals with varying levels of expertise in smart home technologies, including electronic product design (EPD) and user experience design students.
- **Group Division:** Participants will be divided into three groups: Group A (5 participants), Group B (5 participants) and Group C (5 participants).

Materials:

- The newly proposed SH-PSS Innovator Toolkit.
- Ideation sheets for each participant.
- Evaluation forms.
- Timer or stopwatch.
- Prototyping materials (markers, sticky notes, etc.).
- A controlled environment resembling a smart home setup (simulated).

The experiment designed for the validation of the Proposed SH-PSS Innovator Toolkit aims to assess its effectiveness in stimulating innovative ideation for Smart Home Product-Service-Systems (SH-PSS). Participants, comprising a diverse group of electronic product design (EPD) and user experience design students, will be divided into two groups: one group will utilize the newly developed toolkit, while the other will engage in a traditional brainstorming session without the toolkit. The experiment will consist of several phases. In the first phase, both groups will be presented with a common SH-PSS challenge. The group using the toolkit will follow the prescribed protocols, including selecting Personas and Scenarios, refining the Mission, and utilizing the toolkit's cards and ideation sheets for sketching and idea evaluation. The control group will engage in a traditional brainstorming session without these tools. In the second phase, participants from both groups will present their ideas. The effectiveness of the toolkit will be evaluated based on the creativity, feasibility, and clarity of the generated ideas, as well as the efficiency of the ideation process. A post-session questionnaire will gather participants' feedback on the toolkit's usability and its impact on their ideation experience. Statistical analysis will be employed to compare the outcomes of the two groups, providing empirical validation of the toolkit's utility in fostering innovative SH-PSS ideation.

5.5 Validation of Proposed SH-PSS Innovator Toolkit

The data collected from the post-test evaluations and observations during presentations will be analyzed using statistical methods to determine the toolkit's effectiveness compared to traditional ideation methods. Key metrics include idea generation rates, creativity scores, and user satisfaction ratings. The results of this experiment will help validate the proposed SH-PSS Innovator Toolkit as an

TH-3294_196105005

effective and user-friendly method for ideation in the context of smart home products and services. It will provide insights into its usability and potential improvements.

Figure 25 Playing SH-PSS Innovator Toolkit

Before choosing the statistical test to test the hypotheses, normality tests were done on the data values. Since the results of the normality tests indicate that the data is normally distributed, a parametric test is used for testing the hypotheses. The paired sample t-test is used to test the hypotheses.

Figure 26 Pictures of Experiment Design -1

Figure 27 Pictures of Experiment Design - 2

Working Null Hypothesis 1:

$H_{1.1}$	In the concepts, there is no significant difference between ratings of peers on the Perceived Ease-of-use attribute, for a design concept in T1 and T2.
$H_{1.2}$	In the concepts, there is no significant difference between ratings of experts on the Perceived Ease-of-use attribute, for a design concept in T1 and T2.

Table 19 Paired Samples Statistical Test for Perceived Ease of Use Rating

Paired Samples Statistics - Perceived Ease-of-use (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{1.1}$	Perceived Ease of Use (T1-Peer)	3.13	15	.915	.236	< 0.001
	Perceived Ease of Use (T2-Peer)	5.67	15	.900	.232	
$H_{1.2}$	Perceived Ease of Use (T1-Expert)	3.33	15	1.234	.319	< 0.001
	Perceived Ease of Use (T2-Expert)	5.27	15	.884	.228	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{1.1}$** and **$H_{1.2}$**

The **Null Hypothesis $H_{1.1}$ and $H_{1.2}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Perceived Ease-of-use attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 3.13, and that of T2-Peer is 5.67. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 3.33, and that of T2- Expert is 5.27. Therefore, significant improvement in idea generation has been observed in terms of Perceived Ease of Use when proposed toolkit is applied.

Working Null Hypothesis 2:

$H_{2.1}$	In the concepts, there is no significant difference between ratings of peers on the Perceived Usefulness attribute, for a design concept in T1 and T2.
$H_{2.2}$	In the concepts, there is no significant difference between ratings of experts on the Perceived Usefulness attribute, for a design concept in T1 and T2.

Table 20 Paired Samples Statistical Test for Perceived Usefulness Rating

Paired Samples Statistics - Perceived Usefulness (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{2.1}$	Perceived Usefulness (T1-Peer)	3.40	15	1.454	.375	< 0.001
	Perceived Usefulness (T2-Peer)	5.27	15	1.387	.358	
$H_{2.2}$	Perceived Usefulness (T1-Expert)	3.07	15	1.223	.316	< 0.001
	Perceived Usefulness (T2-Expert)	5.33	15	1.234	.319	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{2.1}$** and **$H_{2.2}$**

The **Null Hypothesis $H_{2.1}$ and $H_{2.2}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Perceived Usefulness attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 3.40, and that of T2-Peer is 5.27. Similarly, when experts evaluated the ideations,

TH-3294_196105005

the mean of T1- Expert is 3.07, and that of T2- Expert is 5.33. Therefore, significant improvement in idea generation has been observed in terms of Perceived Usefulness when proposed toolkit is applied.

Working Null Hypothesis 3:

$H_{3.1}$	In the concepts, there is no significant difference between ratings of peers on the Context Awareness attribute, for a design concept in T1 and T2.
$H_{3.2}$	In the concepts, there is no significant difference between ratings of experts on the Context Awareness attribute, for a design concept in T1 and T2.

Table 21 Paired Samples Statistical Test for Context Awareness Rating

Paired Samples Statistics - Context Awareness (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{3.1}$	Context Awareness (T1-Peer)	2.73	15	.799	.206	< 0.001
	Context Awareness (T2-Peer)	5.53	15	.834	.215	
$H_{3.2}$	Context Awareness (T1-Expert)	2.93	15	.799	.206	< 0.001
	Context Awareness (T2-Expert)	5.60	15	1.056	.273	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{3.1}$** and **$H_{3.2}$**

The **Null Hypothesis $H_{3.1}$ and $H_{3.2}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Context Awareness attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 2.73, and that of T2-Peer is 5.53. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 2.93, and that of T2- Expert is 5.60. Therefore, significant improvement in idea generation has been observed in terms of Context Awareness when proposed toolkit is applied.

Working Null Hypothesis 4:

$H_{4.1}$	In the concepts, there is no significant difference between ratings of peers on the Muti-functional attribute, for a design concept in T1 and T2.
$H_{4.2}$	In the concepts, there is no significant difference between ratings of experts on the Muti-functional attribute, for a design concept in T1 and T2.

Table 22 Paired Samples Statistical Test for Multi-functional Rating

Paired Samples Statistics - Muti-functional (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{4.1}$	Multi-functional (T1-Peer)	2.20	15	.941	.243	< 0.001
	Multi-functional (T2-Peer)	4.73	15	1.100	.284	
$H_{4.2}$	Multi-functional (T1-Expert)	2.87	15	.834	.215	< 0.001
	Multi-functional (T2-Expert)	5.07	15	1.100	.284	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{4.1}$** and **$H_{4.2}$**

The **Null Hypothesis $H_{4.1}$ and $H_{4.2}$ is rejected** and concluded that there is a significant difference

TH-3294_196105005

between the ratings of peer and rating of expert on the Muti-functional attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 2.20, and that of T2-Peer is 4.73. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 2.87, and that of T2- Expert is 5.07. Therefore, significant improvement in idea generation has been observed in terms of Muti-functional when proposed toolkit is applied.

Working Null Hypothesis 5:

$H_{5.1}$	In the concepts, there is no significant difference between ratings of peers on the Ability to co-operate attribute, for a design concept in T1 and T2.
$H_{5.2}$	In the concepts, there is no significant difference between ratings of experts on the Ability to co-operate attribute, for a design concept in T1 and T2.

Table 23 Paired Samples Statistical Test for Ability to Co-operate Rating

Paired Samples Statistics - Ability to co-operate (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{5.1}$	Ability to Co-operate (T1-Peer)	1.80	15	.676	.175	< 0.001
	Ability to Co-operate (T2-Peer)	4.60	15	1.121	.289	
$H_{5.2}$	Ability to Co-operate (T1-Expert)	2.13	15	.743	.192	< 0.001
	Ability to Co-operate (T2-Expert)	4.80	15	1.014	.262	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{5.1}$** and **$H_{5.2}$**

The **Null Hypothesis $H_{5.1}$ and $H_{5.2}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Ability to co-operate attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 1.80, and that of T2-Peer is 4.60. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 2.13, and that of T2- Expert is 4.80. Therefore, significant improvement in idea generation has been observed in terms of Ability to co-operate when proposed toolkit is applied.

Working Null Hypothesis 6:

$H_{6.1}$	In the ideations, there is no significant difference between ratings of peers on the Personalization attribute, for a design concept in T1 and T2.
$H_{6.2}$	In the ideations, there is no significant difference between ratings of experts on the Personalization attribute, for a design concept in T1 and T2.

Table 24 Paired Samples Statistical Test for Personalization Rating

Paired Samples Statistics - Personalization (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{6.1}$	Personalization (T1-Peer)	2.40	15	1.502	.388	< 0.001
	Personalization (T2-Peer)	5.00	15	1.309	.338	
$H_{6.2}$	Personalization (T1-Expert)	3.27	15	1.100	.284	< 0.001
	Personalization (T2-Expert)	5.73	15	.799	.206	

TH-3294_196105005

Since p-value= < 0.001, we reject Null Hypothesis for $\mathbf{H_{6.1}}$ and $\mathbf{H_{6.2}}$

The **Null Hypothesis $\mathbf{H_{6.1}}$ and $\mathbf{H_{6.2}}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Personalization attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 2.40, and that of T2-Peer is 5.00. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 3.27, and that of T2- Expert is 5.73. Therefore, significant improvement in idea generation has been observed in terms of Personalization when proposed toolkit is applied.

Working Hypothesis 7:

$\mathbf{H_{7.1}}$	In the ideations, there is no significant difference between ratings of peers on the Openness attribute, for a design concept in T1 and T2.
$\mathbf{H_{7.2}}$	In the ideations, there is no significant difference between ratings of experts on the Openness attribute, for a design concept in T1 and T2.

Table 25 Paired Samples Statistical Test for Openness Rating

Paired Samples Statistics - Openness (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$\mathbf{H_{7.1}}$	Openness (T1-Peer)	1.87	15	.743	.192	< 0.001
	Openness (T2-Peer)	4.27	15	.884	.228	
$\mathbf{H_{7.2}}$	Openness (T1-Expert)	1.80	15	.676	.175	< 0.001
	Openness (T2-Expert)	4.07	15	.961	.248	

Since p-value= < 0.001, we reject Null Hypothesis for $\mathbf{H_{7.1}}$ and $\mathbf{H_{7.2}}$

The **Null Hypothesis $\mathbf{H_{7.1}}$ and $\mathbf{H_{7.2}}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Openness attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 1.87, and that of T2-Peer is 4.27. Similarly, when experts evaluated the ideations, the mean of T1-Expert is 1.80, and that of T2- Expert is 4.07. Therefore, significant improvement in idea generation has been observed in terms of Openness when proposed toolkit is applied.

Working Null Hypothesis 8:

$\mathbf{H_{8.1}}$	In the ideations, there is no significant difference between ratings of peers on the Service dominant attribute, for a design concept in T1 and T2.
$\mathbf{H_{8.2}}$	In the ideations, there is no significant difference between ratings of experts on the Service dominant attribute, for a design concept in T1 and T2.

Table 26 Paired Samples Statistical Test for Service dominant Design Rating

Paired Samples Statistics - Service dominant (T1-Peer/T2-Peer and T1-Expert/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$\mathbf{H_{8.1}}$	SD Design (T1-Peer)	2.47	15	.834	.215	< 0.001
	SD Design (T2-Peer)	5.80	15	.775	.200	

TH-3294_196105005

$H_{8.2}$	SD Design (T1-Expert)	2.60	15	.828	.214	< 0.001
	SD Design (T2-Expert)	6.13	15	.743	.192	

Since p-value= < 0.001, we reject Null Hypothesis for **$H_{8.1}$** and **$H_{8.2}$**

The **Null Hypothesis $H_{8.1}$ and $H_{8.2}$ is rejected** and concluded that there is a significant difference between the ratings of peer and rating of expert on the Service dominant attribute between Treatment-1 (T1) and Treatment-2 (T2). In the current sample, when peers evaluated the ideations, the mean of T1-Peer is 2.47, and that of T2-Peer is 5.80. Similarly, when experts evaluated the ideations, the mean of T1- Expert is 2.60, and that of T2- Expert is 6.13. Therefore, significant improvement in idea generation has been observed in terms of Service dominant when proposed toolkit is applied.

- **Understanding Bias in the rating of peers and experts**

It is essential to assess if there is any bias in the rating of peers and experts when evaluating various attributes. Formulating new hypotheses for this purpose is a crucial step. Following are the hypotheses for understanding the biasness through Paired Sample Test for all the attribute:

Working Null Hypothesis 9:

$H_{9.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Perceived Ease-of-use attribute, for a design concept in T1.
$H_{9.2}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Perceived Ease-of-use attribute, for a design concept in T2.

Table 27 Understanding Bias through Paired Samples Test for Perceived Ease of Use Rating

Paired Samples Statistics - Ease of Use - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{9.1}$	Perceived Ease of Use (T1-Peer)	3.00	15	1.000	.258	0.510
	Perceived Ease of Use (T1-Expert)	3.20	15	1.320	.341	
$H_{9.2}$	Perceived Ease of Use (T2-Peer)	5.67	15	.900	.232	1.000
	Perceived Ease of Use (T2-Expert)	5.67	15	.900	.232	

Since p-value= 0.510 and 1.000, we accept Null Hypothesis for **$H_{9.1}$** and **$H_{9.2}$**

Null Hypothesis $H_{9.1}$ and $H_{9.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Perceived Ease of Use attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Null Hypothesis 10:

$H_{10.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Perceived Usefulness attribute, for a design concept in T1.
$H_{10.2}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Perceived Usefulness attribute, for a design

TH-3294_196105005

	concept in T2.

Table 28 Understanding Bias through Paired Samples Test for Perceived Usefulness Rating

Paired Samples Statistics - Perceived Usefulness - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{10.1}$	Perceived Usefulness (T1-Peer)	3.40	15	1.454	.375	0.313
	Perceived Usefulness (T1-Expert)	3.07	15	1.223	.316	
$H_{10.2}$	Perceived Usefulness (T2-Peer)	5.27	15	1.387	.358	0.774
	Perceived Usefulness (T2-Expert)	5.33	15	1.234	.319	

Since p-value= 0.313 and 0.774, we accept Null Hypothesis for **$H_{10.1}$** and **$H_{10.2}$**

Null Hypothesis $H_{10.1}$ and $H_{10.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Perceived Usefulness attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Null Hypothesis 11:

$H_{11.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Context Awareness attribute, for a design concept in T1.
$H_{11.2}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Context Awareness attribute, for a design concept in T2.

Table 29 Understanding Bias through Paired Samples Test for Context Awareness Rating

Paired Samples Statistics - Context Awareness - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{11.1}$	Context Awareness (T1-Peer)	2.73	15	.799	.206	0.458
	Context Awareness (T1-Expert)	2.93	15	.799	.206	
$H_{11.2}$	Context Awareness (T2-Peer)	5.53	15	.834	.215	0.818
	Context Awareness (T2-Expert)	5.60	15	1.056	.273	

Since p-value= 0.458 and 0.818, we accept Null Hypothesis for **$H_{11.1}$** and **$H_{11.2}$**

Null Hypothesis $H_{11.1}$ and $H_{11.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Context Awareness attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Null Hypothesis 12:

$H_{12.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Muti-functional attribute, for a design concept in T1.
$H_{12.2}$	In the evaluation ratings, there is no significant difference between the ratings of

TH-3294_196105005

	peer and the rating of expert on the Muti-functional attribute, for a design concept in T2.

Table 30 Understanding Bias through Paired Samples Test for Multi-functional Rating

Paired Samples Statistics - Multi-functional - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{12.1}$	Multi-functional (T1-Peer)	1.60	15	.828	.214	< 0.001
	Multi-functional (T1-Expert)	2.87	15	.834	.215	
$H_{12.2}$	Multi-functional (T2-Peer)	5.80	15	.676	.175	0.014
	Multi-functional (T2-Expert)	6.27	15	.961	.248	

Since p-value= < 0.001 and 0.014, we accept Null Hypothesis for **$H_{12.1}$** and **$H_{12.2}$**

Null Hypothesis $H_{12.1}$ is rejected and $H_{12.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Multi-functional attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Null Hypothesis 13:

$H_{13.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Ability to co-operate attribute, for a design concept in T1.
$H_{13.2}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Ability to co-operate attribute, for a design concept in T2.

Table 31 Understanding Bias through Paired Samples Test for Ability to Co-operate Rating

Paired Samples Statistics - Ability to Co-operate - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{13.1}$	Ability to Co-operate (T1-Peer)	1.53	15	.516	.133	0.003
	Ability to Co-operate (T1-Expert)	2.13	15	.743	.192	
$H_{13.2}$	Ability to Co-operate (T2-Peer)	4.93	15	1.223	.316	0.301
	Ability to Co-operate (T2-Expert)	5.20	15	.862	.223	

Since p-value= 0.003 and 0.301, we accept Null Hypothesis for **$H_{13.1}$** and **$H_{13.2}$**

Null Hypothesis $H_{13.1}$ and $H_{13.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Ability to Co-operate attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Null Hypothesis 14:

$H_{14.1}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Personalization attribute, for a design concept in T1.

TH-3294_196105005

$H_{14.2}$	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Personalization attribute, for a design concept in T2.

Table 32 Understanding Bias through Paired Samples Test for Personalization Rating

Paired Samples Statistics - Personalization - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{14.1}$	Personalization (T1-Peer)	2.40	15	1.502	.388	0.032
	Personalization (T1-Expert)	3.27	15	1.100	.284	
$H_{14.2}$	Personalization (T2-Peer)	5.00	15	1.309	.338	0.077
	Personalization (T2-Expert)	5.73	15	.799	.206	

Since p-value= 0.032 and 0.077, we accept Null Hypothesis for **$H_{14.1}$** and **$H_{14.2}$**

Null Hypothesis $H_{14.1}$ and $H_{14.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Personalization attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Hypothesis 15:

Null Hypothesis (**$H_{15.1}$**):	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Openness attribute, for a design concept in T1.
Null Hypothesis (**$H_{15.2}$**):	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Openness attribute, for a design concept in T2.

Table 33 Understanding Bias through Paired Samples Test for Openness Rating

Paired Samples Statistics - Openness - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{15.1}$	Openness (T1-Peer)	1.20	15	.414	.107	0.003
	Openness (T1-Expert)	1.80	15	.676	.175	
$H_{15.2}$	Openness (T2-Peer)	5.00	15	.756	.195	0.836
	Openness (T2-Expert)	4.93	15	1.033	.267	

Since p-value= 0.003 and 0.836, we accept Null Hypothesis for **$H_{15.1}$** and **$H_{15.2}$**

Null Hypothesis $H_{15.1}$ and $H_{15.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the Personalization attribute in Treatment-1 (T1) and Treatment-2 (T2).

Working Hypothesis 16:

Null Hypothesis (**$H_{16.1}$**):	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Service dominant attribute, for a design

TH-3294_196105005

	concept in T1.
Null Hypothesis (**$H_{16.2}$**):	In the evaluation ratings, there is no significant difference between the ratings of peer and the rating of expert on the Service dominant attribute, for a design concept in T2.

Table 34 Understanding Bias through Paired Samples Test for Service dominant Design Rating

Paired Samples Statistics - SD Design - (T1-Peer/T1-Expert and T2-Peer/T2-Expert)						
		Mean	N	Std. Deviation	Std. Error Mean	p-value
$H_{16.1}$	SD Design (T1-Peer)	2.47	15	.834	.215	0.610
	SD Design (T1-Expert)	2.60	15	.828	.214	
$H_{16.2}$	SD Design (T2-Peer)	5.80	15	.775	.200	0.096
	SD Design (T2-Expert)	6.13	15	.743	.192	

Since p-value= 0.610 and 0.096, we accept Null Hypothesis for **$H_{16.1}$** and **$H_{16.2}$**

Null Hypothesis $H_{16.1}$ and $H_{16.2}$ is accepted and concluded that there is no significant difference between the ratings of peer vs. ratings of expert on the SD Design attribute in Treatment-1 (T1) and Treatment-2 (T2).

5.6 Chapter Conclusion

In this final chapter, we embarked on a journey of designing and developing a Smart Home Product-Service-System (SH-PSS) Innovator Toolkit aimed at enhancing the ideation process within the context of smart homes. This Toolkit, comprising various new proposed card tools, including the Reflection Criteria Card Tool, Mission Card Tool, Benefits Card Tool, Barrier Card Tool, Persona Card Tool, and Things Card Tool, was meticulously crafted to address the specific challenges and requirements of SH-PSS design.

Through a controlled experiment design, we sought to rigorously assess the impact of the SH-PSS Innovator Toolkit on ideation outcomes. Participants were divided into two treatment groups: Treatment T1, the Control Group, and Treatment T2, the Experimental Group, each comprising 15 participants. Treatment T1 engaged in ideation without the aid of the SH-PSS Toolkit, while Treatment T2 utilized the Toolkit during their ideation session. The study used a predefined SH-PSS challenge as the foundation for idea generation. Upon the culmination of the experiment and analysis of the results, it became evident that the proposed SH-PSS Innovator Toolkit had a substantial and positive impact on various attributes of ideation concepts in Treatment T2 when compared to Treatment T1. This compelling evidence underscores the Toolkit's effectiveness in enhancing key aspects of ideation, including perceived ease of use, usefulness, context awareness, multifunctionality, ability to co-operate, personalization, openness, and service dominance. These attributes, as assessed by both peers and experts, demonstrated marked improvements in ideation outcomes. The outcomes of this experiment provide substantial validation for the efficacy of the SH-PSS Innovator Toolkit, suggesting its potential as a valuable resource for designers, innovators, and stakeholders engaged in SH-PSS design and development.

Chapter 6: Conclusion, Limitations and Future Scope of Work

6.1 Introduction

The present chapter briefly discusses the novelties (key contributions) of the present thesis. This chapter also includes how research objectives have been fulfilled and how hypotheses have been tested. This chapter also lists the novelties of present research in terms of methodology and knowledge-base. This chapter ends with limitations, future scopes, and an overall conclusion of the present thesis work.

6.2 Novelties (key contributions) of the Present Thesis

- In the present research, we conducted an integrative review of articles relevant to the topic of smart homes and new technology adoption (Figure 1.1). Through the critical analysis of these articles, four main themes or categories emerged: 1. The Terminology used in smart home and IoT products, 2. Consumer behavior and its relation with other factors such as benefits, barriers, and socio-cultural aspects in smart homes, 3. New technology acceptance, and 4. Product service system (PSS) design in smart homes. The integration of valuable insights drawn from reviewing the first two categories has resulted in developing a conceptual framework of smart homes' benefits, barriers, and socio-cultural aspects. Valuable insights drawn from the third category is technology adoption through various theoretical models in smart home products and services. Among the multitude of models explored, the Technology Acceptance Model (TAM) emerges as a central and frequently employed framework, underlining its paramount relevance in comprehending the dynamics of new technology adoption in this context. An essential contribution of this study is that the insights gained from the review of the available literature provide an overview of the range of smart home factors that are most likely to influence consumer behavior response to new technology in the smart home context. Consequently, the proposed framework is an important guideline on how these factors link with each other. Moreover, the framework shows direct, indirect, or both (direct and indirect) relationships between specific factors and consumer behavior. The framework presented effectively suggests promising future research directions to conduct studies based on specific parts and contributing factors of the framework, which were unexplored previously, and investigate their role in influencing consumer behavior.

- This current study we identified several features that need to be improved in the SH-PSS implemented in India. We utilized the Kano Model by testing 22 characteristics representing features and recommended improvements for the future development of SH-PSS. The Kano model explains the relationship between the degree of sufficiency and customer satisfaction/dissatisfaction with respect to an attribute of customer requirement. The customer requirements can be classified into six categories: attractive, one-dimensional, must-be, indifferent, reverse and questionable. The characteristics that are in the category of "**Attractive**": Two characteristics of smart home functions: *health therapy and consultancy* (*C.3.1, C.5.2*)*;* four characteristics of product smartness: *independent, multi-functional, ability to cooperate, and humanlike interaction (C.6.2, C.9.1, C.9.2, C.10.1, C.10.2, C.11.2);* and five characteristics of qualities consumer looking for in SH-PSS: *context awareness, personalization, communication, openness, collaboration (C.13.1, C.13.2, C.17.1, C.17.2, C.19.1, C.21.1, C.21.2,*

TH-3294_196105005

C.22.2) fall into the category of "*Attractive*". These characteristics will definitely result in customer satisfaction. However, if this element is not obtained, it will not result in dissatisfaction.

- In the present study, we developed a Smart Home Product-Service-System (SH-PSS) conceptual framework. This study provides a comprehensive model encompassing the key elements and principles of SH-PSS design, and current gaps and challenges in SH-PSS design to meet user needs and enhance user experience are addressed. The investigation delves into three pivotal components: Service Dominant Design, Data-Driven Value Co-Creation, and Closed Loop Design. These elements are essential considerations when crafting user-centric and efficient SH-PSS solutions.

- In the present study, various design methods and toolkits for ideating IoT and Smart Home products are identified. These include Card 'n' Dice, Co-create the IoT, IoT Design Deck, IoT Ideation Design Kit, Know Cards, Mapping the IoT, and Tiles IoT Toolkit. Each of these tools plays a vital role in stimulating creativity and generating innovative ideas in the context of Smart Home design. Comprehensive landscape mapping of design toolkits for Smart Product-Service-System is presented. This mapping serves as a valuable resource for both designers and researchers, providing a structured overview of the existing design tools and their precise applications within SH-PSS.

- In the present study, we present the "Design and Development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit," a novel and specialized Toolkit designed to facilitate the ideation and development of smart home products and services. The new Toolkit streamlines the process of sketching and generating ideas, allowing participants to visualize their concepts quickly. It also introduces a structured framework for elevator pitches and the evaluation of ideation sheets, promoting effective communication and assessment of smart home ideas. The Toolkit consists of a variety of physical tiles or cards that can be connected together to create various ideas. This Toolkit, comprising various new proposed card tools, including the Reflection Criteria Card Tool, Mission Card Tool, Benefits Card Tool, Barrier Card Tool, Persona Card Tool, and Things Card Tool. The new ideation sheet is a pivotal addition to the SH-PSS Innovator Toolkit, enhancing the ideation process by seamlessly integrating cards and creative thinking.

6.3 Fulfillment of the Objective and Testing of Hypotheses

Obj 1. To study technology adoption models with special emphasis to PSS design frameworks and toolkits.

In line with Objective 1, the research delved into an extensive exploration of various technology adoption models, specifically focusing on their applicability within the context of Product-Service-System (PSS) design for smart homes. Section 2.4 of the study meticulously examines these theoretical models, shedding light on their distinctive characteristics and their collective influence on the adoption of innovative smart home solutions. Among the plethora of models investigated, the Technology Acceptance Model (TAM) prominently emerges as a central and frequently utilized framework. This emphasizes the pivotal role of TAM in comprehending the intricate dynamics of new technology adoption, particularly within the smart home context. Thus, through this comprehensive investigation, it can be conclusively asserted that **Objective 1 of the research has been effectively fulfilled**.

TH-3294_196105005

Obj 2. To identify PSS design frameworks suitable for smart home PSS design.

In Chapter 2, the proposed framework initially focused on the factors which define any product as a "smart" product and the qualities that consumers look for within the product while using it in cooperation with other products and using smart products. Secondly, we focused on consumer benefits and barriers which influence the new technology acceptance. Also, we have identified consumer behavior and its relation to socio-cultural aspects of smart home products. At last, we have determined a need for user-centric research and a product service system design (PSS) perspective in smart homes, which includes a communication network between tangible products, intangible services and all the stakeholders involved in the system. **Thus, objective 2 of the research was fulfilled.**

Obj 3. To customize the generic PSS design framework incorporating "service dominance" in the context of smart home PSS design projects.

Chapter 4 of this research stands as a testament to the successful fulfilment of Objective 3, which was dedicated to the customization of a generic PSS design framework, infusing it with the essential concept of "service dominance" within the intricate context of smart home Product-Service-System (SH-PSS) design projects. This framework is not only an academic exercise but a practical roadmap, guiding researchers, designers, and stakeholders through the complex landscape of the smart home domain. One of the significant accomplishments of this chapter is its ability to address the existing gaps and challenges that have plagued SH-PSS design. The research examines three critical facets: Service Dominant Design, a multidisciplinary approach to smart home innovation that centers around the creation of value through services; Data-Driven Value Co-Creation, which harnesses the power of real-time data to sculpt user experiences; and Closed-Loop Design, an iterative and adaptive approach that ensures the longevity and relevance of SH-PSS. Thus, **objective 3 of the research was fulfilled**.

Obj 4. To develop a specific PSS design toolkit for PSS designers for smart home PSS design projects.

In Chapter 5, we designed and developed a Smart Home Product-Service-System (SH-PSS) Innovator Toolkit to enhance the ideation process within the context of smart homes. This Toolkit, comprising various new proposed card tools, including the Reflection Criteria Card Tool, Mission Card Tool, Benefits Card Tool, Barrier Card Tool, Persona Card Tool, and Things Card Tool, was meticulously crafted to address the specific challenges and requirements of SH-PSS design. Thus, **objective 4 of the research was fulfilled**.

The results of this experiment provide robust validation for the Toolkit's efficacy. The evidence is compelling, showing that the SH-PSS Innovator Toolkit significantly and positively influenced various attributes of ideation concepts in Treatment T2 compared to Treatment T1. These attributes, ranging from perceived ease of use and usefulness to context awareness, multifunctionality, ability to co-operate, personalization, openness, and service dominance, all experienced marked improvements. What is particularly noteworthy is that these improvements were recognized and confirmed by both peers and experts, lending further credence to the Toolkit's potential.

TH-3294_196105005

6.4 Limitations and Recommendations for Further Research

- The research primarily focused on the context of smart homes. The toolkit's applicability in other contexts or industries remains unexplored. Investigating the toolkit's applicability beyond smart homes and exploring its effectiveness in different industries and contexts to determine its versatility. Future research could investigate its effectiveness in diverse settings.

- The participants in the experiments were assumed to have a certain level of expertise in SH-PSS design. Future studies could examine how the toolkit performs with participants of varying expertise levels. Furthermore, one of the limitations of this research is the relatively small sample size used in the experiments. While the results are promising, a larger and more diverse sample could provide additional insights and strengthen the findings. Extend the research to encompass a broader user base with varying levels of familiarity with SH-PSS design. This can provide insights into how the toolkit caters to different user profiles.

- The experiments were conducted using a single predefined challenge. While this provided a standardized basis for evaluation, exploring the toolkit's performance across different challenges could offer a more comprehensive understanding of its capabilities. Also, the experiments conducted to assess the impact of the SH-PSS Innovator Toolkit were relatively short-term. Long-term evaluations of how the toolkit influences ideation processes and outcomes over extended periods could yield valuable insights.

- Continuously refine and expand the toolkit based on user feedback and evolving design needs in the field of SH-PSS. Assess how the ideation outcomes influenced by the toolkit translate into actual SH-PSS designs and their reception in the market. Combine quantitative data with qualitative insights, such as user interviews and observations, to gain a deeper understanding of the toolkit's impact on the design process. Explore the scalability of the toolkit for use in larger design teams and more complex SH-PSS projects.

These recommendations can contribute to a more comprehensive understanding of the toolkit's potential and its role in shaping the future of SH-PSS design.

6.5 Conclusion

In conclusion, this thesis has undertaken a comprehensive exploration of the design and development of Smart Home Product-Service-System (SH-PSS) Innovator Toolkit and its impact on ideation processes within the context of smart homes. This study studied technology adoption models, emphasizing PSS design frameworks. This objective was fulfilled by delving into various theoretical models and highlighting the Technology Acceptance Model's (TAM) central role in comprehending new technology adoption in smart homes. Through a comprehensive literature review, this objective was met by identifying key factors defining smart products, understanding consumer benefits and barriers, analyzing consumer behavior with socio-cultural aspects, and advocating for user-centric PSS design perspectives. This study customizes a generic PSS design framework by incorporating "service dominance" in the context of smart home PSS design projects. Developing the Smart Home Product-Service-System (SH-PSS) Conceptual Framework provides a valuable guide for designers, researchers, and stakeholders involved in SH-PSS design. This study finally involved designing and

TH-3294_196105005

developing a specific PSS design toolkit tailored for SH-PSS design projects. The creation of the SH-PSS Innovator Toolkit, comprising various card tools, and its validation through controlled experiments demonstrated its effectiveness in enhancing ideation processes in smart home design.

Throughout this thesis, the experiments conducted to assess the SH-PSS Innovator Toolkit's impact yielded promising results. The toolkit positively influenced various attributes of ideation concepts, including perceived ease of use, usefulness, context awareness, multifunctionality, ability to cooperate, personalization, openness, and service dominance. These improvements were observed in assessments by both peers and experts, validating the toolkit's efficacy.

In summary, this research advances the field of SH-PSS design by offering a comprehensive framework and toolkit that can enhance the ideation process, ultimately leading to the development of innovative and user-centric smart home solutions. The fulfilment of the four primary objectives underscores the significance of this work in contributing to the evolution of smart home technology and design practices. This research invites further exploration and application of the SH-PSS Innovator Toolkit and its principles in real-world design projects, with the potential to shape the future of smart homes and their seamless integration into our lives.

TH-3294_196105005

REFERENCES

Ahram, T., & Karwowski, W. (2011, July). Social networking applications: Smarter product design for complex human behaviour modeling. In International Conference on Human Centered Design (pp. 471-480). Springer, Berlin, Heidelberg.

Alaa, M., Zaidan, A. A., Zaidan, B. B., Talal, M., & Kiah, M. L. M. (2017). A review of smart home applications based on Internet of Things. Journal of Network and Computer Applications, 97, 48-65. 4.

Alaiad, A., & Zhou, L. (2017). Patients' adoption of WSN-based smart home healthcare systems: an integrated model of facilitators and barriers. IEEE Transactions on Professional Communication, 60(1), 4-23.

Alam, M. R., Reaz, M. B. I., & Ali, M. A. M. (2012). A review of smart homes-Past, present, and future. IEEE transactions on systems, man, and cybernetics, part C (applications and reviews), 42(6), 1190- 1203.

Alcayaga, A., Wiener, M., & Hansen, E. G. (2019). Towards a framework of smart-circular systems: An integrative literature review. Journal of cleaner production, 221, 622-634.

Aldrich, F. K. (2003). Smart homes: past, present and future. In Inside the smart home (pp. 17-39). Springer, London.

Aldossari, M. Q., & Sidorova, A. (2020). Consumer acceptance of Internet of Things (IoT): Smart home context. Journal of Computer Information Systems, 60(6), 507-517.

Aljomaa, S. S., Qudah, M. F. A., Albursan, I. S., Bakhiet, S. F., & Abduljabbar, A. S. (2016). Smartphone addiction among university students in the light of some variables. Computers in Human Behavior, 61, 155-164.

Alsulami, M. H., & Atkins, A. S. (2016). Factors influencing ageing population for adopting ambient assisted living technologies in the Kingdom of Saudi Arabia. Ageing International, 41(3), 227-239. 8.

Amazon Alexa. AVS International [Internet]. Development Resources. 2020 [cited 2020 Oct 18]. Available from: https://developer.amazon.com/en-US/alexa/devices/alexa-built-in/development-resources/international

Amiribesheli, M., Benmansour, A., & Bouchachia, A. (2015). A review of smart homes in healthcare. Journal of Ambient Intelligence and Humanized Computing, 6(4), 495-517.

Annarelli, A., Battistella, C., & Nonino, F. (2016). Product service system: A conceptual framework from a systematic review. Journal of cleaner production, 139, 1011-1032.

Arunvivek, J., Srinath, S., & Balamurugan, M. S. (2015). Framework development in home automation to provide control and security for home automated devices. Indian J. Sci. Technol, 8, 1-10.

TH-3294_196105005

Arne Berger, Albrecht Kurze, Sören Totzauer, Michael Storz, Andreas Bischof, and Kevin Lefeuvre. 2019. Loaded Dice. Retrieved February 6, 2019 from https://nebeneinander-miteinander.de/portfolio/loaded-dice/

Atoyebi, O. A., Stewart, A., & Sampson, J. (2015). Use of information technology for falls detection and prevention in the elderly. Ageing international, 40(3), 277-299.

Aye, N. N., & Fujiwara, T. (2014). Application of option-games approach to the irreversible investment for a new energy industry in Myanmar by simple one-stage strategic model: focused on potential of smart house. Global Journal of Flexible Systems Management, 15(3), 191-202.

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). Social barriers to the adoption of smart homes. Energy Policy, 63, 363-374.

Balta-Ozkan, N., Davidson, R., Bicket, M., & Whitmarsh, L. (2013). The development of smart homes market in the UK. Energy, 60, 361-372.

Balta-Ozkan, N., Amerighi, O., & Boteler, B. (2014). A comparison of consumer perceptions towards smart homes in the UK, Germany and Italy: reflections for policy and future research. Technology Analysis & Strategic Management, 26(10), 1176-1195.

Bardhan, A. Jaffee, D., Kroll, C., & Wallace, N. (2014). Energy efficiency retrofits for US housing: Removing the bottlenecks. Regional Science and Urban Economics, 47, 45-60.

Bauer, S. R., & Mead, P. (1995). After you open the box: Making smart products more usable, useful, and desirable through interactive technology. Design Management Journal (Former Series), 6(4), 21-26.

Beaudin, M., & Zareipour, H. (2015). Home energy management systems: A review of modelling and complexity. Renewable and sustainable energy reviews, 45, 318-335.

Bhati, A., Hansen, M., & Chan, C. M. (2017). Energy conservation through smart homes in a smart city: A lesson for Singapore households. Energy Policy, 104, 230-239.

Blaschke, C. M., Freddolino, P. P., & Mullen, E. E. (2009). Ageing and technology: A review of the research literature. British Journal of Social Work, 39(4), 641-656.

Bowes, A., Dawson, A., & Bell, D. (2012). Ethical implications of lifestyle monitoring data in ageing research. Information, Communication & Society, 15(1), 5-22.

Bradshaw, J. M. (1997). Software Agents. Menlo Park, CA: American Association for Artificial Intelligence.

Brandt, Å., Samuelsson, K., Töytäri, O., & Salminen, A. L. (2011). Activity and participation, quality of life and user satisfaction outcomes of environmental control systems and smart home technology: a systematic review. Disability and Rehabilitation: Assistive Technology, 6(3), 189- 206.

Buolamwini, J., & Gebru, T. (2018, January). Gender shades: Intersectional accuracy disparities in

TH-3294_196105005

commercial gender classification. In Conference on fairness, accountability and transparency (pp. 77-91). PMLR.

Bu, L., Chen, C. H., Ng, K. K., Zheng, P., Dong, G., & Liu, H. (2021). A user-centric design approach for smart product-service systems using virtual reality: A case study. Journal of Cleaner Production, 280, 124413.

Carley, S., Evans, T. P., & Konisky, D. M. (2018). Adaptation, culture, and the energy transition in American coal country. Energy Research & Social Science, 37, 133-139.

Cassarino, M., & Setti, A. (2016). Complexity as key to designing cognitive-friendly environments for older people. Frontiers in psychology, 7, 1329.

Cavicchi, C., & Vagnoni, E. (2017). Does intellectual capital promote the shift of healthcare organizations towards sustainable development? Evidence from Italy. Journal of Cleaner Production, 153, 275-286.

Celler, B. G., Lovell, N. H., & Basilakis, J. (2003). Using information technology to improve the management of chronic disease. Medical Journal of Australia, 179(5), 242-246.

Chan, H., & Perrig, A. (2003). Security and privacy in sensor networks. computer, 36(10), 103-105. 34.

Chan, M., Estève, D., Escriba, C., & Campo, E. (2008). A review of smart homes-Present state and future challenges. Computer methods and programs in biomedicine, 91(1), 55-81.

Chan, M., Campo, E., Estève, D., & Fourniols, J. Y. (2009). Smart homes-current features and future perspectives. Maturitas, 64(2), 90-97.

Chan, M., Estève, D., Fourniols, J. Y., Escriba, C., & Campo, E. (2012). Smart wearable systems: Current status and future challenges. Artificial intelligence in medicine, 56(3), 137-156.

Chen, S., Liu, T., Gao, F., Ji, J., Xu, Z., Qian, B., ... & Guan, X. (2017). Butler, not servant: A human- centric smart home energy management system. IEEE Communications Magazine, 55(2), 27-33.

Chou, J. R. (2021). A TRIZ-based product-service design approach for developing innovative products. Computers & Industrial Engineering, 161, 107608.

Cong, J., Chen, C. H., & Zheng, P. (2020a). Design entropy theory: A new design methodology for smart PSS development. Advanced Engineering Informatics, 45, 101124.

Cong, J. C., Chen, C. H., Zheng, P., Li, X., & Wang, Z. (2020b). A holistic relook at engineering design methodologies for smart product-service systems development. Journal of Cleaner Production, 272, 122737.

Chiang, K. F., & Wang, H. H. (2016). Nurses' experiences of using a smart mobile device application to assist home care for patients with chronic disease: a qualitative study. Journal of Clinical Nursing, 25(13-14), 2008-2017.

Christensen B. T. and Schunn C. D. The relationship of analogical distance to analogical function

TH-3294_196105005

and preinventive structure: The case of engineering design. *Memory and Cognition*, 2007, 35(1), 29–38. https://doi.org/10.3758/BF03195939

Chung, J., Demiris, G., & Thompson, H. J. (2016). Ethical considerations regarding the use of smart home technologies for older adults: an integrative review. Annual review of nursing research, 34(1), 155-181.

C. Lopez-Lloreda, How speech-recognition software discriminates against minority voices, Sci. Am. (2020) Oct; Available from: https://www.scientificamerican.com/article/how-speech-reconition-softwre-discriminates-against-minority-voices/.

Costa, N., Patrício, L., Morelli, N., & Magee, C. L. (2018). Bringing service design to manufacturing companies: integrating PSS and service design approaches. Design Studies, 55, 112-145.

Coughlan, T., Leder Mackley, K., Brown, M., Martindale, S., Schlögl, S., Mallaband, B., ... & Hine, N. (2013). Current issues and future directions in methods for studying technology in the home. PsychNology Journal, 11(2), 159-184.

Courtney, K. L. (2008). Privacy and senior willingness to adopt smart home information technology in residential care facilities. Methods of information in medicine, 47(01), 76-81.

Czaja, S. J. (2016). Long-term care services and support systems for older adults: The role of technology. American Psychologist, 71(4), 294.

Del Rio, D. D. F., Sovacool, B. K., & Griffiths, S. (2021). Culture, energy and climate sustainability, and smart home technologies: A mixed methods comparison of four countries. Energy and Climate Change, 2, 100035.

Damodaran, L., & Olphert, W. (2010). User responses to assisted living technologies (ALTs)-a review of the literature. Journal of Integrated Care.

Darby, S. J., & McKenna, E. (2012). Social implications of residential demand response in cool temperate climates. Energy Policy, 49, 759-769.

Das, S. K., Cook, D. J., Battacharya, A., Heierman, E. O., & Lin, T. Y. (2002). The role of prediction algorithms in the MavHome smart home architecture. IEEE Wireless Communications, 9(6), 77-84.

Dawid, H., Decker, R., Hermann, T., Jahnke, H., Klat, W., König, R., & Stummer, C. (2017). Management science in the era of smart consumer products: challenges and research perspectives. Central European Journal of Operations Research, 25(1), 203-230.

De Silva, L. C., Morikawa, C., & Petra, I. M. (2012). State of the art of smart homes. Engineering Applications of Artificial Intelligence, 25(7), 1313-1321.

De Roeck, D., and Brito, Ricardo. 2016. Ideation & the Internet of Things. ThingsCon. Retrieved January 14, 2019 from https://medium.com/thingscon/ideation-the-internet-of-things-

TH-3294_196105005

f5154cb040f9

De Roeck, D., Tanghe, J., Jacoby, A., Moons, I., & Slegers, K. (2019, June). Ideas of things: the iot design kit. In Companion publication of the 2019 on designing interactive systems conference 2019 companion (pp. 159-163).

Demiris, G. (2004). Electronic home healthcare: concepts and challenges. International Journal of Electronic Healthcare, 1(1), 4-16.

Demiris, G., & Hensel, B. K. (2008). Technologies for an aging society: a systematic review of "smart home" applications. Yearbook of medical informatics, 17(01), 33-40.

Demiris, G., & Hensel, B. (2009). Smart homes for patients at the end of life J. Housing Elderly 23 (1-2), 106-115.

Demiris, G., Oliver, D. P., Dickey, G., Skubic, M., & Rantz, M. (2008). Findings from a participatory evaluation of a smart home application for older adults. Technology and health care, 16(2), 111- 118.

Del Rio, D. D. F., Sovacool, B. K., Bergman, N., & Makuch, K. E. (2020). Critically reviewing smart home technology applications and business models in Europe. Energy Policy, 144, 111631.

Design Council. 2005. The Design Process: What is the Double Diamond? Design Council. Retrieved September 25, 2018 from https://www.designcouncil.org.uk/news-opinion/design-process-what- double-diamond

Dhebar, A. (1996). Information technology and product policy: 'Smart' products. European Management Journal, 14(5), 477-485.

Diegel, O. (2005, November). Intelligent automated health systems for compliance monitoring. In TENCON 2005-2005 IEEE Region 10 Conference (pp. 1-6). IEEE.

Diegel, O., Lomiwes, G., Messom, C., Moir, T., Ryu, H., Thomsen, F., ... & Zhenqing, L. (2005, April). A BLUETOOTH HOME DESIGN@ NZ. In International Conference on Home-Oriented Informatics and Telematics (pp. 87-99). Springer, Boston, MA.

Dong, Y., Zhu, R., Tian, Q., Liu, W., & Peng, W. (2019). A Scenario Interaction-centered Conceptual Information Model for UX Design of User-oriented Product-service System. Procedia CIRP, 83, 335-338.

Dorsten, A. M., Sifford, K. S., Bharucha, A., Mecca, L. P., & Wactlar, H. (2009). Ethical perspectives on emerging assistive technologies: insights from focus groups with stakeholders in long-term care facilities. Journal of Empirical Research on Human Research Ethics, 4(1), 25-36.

Dries De Roeck, Pieter Jan Stappers, and Achiel Standaert. 2014. Gearing Up!: A Designer-focused Evaluation of Ideation Tools for Connected Products. In Proceedings of the 8th Nordic Conference on Human-Computer Interaction: Fun, Fast, Foundational (NordiCHI

TH-3294_196105005

’14), 521–530. https://doi.org/10.1145/2639189.2639204

Dries De Roeck, Jürgen Tanghe, Alexis Jacoby, Ingrid Moons, and Karin Slegers. 2019. Ideas of Things: The IOT Design Kit. In Proceedings of the 2019 Designing Interactive Systems Conference, 159–163. https://doi.org/10.1145/3301019.3323888

E Carrie, Alexa and Google Home are no Threat to Regional Accents - Here's Why [Internet], The Conversation, 2018 [cited 2021 Apr 6]. Available from: https://theconversation.com/alexa-and- google-home-are-no-threat-to-regional- accents-heres-why-101866.

Ehrenhard, M., Kijl, B., & Nieuwenhuis, L. (2014). Market adoption barriers of multi-stakeholder technology: Smart homes for the aging population. Technological forecasting and social change, 89, 306-315.

El-Hawary, M. E. (2014). The smart grid-state-of-the-art and future trends. Electric Power Components and Systems, 42(3-4), 239-250.

Elizabeth B.-N. Sanders and Pieter Jan Stappers. 2014. Probes, toolkits and prototypes: three approaches to making in codesigning. CoDesign 10, 1: 5–14. https://doi.org/10.1080/15710882.2014.888183

Elkhorchani, H., & Grayaa, K. (2016). Novel home energy management system using wireless communication technologies for carbon emission reduction within a smart grid. Journal of Cleaner Production, 135, 950-962.

E. Vogels, Millennials stand out for their technology use, but older gen- erations also embrace digital life [Internet], Pew Research Center, 2019 [cited 2021 Feb 23]. Available from: https:// www.pewresearch.org/ fact-tank/2019/09/09/us-generations-technology-use/.

Faruqui, A., Harris, D., & Hledik, R. (2010). Unlocking the- 53 billion savings from smart meters in the EU: How increasing the adoption of dynamic tariffs could make or break the EU's smart grid investment. Energy Policy, 38(10), 6222-6231.

Fernandez K. Why it's so tricky for Arabic voice apps to walk the talk [Internet]. Wired. 2019 [cited 2020 Oct 18]. Available from: https://wired.me/technology/making-arabic-voice-apps- assistants/.

Finch, T. L., Mort, M., Mair, F. S., & May, C. R. (2008). Future patients? Telehealthcare, roles and responsibilities. Health & social care in the community, 16(1), 86-95.

Finkelstein, S. M., Speedie, S. M., Demiris, G., Veen, M., Lundgren, J. M., & Potthoff, S. (2004). Telehomecare: quality, perception, satisfaction. Telemedicine Journal & E-Health, 10(2), 122-128.

Forlizzi, J. (2018). Moving beyond user-centered design. Interactions, 25(5), 22-23. 73. Galperin H. Digital society: gaps and challenges for digital inclusion in Latin America and the Caribbean [Internet]. Paris; 2017. Available from:

TH-3294_196105005

https://unesdoc.unesco.org/ark:/48223/pf0000262860_eng
Foye, C., Clapham, D., & Gabrieli, T. (2018). Home-ownership as a social norm and positional good: Subjective wellbeing evidence from panel data. Urban Studies, 55(6), 1290-1312.
Frank, A. G., Mendes, G. H., Ayala, N. F., & Ghezzi, A. (2019). Servitization and Industry 4.0 convergence in the digital transformation of product firms: A business model innovation perspective. Technological Forecasting and Social Change, 141, 341-351.
Gaul, S., & Ziefle, M. (2009, November). Smart home technologies: Insights into generation-specific acceptance motives. In Symposium of the Austrian HCI and usability engineering group (pp. 312-332). Springer, Berlin, Heidelberg.
Galperin H. Digital society: gaps and challenges for digital inclusion in Latin America and the Caribbean [Internet]. Paris; 2017.
Available from: https://unesdoc.unesco.org/ark:/48223/pf0000262860_eng.
Google. Google Nest Help [Internet]. Google Nest Help. 2020 [cited 2020 Oct 18]. Available from: https://support.google.com/googlenest/thread/4995832?hl=en
Gram-Hanssen, K., & Bech-Danielsen, C. (2004). House, home and identity from a consumption perspective. Housing, theory and society, 21(1), 17-26.
Gram-Hanssen, K. (2014). Retrofitting owner-occupied housing: remember the people. Building Research & Information, 42(4), 393-397.
Gram-Hanssen, K., & Darby, S. J. (2018). "Home is where the smart is"? Evaluating smart home research and approaches against the concept of home. Energy Research & Social Science, 37, 94-101.
Gutiérrez, C., Garbajosa, J., Diaz, J., & Yagüe, A. (2013, April). Providing a consensus definition for the term" smart product". In 2013 20th IEEE international conference and workshops on engineering of computer based systems (ECBS) (pp. 203-211). IEEE.
Hallstedt, S. I., Isaksson, O., & Öhrwall Rönnbäck, A. (2020). The need for new product development capabilities from digitalization, sustainability, and servitization trends. Sustainability, 12(23), 10222.
He, J., & Zhang, S. (2022). How digitalized interactive platforms create new value for customers by integrating B2B and B2C models? An empirical study in China. Journal of Business Research, 142, 694-706.
Hribernik, K., Franke, M., Klein, P., Thoben, K. D., & Coscia, E. (2017, June). Towards a platform for integrating product usage information into innovative product-service design. In 2017 international conference on engineering, technology and innovation (ICE/ITMC) (pp. 1407-1413). IEEE.
Hargreaves, T., Nye, M., & Burgess, J. (2013). Keeping energy visible? Exploring how householders interact with feedback from smart energy monitors in the longer term. Energy

TH-3294_196105005

policy, 52, 126-134.

Hong, A., Nam, C., & Kim, S. (2020). What will be the possible barriers to consumers' adoption of smart home services?. Telecommunications Policy, 44(2), 101867.

Hong, J., Shin, J., & Lee, D. (2016). Strategic management of next-generation connected life: Focusing on smart key and car-home connectivity. Technological Forecasting and Social Change, 103, 11-20.

Hubert, M., Blut, M., Brock, C., Zhang, R. W., Koch, V., & Riedl, R. (2019). The influence of acceptance and adoption drivers on smart home usage. European journal of marketing, 53(6), 1073-1098.

Hunter, M. (2015). The design process: what is the double diamond. Design Council, London.

International Organization for Standardization. (2010). Ergonomics of Human-system Interaction: Part 210: Human-centred Design for Interactive Systems. ISO.

Ilaria Vitali and Venanzio Arquilla. 2018. Developing a Design Toolkit for the Internet of Things. 1159–1174. Retrieved January 14, 2019 from https://re.public.polimi.it/handle/11311/1063946#.XDzclM21K70

Ilaria Vitali, Venanzio Arquilla, and Valentina Rognoli. 2019. Mapping the IoT toolkit. Mapping The IoT Toolkit. Retrieved February 6, 2019 from http://mappingtheiot.polimi.it/

Ilaria Vitali, Valentina Rognoli, and Venanzio Arquilla. 2016. Mapping the IoT: Co-design, Test and Refine a Design Framework for IoT Products. In Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16), 142:1–142:3. https://doi.org/10.1145/2971485.2987681

James Burch. Beloved robot dogs honored in funeral ceremony. National Geographic [Internet]. 2018 May; Available from: https://www.nationalgeographic.com/travel/destinations/asia/japan/in-japan-a-buddhist-funeral-service-for-robot-dogs/

Jansson D. G. and Smith S. M. Design fixation. *Design Studies*, 1991, 12(1), 3–11.

Ji, W., & Chan, E. H. (2019). Critical factors influencing the adoption of smart home energy technology in China: A Guangdong province case study. *Energies*, *12*(21), 4180.

Jia, G., Zhang, G., Yuan, X., Gu, X., Liu, H., Fan, Z., & Bu, L. (2021). A synthetical development approach for rehabilitation assistive smart product–service systems: A case study. Advanced Engineering Informatics, 48, 101310.

Kanda, W., & Matschewsky, J. (2018). An exploratory expansion of the concept of product-service systems beyond products and services. Procedia Cirp, 73, 185-190.

Kano, N. (1984). Attractive quality and must-be quality. *Journal of the Japanese society for quality control*, *31*(4), 147-156.

Kerbler, B. (2013). Attitudes of the elderly towards a remote home care. Dela, 87-106.

TH-3294_196105005

Koenecke, A., Nam, A., Lake, E., Nudell, J., Quartney, M., Mengesha, Z., ... & Goel, S. (2020). Racial disparities in automated speech recognition. Proceedings of the National Academy of Sciences, 117(14), 7684-7689.

Khedekar, D. C., Truco, A. C., Oteyza, D. A., & Huertas, G. F. (2017). Home automation-a fast-expanding market. Thunderbird International Business Review, 59(1), 79-91.

Kiesling, L. L. (2016). The connected home and an electricity-Market platform for the twenty-First century. The Independent Review, 20(3), 405-409.

Kim, M. J., Oh, M. W., Cho, M. E., Lee, H., & Kim, J. T. (2013). A critical review of user studies on healthy smart homes. Indoor and Built Environment, 22(1), 260-270.

Kim, S., & Baek, J. S. (2019, July). Definitions and attributes of smart home appliances. In Proceedings of the Design Society: International Conference on Engineering Design (Vol. 1, No. 1, pp. 2071-2080). Cambridge University Press.

Kim, S., Christiaans, H., & Baek, J. S. (2019). Smart homes as product-service systems: Two focal areas for developing competitive smart home appliances. Service Science, 11(4), 292-310.

Kim, Y., Park, Y., & Choi, J. (2017). A study on the adoption of IoT smart home service: using Value-based Adoption Model. Total Quality Management & Business Excellence, 28(9-10), 1149-1165.

Kleinberger, T., Becker, M., Ras, E., Holzinger, A., & Müller, P. (2007, July). Ambient intelligence in assisted living: enable elderly people to handle future interfaces. In International conference on universal access in human-computer interaction (pp. 103-112). Springer, Berlin, Heidelberg.

Kun, L. G. (2001). Telehealth and the global health network in the 21st century. From homecare to public health informatics. Computer methods and programs in biomedicine, 64(3), 155-167.

Kyriakopoulos, G. L., & Arabatzis, G. (2016). Electrical energy storage systems in electricity generation: Energy policies, innovative technologies, and regulatory regimes. Renewable and Sustainable Energy Reviews, 56, 1044-1067.

Kaasinen, E., Roto, V., Hakulinen, J., Heimonen, T., Jokinen, J. P., Karvonen, H., ... & Turunen, M. (2015). Defining user experience goals to guide the design of industrial systems. Behaviour & Information Technology, 34(10), 976-991.

Kammler, F., Kemmerich, H., Brinker, J., & Thomas, O. (2019). Scrutinizing the design specifications of smart products: a practical evaluation in yachting.

Kanda, W., & Matschewsky, J. (2018). An exploratory expansion of the concept of product-service systems beyond products and services. Procedia Cirp, 73, 185-190.

Kim, Y. S., & Hong, Y. (2019). A systematic method to design product-service systems using

TH-3294_196105005

personalisation services based on experience evaluations. International Journal of Product Development, 23(4), 353-386.

Kiritsis, D. (2011). Closed-loop PLM for intelligent products in the era of the Internet of things. Computer-Aided Design, 43(5), 479-501.

Lach, C., Punchihewa, A., De Silva, L. C., & Mercer, K. (2007, November). Smart home system operating remotely Via 802.11 b/g wireless technology. In published in the proceedings of the 4th International Conference Computational Intelligence and Robotics and Autonomous Systems (CIRAS2007), held in Palmerston North, New Zealand.

Leclercq P. and Heylighen A. 5. 8 Analogies per Hour. In: J. S. Gero (Ed.), *Artificial Intelligence in Design '02*, 2002, 285–303. Springer, Netherlands. https://doi.org/10.1007/978- 94-017-0795-4_14

Lee, B., Kwon, O., Lee, I., & Kim, J. (2017). Companionship with smart home devices: The impact of social connectedness and interaction types on perceived social support and companionship in smart homes. Computers in Human Behavior, 75, 922-934.

Lee, L. N., & Kim, M. J. (2020). A critical review of smart residential environments for older adults with a focus on pleasurable experience. Frontiers in psychology, 10, 3080.

Luor, T. T., Lu, H. P., Yu, H., & Lu, Y. (2015). Exploring the critical quality attributes and models of smart homes. *Maturitas*, *82*(4), 377-386.

Lutolf, R. (1992, November). Smart home concept and the integration of energy meters into a home based system. In Seventh international conference on metering apparatus and tariffs for electricity supply 1992 (pp. 277-278). IET.

Lenka, S., Parida, V., & Wincent, J. (2017). Digitalization capabilities as enablers of value co-creation in servitizing firms. Psychology & marketing, 34(1), 92-100.

Li, X., Wang, Z., Zheng, P., Peng, T., & Chen, C. H. (2020, August). A Closed-Loop Context-Aware Framework for Sustainable Smart PSS Development. In 2020 IEEE 16th International Conference on Automation Science and Engineering (CASE) (pp. 311-316). IEEE

Li, X., Chen, C. H., Zheng, P., Wang, Z., Jiang, Z., & Jiang, Z. (2020). A knowledge graph-aided concept–knowledge approach for evolutionary smart product–service system development. Journal of Mechanical Design, 142(10), 101403.

Li, X., Wang, Z., Chen, C. H., & Zheng, P. (2021). A data-driven reversible framework for achieving Sustainable Smart product-service systems. Journal of Cleaner Production, 279, 123618.

Liu, A. C., & Chou, T. Y. (2020). AN INTEGRATED TECHNOLOGY ACCEPTANCE MODEL TO APPROACH THE BEHAVIORAL INTENTION OF SMART HOME APPLIANCE. International Journal of Organizational Innovation, 13(2).

Liu, Z., Ming, X., Song, W., Qiu, S., & Qu, Y. (2018). A perspective on value co-creation-oriented framework for smart product-service system. Procedia Cirp, 73, 155-160.

TH-3294_196105005

Maass, W. (2007). A Tentative Design Model for Smart Products. 97. Mani, Z., & Chouk, I. (2017). Drivers of consumers' resistance to smart products. Journal of Marketing Management, 33(1-2), 76-97.

Mamonov, S., & Benbunan-Fich, R. (2021). Unlocking the smart home: exploring key factors affecting the smart lock adoption intention. Information Technology & People, 34(2), 835-861.

Mani, Z., & Chouk, I. (2017). Drivers of consumers' resistance to smart products. Journal of Marketing Management, 33(1-2), 76-97.

Marikyan, D., Papagiannidis, S., & Alamanos, E. (2019). A systematic review of the smart home literature: A user perspective. Technological Forecasting and Social Change, 138, 139-154.

Marikyan, D., Papagiannidis, S., & Alamanos, E. (2020). Cognitive dissonance in technology adoption: a study of smart home users. Information Systems Frontiers, 1-23.

Martin, S., Kelly, G., Kernohan, W. G., McCreight, B., & Nugent, C. (2008). Smart home technologies for health and social care support. Cochrane database of systematic reviews, (4).

Mashal, I., & Shuhaiber, A. (2018). What makes Jordanian residents buy smart home devices? A factorial investigation using PLS-SEM. Kybernetes, 48(8), 1681-1698.

Massimiliano Dibitonto, Katarzyna Leszczynska, and Federica Tazzi. 2019. The IoT Design Deck – A Co-Design method for the connected products. Retrieved February 6, 2019 from http://www.iotdesigndeck.com/

Massimiliano Dibitonto, Federica Tazzi, Katarzyna Leszczynska, and Carlo M. Medaglia. 2017. The IoT Design Deck: A Tool for the Co-design of Connected Products. In Advances in Usability and User Experience (Advances in Intelligent Systems and Computing), 217–227. https://doi.org/10.1007/978-3-319-60492- 3_21

Mayer, P., Volland, D., Thiesse, F., & Fleisch, E. (2011). User acceptance of'smart products': an empirical investigation.

Mulcahy, R., Letheren, K., McAndrew, R., Glavas, C., & Russell-Bennett, R. (2019). Are households ready to engage with smart home technology?. Journal of Marketing Management, 35(15-16), 1370-1400.

Mühlhäuser, M. (2007, November). Smart products: An introduction. In European Conference on Ambient Intelligence(pp. 158-164). Springer, Berlin, Heidelberg.

Masuda, Y., Sekimoto, M., Nambu, M., Higashi, Y., Fujimoto, T., Chihara, K., & Tamura, Y. (2005). An unconstrained monitoring system for home rehabilitation. IEEE engineering in medicine and biology magazine, 24(4), 43-47.

Miche, M., Schreiber, D., & Hartmann, M. (2009, November). Core services for smart products. In 3rd European Workshop on Smart Products (Vol. 19, pp. 1-4).

Matlabi, H., Parker, S. G., & McKee, K. (2012). Experiences of extra care housing residents aged fifty-five and over with home-based technology. Social Behavior and Personality: an

TH-3294_196105005

international journal, 40(2), 293-300.
Mayer, P., Volland, D., Thiesse, F., & Fleisch, E. (2011). User acceptance of'smart products': an empirical investigation.
Morris, M. E., Adair, B., Ozanne, E., Kurowski, W., Miller, K. J., Pearce, A. J., ... & Said, C. M. (2014). Smart technologies to enhance social connectedness in older people who live at home. Australasian journal on ageing, 33(3), 142-152.
M West, R Kraut, HE. Chew, I'd blush if I could: closing gender divides in digi- tal skills through education [Internet], Unesco-Equals 306 (2019) Available from: https://unesdoc.unesco.org/ark:/48223/pf0000367416.
Mynatt, E. D., Melenhorst, A. S., Fisk, A. D., & Rogers, W. A. (2004). Aware technologies for aging in place: understanding user needs and attitudes. IEEE Pervasive Computing, 3(2), 36-41.
Mourtzis, D., Fotia, S., Vlachou, E., & Koutoupes, A. (2018). A Lean PSS design and evaluation framework supported by KPI monitoring and context sensitivity tools. The International Journal of Advanced Manufacturing Technology, 94(5), 1623-1637.
Nathalie Stembert. 2017. Co-Creative Workshop Methodology Handbook. Zenodo. https://doi.org/10.5281/zenodo.1146240
Nathalie Stembert. 2019. Co-Creation & the IoT. Retrieved February 6, 2019 from http://www.stembertdesign.com/cocreation-and-the-iot.html
Nicholls, L., Strengers, Y., & Sadowski, J. (2020). Social impacts and control in the smart home. Nature Energy, 5(3), 180-182.
Nicoll, D. (1999). Taxonomy of information intensive products. The University of Edinburgh Management School: Edimburgh, Scotland, UK.
Nikou, S. (2019). Factors driving the adoption of smart home technology: An empirical assessment. Telematics and Informatics, 45, 101283.
Nguyen Ngoc, H., Lasa, G., & Iriarte, I. (2022). Human-centred design in industry 4.0: case study review and opportunities for future research. Journal of Intelligent Manufacturing, 33(1), 35-76.
Orwat, C., Graefe, A., & Faulwasser, T. (2008). Towards pervasive computing in health care-A literature review. BMC medical informatics and decision making, 8(1), 1-18.
Paetz, A. G., Becker, B., Fichtner, W., & Schmeck, H. (2011, October). Shifting electricity demand with smart home technologies-an experimental study on user acceptance. In 30th USAEE/IAEE North American conference online proceedings (Vol. 19, p. 20).
Paetz, A. G., Dütschke, E., & Fichtner, W. (2012). Smart homes as a means to sustainable energy consumption: A study of consumer perceptions. Journal of consumer policy, 35(1), 23-41.
Pal, D., Funilkul, S., Vanijja, V., & Papasratorn, B. (2018). Analyzing the elderly users' adoption of smart-home services. IEEE access, 6, 51238-51252.

TH-3294_196105005

Park, E., Kim, S., Kim, Y., & Kwon, S. J. (2018). Smart home services as the next mainstream of the ICT industry: determinants of the adoption of smart home services. Universal Access in the Information Society, 17, 175-190.

Papazoglou, M. P., Elgammal, A., & Krämer, B. J. (2020). Collaborative on-demand Product-Service Systems customization lifecycle. CIRP Journal of Manufacturing Science and Technology, 29, 205-219.

Park, E., Kim, S., Kim, Y., & Kwon, S. J. (2018). Smart home services as the next mainstream of the ICT industry: determinants of the adoption of smart home services. Universal Access in the Information Society, 17(1), 175-190.

Patel, S., Park, H., Bonato, P., Chan, L., & Rodgers, M. (2012). A review of wearable sensors and systems with application in rehabilitation. Journal of neuroengineering and rehabilitation, 9(1), 1-17.

Peek, S. T., Wouters, E. J., Van Hoof, J., Luijkx, K. G., Boeije, H. R., & Vrijhoef, H. J. (2014). Factors influencing acceptance of technology for aging in place: a systematic review. International journal of medical informatics, 83(4), 235-248.

Peetoom, K. K., Lexis, M. A., Joore, M., Dirksen, C. D., & De Witte, L. P. (2015). Literature review on monitoring technologies and their outcomes in independently living elderly people. Disability and Rehabilitation: Assistive Technology, 10(4), 271-294.

Peine, A., Rollwagen, I., & Neven, L. (2014). The rise of the "innosumer"-Rethinking older technology users. Technological forecasting and social change, 82, 199-214.

Percival, J., & Hanson, J. (2006). Big brother or brave new world? Telecare and its implications for older people's independence and social inclusion. Critical Social Policy, 26(4), 888-909.

Petersson, J. (2016). Technospatialities and telehealthcare: unfolding new spaces of visibility. Information, Communication & Society, 19(6), 824-842.

Pezzotta, G., Cavalieri, S., & Romero, D. (2017, June). Collaborative product-service systems engineering: Towards an active role of customers and stakeholders in value co-creation. In 2017 International Conference on Engineering, Technology and Innovation (ICE/ITMC) (pp. 1247-1254). IEEE.

Poole, S., & Simon, M. (1997). Technological trends, product design and the environment. Design Studies, 18(3), 237-248.

Pirola, F., Boucher, X., Wiesner, S., & Pezzotta, G. (2020). Digital technologies in product-service systems: a literature review and a research agenda. Computers in Industry, 123, 103301.

Prasetyo, D. A., & Suryanegara, M. (2020, June). Identifying Features for the Improvement of IoT Services: A Kano Model Approach. In *2020 International Conference on Electrical, Communication, and Computer Engineering (ICECCE)* (pp. 1-5). IEEE.

International Organization for Standardization. (2010). Ergonomics of Human-system

TH-3294_196105005

Interaction: Part 210: Human-centred Design for Interactive Systems. ISO.

Rahimpour, M., Lovell, N. H., Celler, B. G., & McCormick, J. (2008). Patients' perceptions of a home telecare system. International journal of medical informatics, 77(7), 486-498.

Rantz, M. J., Marek, K. D., Aud, M., Tyrer, H. W., Skubic, M., Demiris, G., & Hussam, A. (2005). A technology and nursing collaboration to help older adults age in place. Nursing Outlook, 53(1), 40-45.

Reeder, B., Meyer, E., Lazar, A., Chaudhuri, S., Thompson, H. J., & Demiris, G. (2013). Framing the evidence for health smart homes and home-based consumer health technologies as a public health intervention for independent aging: A systematic review. International journal of medical informatics, 82(7), 565-579.

Reinisch, C., Kofler, M., Iglesias, F., & Kastner, W. (2011). Thinkhome energy efficiency in future smart homes. EURASIP Journal on Embedded Systems, 2011, 1-18.

Rijsdijk, S. A., & Hultink, H. J. (2002). The impact of product smartness on consumer satisfaction through product advantage, complexity, and compatibility. In Tomorrow's product today-from imagination to implementation, PDMA Research conference proceedings 2002 (pp. 177-196). Product Development and Management Association.

Rijsdijk, S. A., & Hultink, E. J. (2009). How today's consumers perceive tomorrow's smart products. Journal of Product Innovation Management, 26(1), 24-42.

Rob van Kranenburg, Nathalie Stembert, M. Victoria Moreno, Antonio F. Skarmeta, Carmen López, Ignacio Elicegui, and Luis Sánchez. 2014. Co- creation as the Key to a Public, Thriving, Inclusive and Meaningful EU IoT. In Ubiquitous Computing and Ambient Intelligence. Personalisation and User Adapted Services (Lecture Notes in Computer Science), 396–403.

Saville-Smith, K. (2008). House owners and energy-retrofit, renovation and getting house performance. Report EN-6570 for Beacon Pathway Limited.

Schill, M., Godefroit-Winkel, D., Diallo, M. F., & Barbarossa, C. (2019). Consumers' intentions to purchase smart home objects: Do environmental issues matter?. Ecological Economics, 161, 176-185.

Simone Mora, Francesco Gianni, and Monica Divitini. 2017. Tiles: A Card- based Ideation Toolkit for the Internet of Things. In Proceedings of the 2017 Conference on Designing Interactive Systems (DIS '17), 587–598. https://doi.org/10.1145/3064663.3064699

Sovacool, B. K., Kester, J., Noel, L., & de Rubens, G. Z. (2018). The demographics of decarbonizing transport: The influence of gender, education, occupation, age, and household size on electric mobility preferences in the Nordic region. Global Environmental Change, 52, 86-100.

Sovacool, B. K., Del Rio, D. F., & Griffiths, S. (2021). Policy mixes for more sustainable smart

TH-3294_196105005

home technologies. Environmental Research Letters, 16(5), 054073.

Sovacool, B. K., & Del Rio, D. D. F. (2020). Smart home technologies in Europe: A critical review of concepts, benefits, risks and policies. Renewable and sustainable energy reviews, 120, 109663. 25. Bowes, A., Dawson, A., & Bell, D. (2012). Ethical implications of lifestyle monitoring data in ageing research. Information, Communication & Society, 15(1), 5-22.

Sakao, T., & Lindahl, M. (2009). Introduction to product/service-system design. London: Springer. 129. Carley, S., Evans, T. P., & Konisky, D. M. (2018). Adaptation, culture, and the energy transition in American coal country. Energy Research & Social Science, 37, 133-139.

Scott, F. (2007). Teaching homes to be green: smart homes and the environment. Green Alliance.

Seo, D. W., Kim, H., Kim, J. S., & Lee, J. Y. (2016). Hybrid reality-based user experience and evaluation of a context-aware smart home. Computers in Industry, 76, 11-23.

Shih, T. Y. (2013). Determinates of consumer adoption attitudes: an empirical study of smart home services. International Journal of E-Adoption (IJEA), 5(2), 40-56.

Shin, J., Park, Y., & Lee, D. (2018). Who will be smart home users? An analysis of adoption and diffusion of smart homes. Technological Forecasting and Social Change, 134, 246-253.

Shuhaiber, A., & Mashal, I. (2019). Understanding users' acceptance of smart homes. Technology in Society, 58, 101110.

Simone Mora, Francesco Gianni, and Monica Divitini. 2019. Tiles IoT Toolkit. Retrieved February 6, 2019 from http://tilestoolkit.io/

Snow, C. C. (2015). Organizing in the age of competition, cooperation, and collaboration. Journal of leadership & organizational studies, 22(4), 433-442.

Smith S. M., Ward T. B., and Schumacher J. S. Constraining effects of examples in a creative generation task. *Memory & Cognition*, 1993, 21(6), 837–845. https://doi.org/10.3758/BF03202751

Snyder, H. (2019). Literature review as a research methodology: An overview and guidelines. Journal of business research, 104, 333-339.

Steele, R., Lo, A., Secombe, C., & Wong, Y. K. (2009). Elderly persons' perception and acceptance of using wireless sensor networks to assist healthcare. International journal of medical informatics, 78(12), 788-801.

Stringer, M., Fitzpatrick, G., & Harris, E. (2006, May). Lessons for the future: Experiences with the installation and use of today's domestic sensors and technologies. In International Conference on Pervasive Computing (pp. 383-399). Springer, Berlin, Heidelberg.

Studio Dott. 2019. IoT Design Kit. Studio Dott. Retrieved April 25, 2019 from https://iotdesignkit.studiodott.be/

Sugihara, T., Fujinami, T., Phaal, R., & Ikawa, Y. (2015). A technology roadmap of assistive

TH-3294_196105005

technologies for dementia care in Japan. Dementia, 14(1), 80-103.

Tina Aspiala. 2014. Cards for brainstorming product design. Boing Boing. Retrieved January 14, 2019 from https://boingboing.net/2014/12/10/cards-for- brainstorming-produc.html

Tina Aspiala and Alexandra Deschamps-Sonsino. 2016. Know Cards: Learn. Play. Collect. Know Cards. Retrieved December 6, 2016 from http://know- cards.myshopify.com/

Tsetsi, E., & Rains, S. A. (2017). Smartphone Internet access and use: Extending the digital divide and usage gap. Mobile Media & Communication, 5(3), 239-255.

Toft, M. B., Schuitema, G., & Thøgersen, J. (2014). Responsible technology acceptance: Model development and application to consumer acceptance of Smart Grid technology. Applied Energy, 134, 392-400.

Ton DT, Wang W-TP. The U.S.Department of Energy Joins with Stake- holders in an R&D Plan [Internet]. Washington D.C; 2015. Available from: https://www.energy.gov/sites/prod/files/2016/06/f32/AMoreResilient Grid.pdf

Tukker, A., & Tischner, U. (2006). New business for old europe: product-service development. Competitiveness and Sustainability.

Tukker, A. (2004). Eight types of product–service system: eight ways to sustainability? Experiences from SusProNet. Business strategy and the environment, 13(4), 246-260.

Tukker, A., & Tischner, U. (Eds.). (2017). New business for old Europe: product-service development, competitiveness and sustainability. Routledge.

Turing, A. M., & Haugeland, J. (1950). Computing machinery and intelligence. The Turing Test: Verbal Behavior as the Hallmark of Intelligence, 29-56.

U.S. Department of Energy. Improving Grid Reliability and Resilience [Internet]. Washington D.C; 2013. Available from: https://www.energy.gov/sites/prod/files/2015/03/f20/GridWise Improving Electric Grid Reliability and Resilience Report June 2013.pdf

Van Dijck, J. (2020). Governing digital societies: Private platforms, public values. Computer Law & Security Review, 36, 105377.

Véliz, C., & Grunewald, P. (2018). Protecting data privacy is key to a smart energy future. Nature Energy, 3(9), 702-704.

Vilas, A. F., Redondo, R. P. D., Arias, J. J. P., Cabrer, M. R., Solla, A. G., & Garcı, J. (2010). Context- aware personalization services for a residential gateway based on the OSGi platform. Expert Systems with Applications, 37(9), 6538-6546.

Valencia, A., Mugge, R., Schoormans, J., & Schifferstein, H. (2015). The design of smart product-service systems (PSSs): An exploration of design characteristics. International Journal of Design, 9(1).

Van Ooijen, I., & Vrabec, H. U. (2019). Does the GDPR enhance consumers' control over personal data? An analysis from a behavioural perspective. Journal of consumer policy,

TH-3294_196105005

42(1), 91-107.

Wang, X., McGill, T. J., & Klobas, J. E. (2018). I want it anyway: Consumer perceptions of smart home devices. Journal of Computer Information Systems.

Wang, Z., Zheng, P., Chen, C. H., & Khoo, L. P. (2019). A survey of requirements management in smart product-service systems. In Transdisciplinary Engineering for Complex Socio-technical Systems (pp. 613-622). IOS Press.

Wang, Z., Li, X., Chen, C. H., & Khoo, L. P. (2020, July). Evaluating smart PSS solutions with context-awareness in usage phase. In 27th ISPE International Conference on Transdisciplinary Engineering (TE) Warsaw, Poland.

Wetter-Edman, K., Sangiorgi, D., Edvardsson, B., Holmlid, S., Grönroos, C., & Mattelmäki, T. (2014). Design for value co-creation: Exploring synergies between design for service and service logic. Service Science, 6(2), 106-121.

Walsh, K., & Callan, A. (2011). Perceptions, preferences, and acceptance of information and communication technologies in older-adult community care settings in Ireland: A case-study and ranked-care program analysis. Ageing International, 36(1), 102-122.

Watanabe, K., Okuma, T., & Takenaka, T. (2020). Evolutionary design framework for Smart PSS: Service engineering approach. Advanced Engineering Informatics, 45, 101119.

West, S., Gaiardelli, P., Resta, B., & Kujawski, D. (2018). Co-creation of value in Product-Service Systems through transforming data into knowledge. IFAC-PapersOnLine, 51(11), 1323-1328. 146.

Wood K. L., Linsey J. S., and Markman A. B. Modality and representation in analogy. Artificial Intelligence for Engineering Design, *Analysis and Manufacturing: AIEDAM* 22(2), 2008, 85–100. https://doi.org/10.1017/S0890060408000061

Wu, C. L., & Fu, L. C. (2011). Design and realization of a framework for human-system interaction in smart homes. IEEE Transactions on Systems, Man, and Cybernetics-Part A: Systems and Humans, 42(1), 15-31.

Wuest, T., & Wellsandt, S. (2016). Design and Development of Product Service Systems (PSS)-Impact on Product Lifecycle Perspective. Procedia Technology, 26, 152-161.

Wilson, C., Hargreaves, T., & Hauxwell-Baldwin, R. (2017). Benefits and risks of smart home technologies. Energy Policy, 103, 72-83.

International Organization for Standardization. (2010). Ergonomics of Human-system Interaction: Part 210: Human-centred Design for Interactive Systems. ISO.

Yamazaki, T. (2006, November). Beyond the smart home. In 2006 International Conference on Hybrid Information Technology (Vol. 2, pp. 350-355). IEEE. 148.

Yang, H., Lee, H., & Zo, H. (2017). User acceptance of smart home services: An extension of the theory of planned behavior. Industrial Management & Data Systems.

TH-3294_196105005

Yang, H., Lee, W., & Lee, H. (2018). IoT smart home adoption: the importance of proper level automation. Journal of Sensors, 2018.

Zheng, P., Yu, S., Wang, Y., Zhong, R. Y., & Xu, X. (2017). User-experience based product development for mass personalization: a case study. Procedia CIRP, 63, 2-7.

Zheng, P., Liu, Y., Tao, F., Wang, Z., & Chen, C. H. (2019). Smart product-service systems solution design via hybrid crowd sensing approach. IEEE Access, 7, 128463-128473.

Zheng, P., Wang, Z., Chen, C. H., & Khoo, L. P. (2019). A survey of smart product-service systems: Key aspects, challenges and future perspectives. Advanced engineering informatics, 42, 100973.

Zhou, T., Chen, Z., Cao, Y., Miao, R., & Ming, X. (2022). An integrated framework of user experience-oriented smart service requirement analysis for smart product service system development. Advanced Engineering Informatics, 51, 101458.

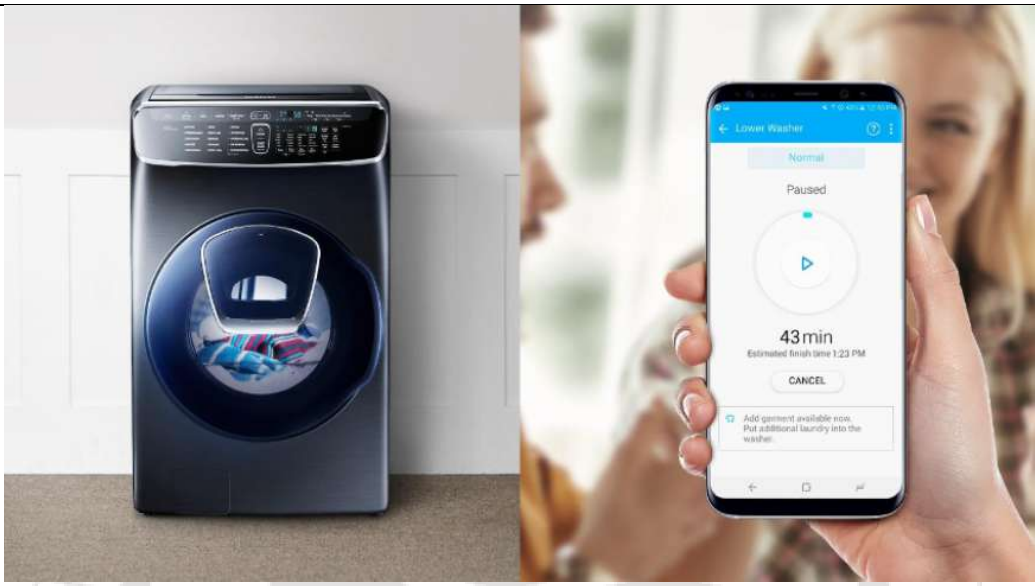
Zhou, B., Li, W., Chan, K. W., Cao, Y., Kuang, Y., Liu, X., & Wang, X. (2016). Smart home energy management systems: Concept, configurations, and scheduling strategies. Renewable and Sustainable Energy Reviews, 61, 30-40.

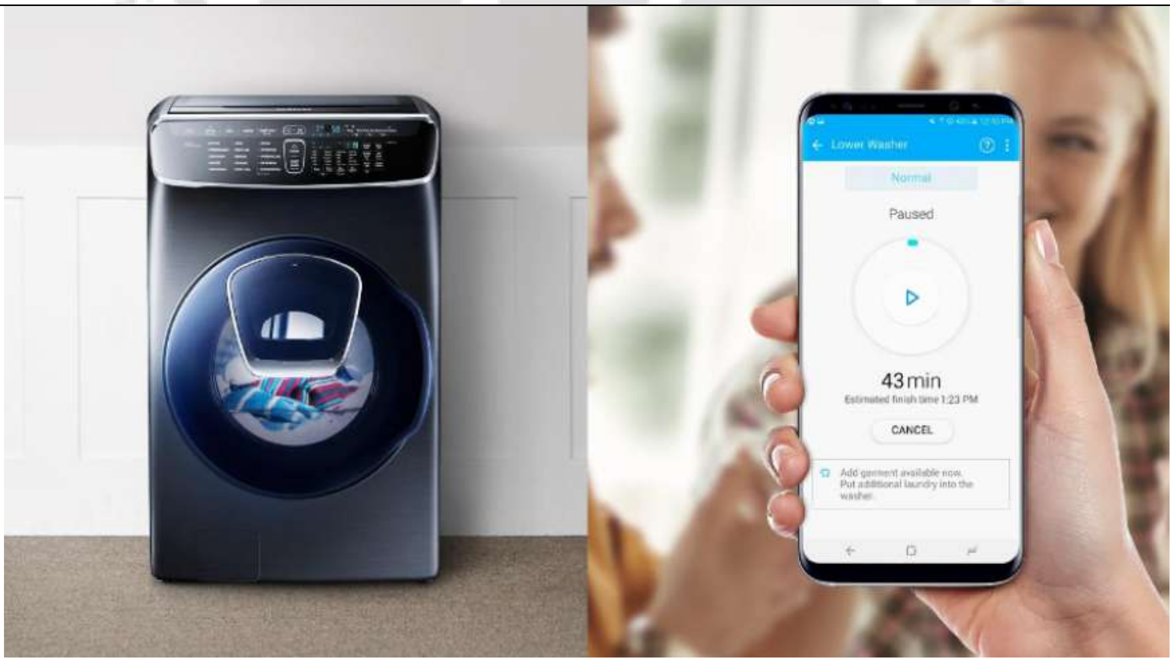
TH-3294_196105005

Appendices

Appendix – A. Kano Questionnaire

C1: Comfort

Example 1.1: SH-PSS helps you in a daily task like washing clothes, dishes, cooking etc.

Functional Question: If smart products help you in daily tasks like washing clothes, dishes, cooking etc., how would you feel?
Dysfunctional Question: If smart products **do not** help you in daily tasks like washing clothes, dishes, cooking etc., how would you feel?

Example 1.2: SH-PSS allows you to manage your home even if you are outside.

Functional Question: If smart products allow you to manage your home even if you're outside, how would you feel?
Dysfunctional Question: If smart products do not allow you to manage your home even if you're outside, how would you feel?

TH-3294_196105005

C2: Monitor

Example 2.1: SH-PSS allows you to analyze your health data like blood pressure, heart rate, ECG etc. and act.

Functional Question: If smart products allow you to analyze your health data like blood pressure, heart rate, ECG etc. and take action, how would you feel?

Dysfunctional Question: If smart products do not allow you to analyze your health data like blood pressure, heart rate, ECG etc. and take action, how would you feel?

Example 2.2: SH-PSS allow you to monitor air quality parameters like PM 2.5, NO2, VOC, relative humidity, ventilation and act.

Functional Question: If smart products allow you to monitor air quality parameters like PM2.5, NO2, VOC, Relative Humidity, Ventilation and take action, how would you feel?

Dysfunctional Question: If smart products do not allow you to monitor air quality parameters like PM2.5, NO2, VOC, Relative Humidity, Ventilation and take action, how would you feel?

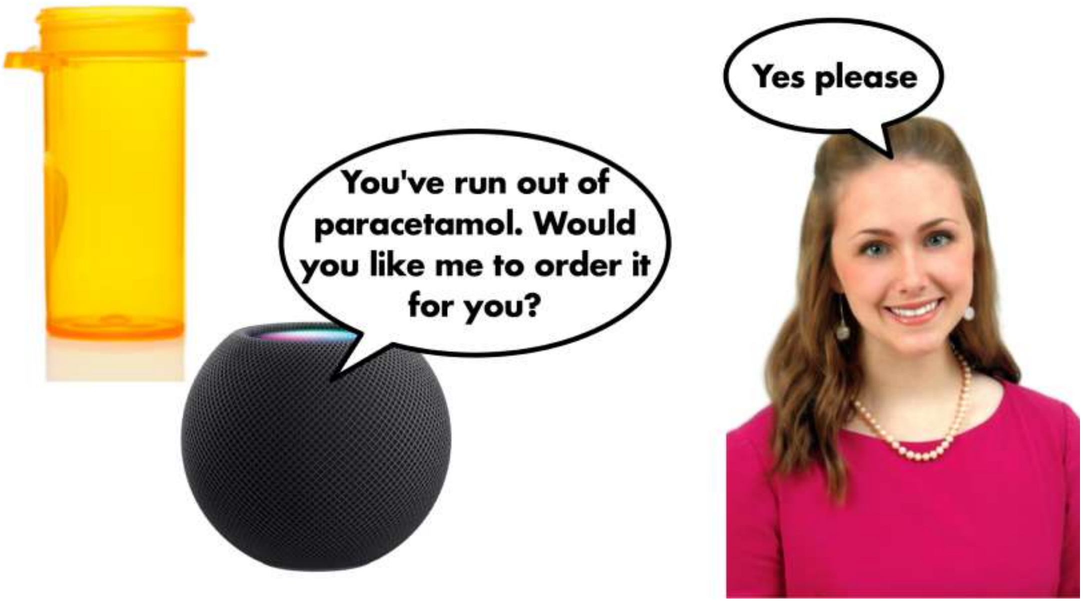
C3: Health therapy

Example 3.1: SH-PSS detects potential injuries or diseases and provide suggestions.

Functional Question: If smart products detect injuries or potential diseases and provide suggestions like shown above, how would you feel?

Dysfunctional Question: If smart products do not detect injuries or potential diseases and provide suggestions like shown above, how would you feel?

Example 3.2: SH-PSS smoke detector ringing alarm as well as showing a warning on the mobile app for people with hearing issues.



Functional Question: If smart products automatically order medicines when the stock runs out, how would you feel?

Dysfunctional Question: If smart products do not automatically order medicines when the stock runs out, how would you feel?

C4: Support

Example 4.1: SH-PSS smoke detector ringing alarm as well as showing a warning on the mobile app for people with hearing issues.

Functional Question: If smart products help people with hearing issues using visual feedback like shown above, how would you feel?

Dysfunctional Question: If smart products do not help people with hearing issues using visual feedback like shown above, how would you feel?

Example 4.2: Smart glasses guiding the way for the visual disable or blind person.

Functional Question: If smart products help people with visual disabilities like shown above, how would you feel?

Dysfunctional Question: If smart products do not help people with visual disabilities like shown above, how would you feel?

C5: Consultancy

Example 5.1: SH-PSS notifying you about real time information about wash cycle status.

Functional Question: If smart products notify you about wash cycle status like shown above, how would you feel?

Dysfunctional Question: If smart products do not notify you about wash cycle status like shown above, how would you feel?

Example 5.2: SH-PSS suggesting how to avoid extreme weather conditions.

Functional Question: If smart products suggest you on how to avoid extreme weather conditions like shown above, how would you feel?

Dysfunctional Question: If smart products do not suggest you on how to avoid extreme weather conditions like shown above, how would you feel?

C6: Independent

Example 6.1: SH-PSS fridge detects that there is no milk, so it automatically orders milk

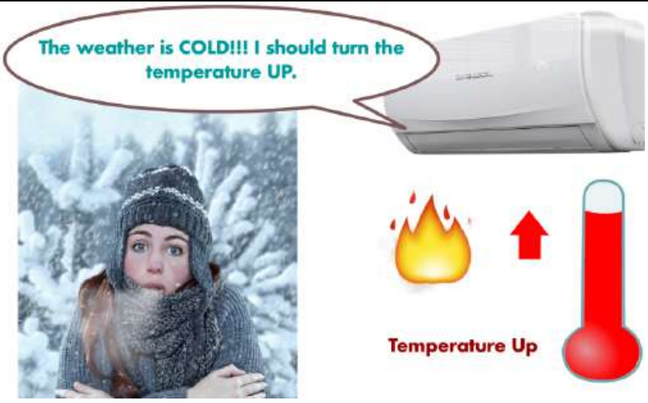
Functional Question: If smart products help you with stocking of the food like shown above, how would you feel?
Dysfunctional Question: If smart products do not help you with stocking of the food like shown above, how would you feel?

Example 6.2: SH-PSS vacuum cleaner avoid obstruction on their own while completing cleaning task

Functional Question: If smart products avoid obstructions on their own while completing tasks like shown above, how would you feel?
Dysfunctional Question: If smart products do not avoid obstructions on their own while completing tasks like shown above, how would you feel?

C7: Adaptive

Example 7.1: SH-PSS air conditioner reacting to the hot weather and turning the temperature down; and vice versa



Functional Question: If smart products automatically adapt to its environment and change temperature like shown above, how would you feel?

Dysfunctional Question: If smart products do not automatically adapt to its environment, how would you feel?

Example 7.2: SH-PSS lights automatically adapt to its environment and adjust lighting

Functional Question: If smart products automatically adapt to its environment and adjust lighting like shown above, how would you feel?

Dysfunctional Question: If smart products do not automatically adapt to its environment, how would you feel?

C8: Reactive

Example 8.1: Smart Watch reminding the runner to take some rest as their heart rate is up.

TH-3294_196105005

Functional Question: If smart products detect a change in your body and react to it like shown above, how would you feel?

Dysfunctional Question: If smart products do not detect a change in your body and react to it like shown above, how would you feel?

Example 8.2: The smart locker recognizes the owner's voice and opens itself.

Functional Question: If smart products are able to analyze the situation and react accordingly like shown above, how would you feel?

Dysfunctional Question: If smart products are unable to analyze the situation and react accordingly like shown above, how would you feel?

C9: Multi-functional

Example 9.1: Smart Fridge that can play music, show the weather, show recipes, order food, show the items inside the fridge and a lot more.

Functional Question: If smart products do a lot of things along with its main purpose like shown above, how would you feel?
Dysfunctional Question: If smart products do not do a lot of things along with its main purpose like shown above, how would you feel?

Example 9.2: SH-PSS television giving updates of surrounding and who is on door apart from their main purpose.

Functional Question: If smart products give updates of the surrounding apart from their main purpose like shown above, how would you feel?
Dysfunctional Question: If smart products do not give updates of the surrounding apart from their main purpose like shown above, how would you feel?

C10: Ability to cooperate

Example 10.1: Smartphone automatically sharing the Wi-Fi password with the smart speaker

Functional Question: If smart products cooperate with each other like shown above, how would you feel?

Dysfunctional Question: If smart products do not cooperate with each other like shown above, how would you feel?

Example 10.2: SH-PSS cooperate with each other to provide a personalized experience

Functional Question: If smart products cooperate with each other to provide a personalized experience like shown above, how would you feel?

Dysfunctional Question: If smart products do not cooperate with each other to provide a personalized experience like shown above, how would you feel?

TH-3294_196105005

C11: Humanlike interaction

Example 11.1: Alexa knows that the resident is angry, so she tries to talk calmly

Functional Question: If smart products understand your mood and react accordingly like shown above, how would you feel?
Dysfunctional Question: If smart products do not understand your mood and react accordingly like shown above, how would you feel?

Example 11.2: SH-PSS communicating with native accent

Functional Question: If smart product have your native accent like shown above, how would you feel?
Dysfunctional Question: If smart product does not have your native accent like shown above, how would you feel?

TH-3294_196105005

C12: Personality

Example 12.1: Smart Thermostat being funny and joking about the weather

Functional Question: If smart products have their own personality like shown above, how would you feel?
Dysfunctional Question: If smart products do not have their own personality like shown above, how would you feel?

Example 12.2: SH-PSS changing its mood based on the status of product

Functional Question: If smart products changed its mood based on the status like shown above, how would you feel?
Dysfunctional Question: If smart products do not change its mood based on the status like shown

above, how would you feel?

C13: Context Awareness

Example 13.1: SH-PSS are aware about their surrounding; e.g.: smart home door welcomes the owner and alerts when it detects unauthorized entry.

Functional Question: If smart products are aware about their surroundings like shown above, how would you feel?

Dysfunctional Question: If smart products are not aware about their surroundings like shown above, how would you feel?

Example 13.2: SH-PSS automatically perform a function based on their surroundings; e.g.: garage door opens up when it detects car coming.

Functional Question: If smart products automatically perform a function based on their surroundings like shown above, how would you feel?

Dysfunctional Question: If smart products do not automatically perform a function based on their surroundings like shown above, how would you feel?

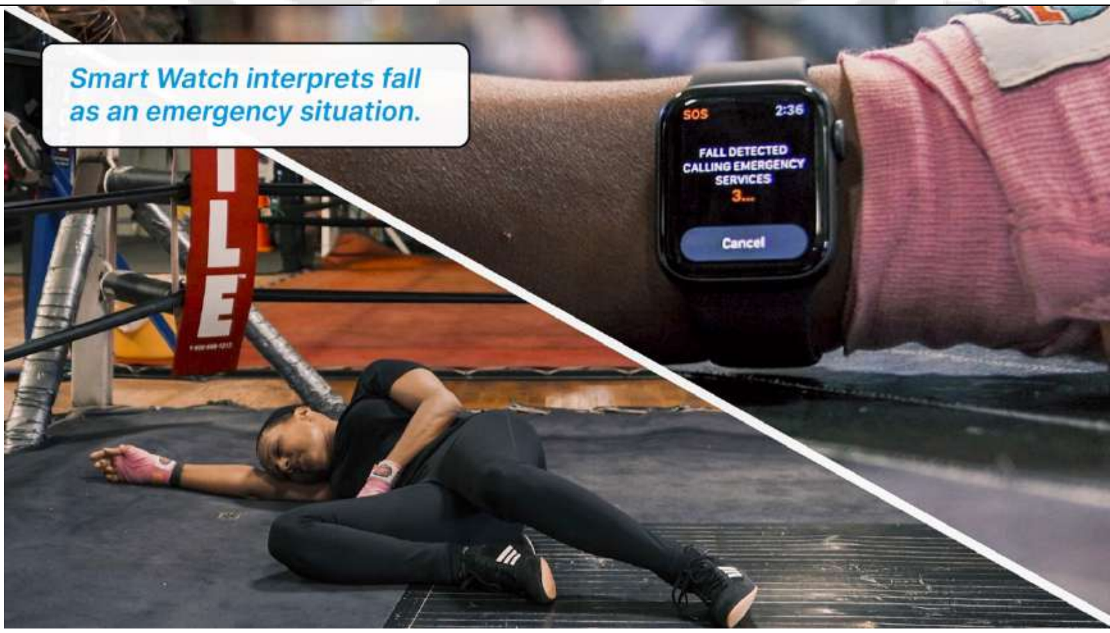
C14: Interpretation

Example 14.1: SH-PSS are able to understand local languages.

Functional Question: If smart products are able to understand local languages like shown above, how would you feel?

Dysfunctional Question: If smart products are not able to understand local languages like shown above, how would you feel?

Example 14.2: SH-PSS are able to interpret accidents as emergency situations; e.g.: smart watch interprets fall as an emergency situation.

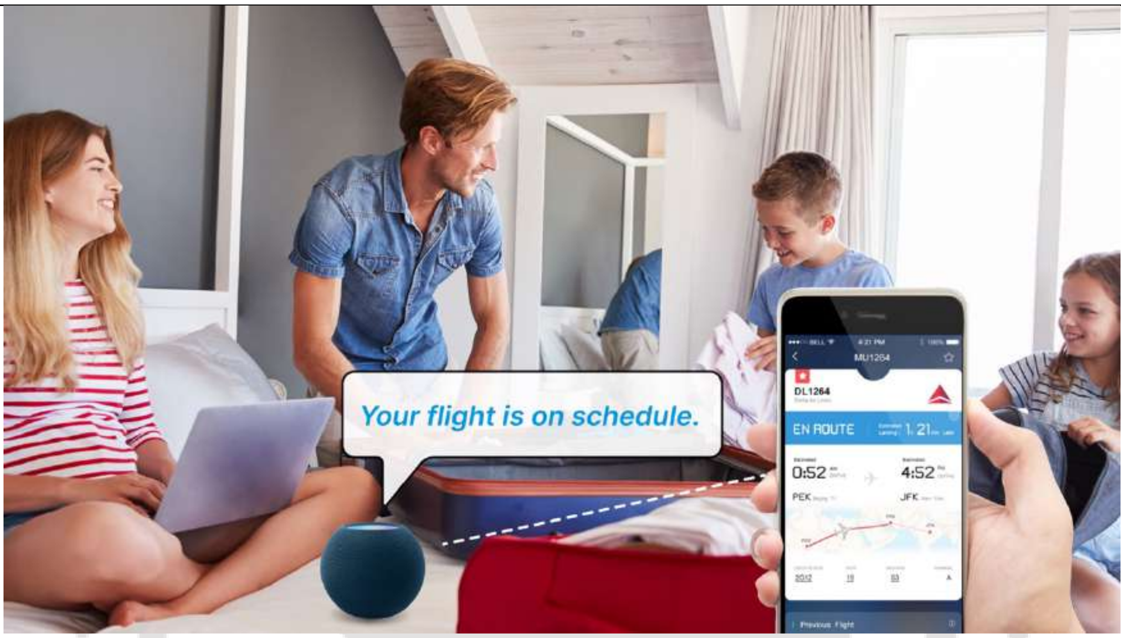


Functional Question: If smart products are able to interpret accidents as emergency situations like shown above, how would you feel?

Dysfunctional Question: If smart products are unable to interpret accidents as emergency situations like shown above, how would you feel?

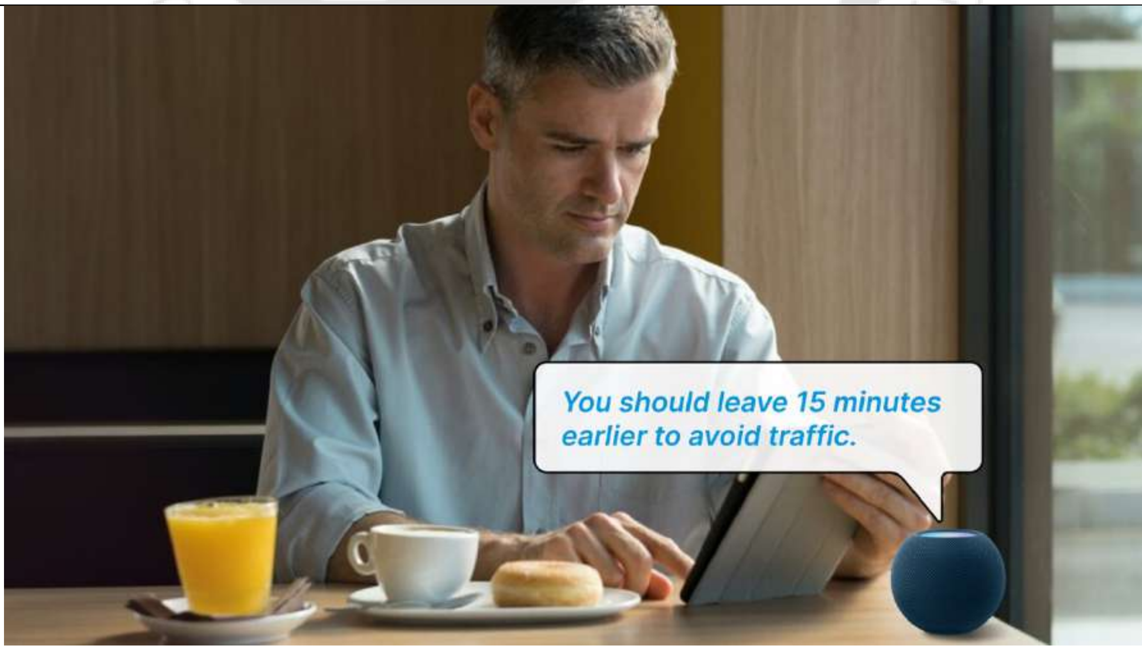
C15: Proactive

Example 15.1: SH-PSS notify you about certain updates that could be important to you like flight schedule.



Functional Question: If smart products notify you about certain updates that could be important to you like shown above, how would you feel?
Dysfunctional Question: If smart products do not notify you about certain updates that could be important to you like shown above, how would you feel?

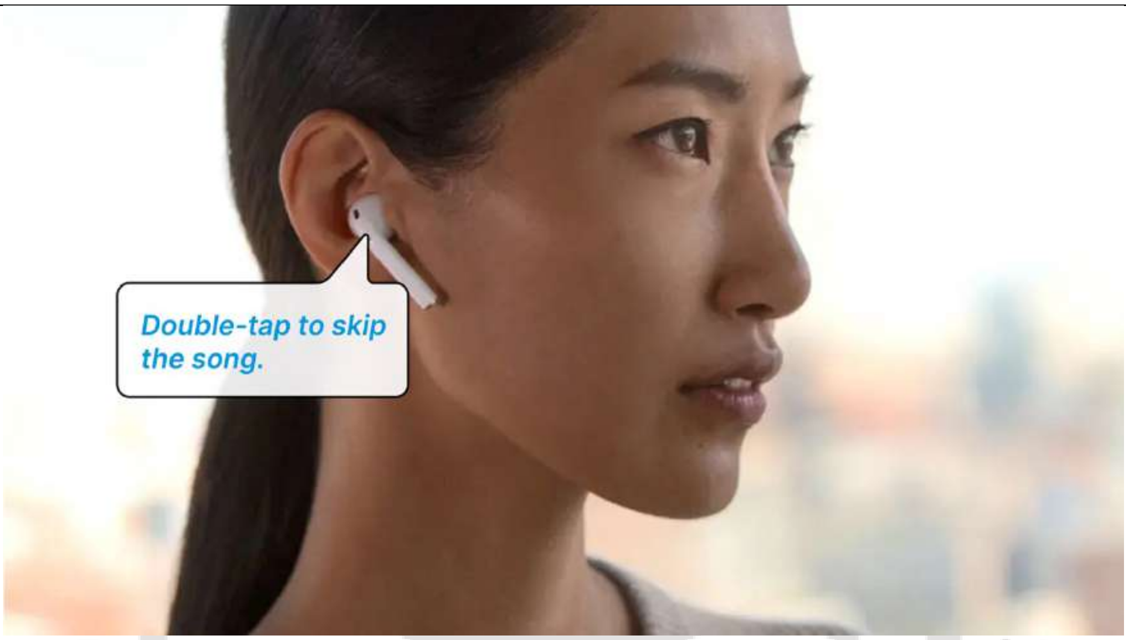
Example 15.2: SH-PSS provide you with suggestions on their own; e.g.: smart speaker suggest user to leave early for work to avoid traffic.



Functional Question: If smart products provide you with suggestions on their own like shown above, how would you feel?
Dysfunctional Question: If smart products do not provide you with suggestions on their own like shown above, how would you feel?

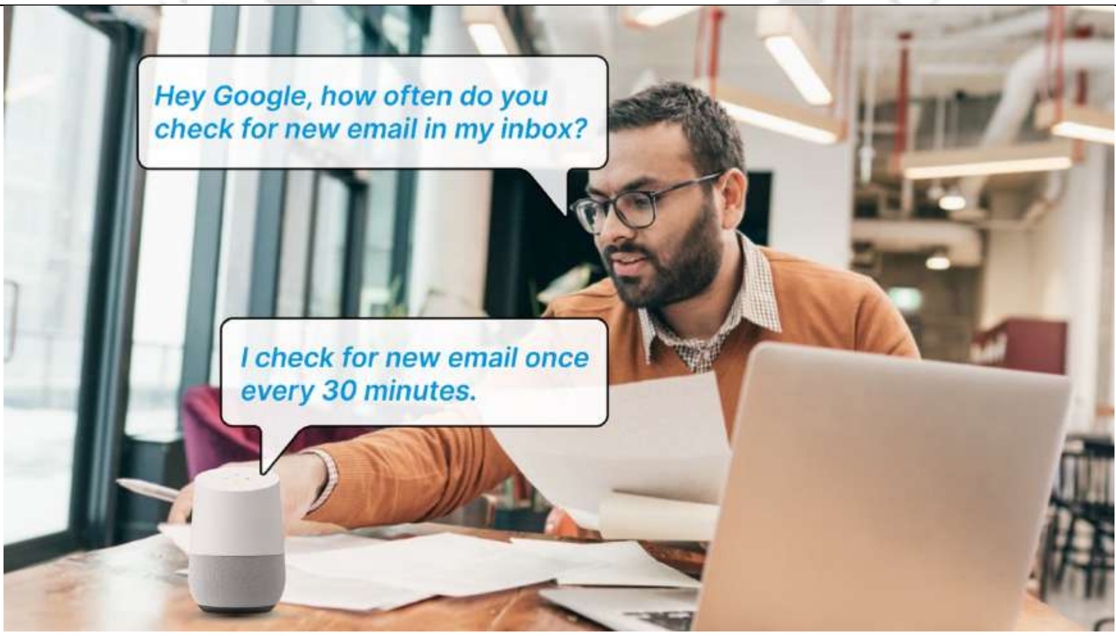
C16: Self-Description

Example 16.1: SH-PSS guide you through their usage.



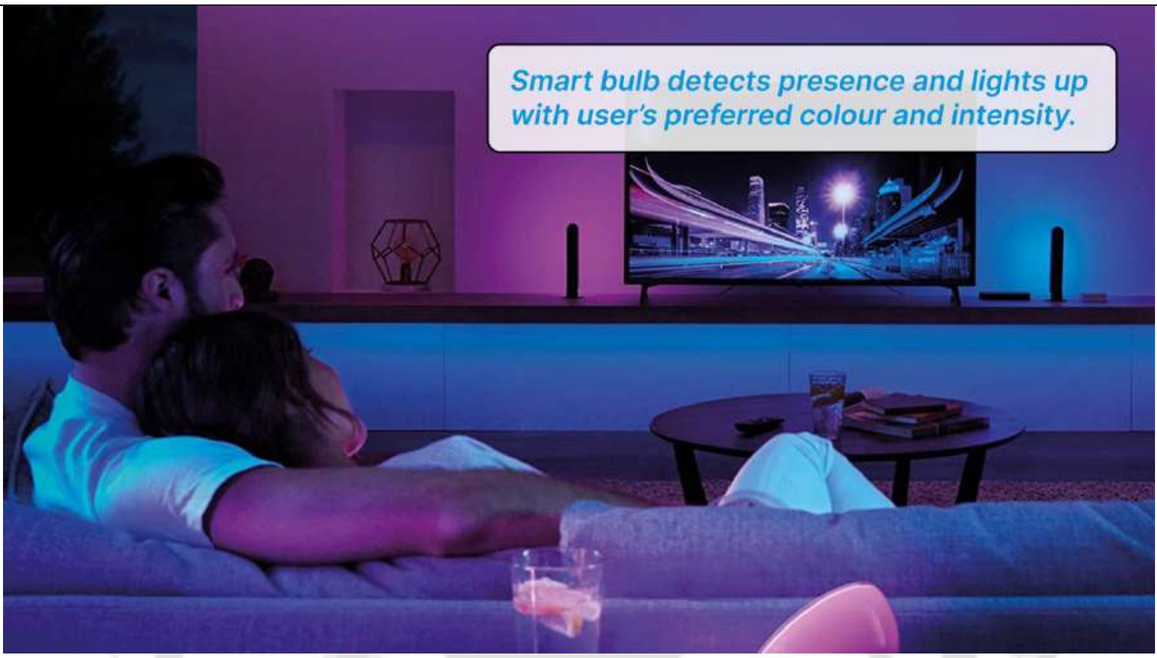
Functional Question: If smart products guide you through their usage like shown above, how would you feel?
Dysfunctional Question: If smart products do not guide you through their usage like shown above, how would you feel?

Example 16.2: SH-PSS provide you with information on how they function; e.g.: user ask how often smart speaker sync email to smart speaker.



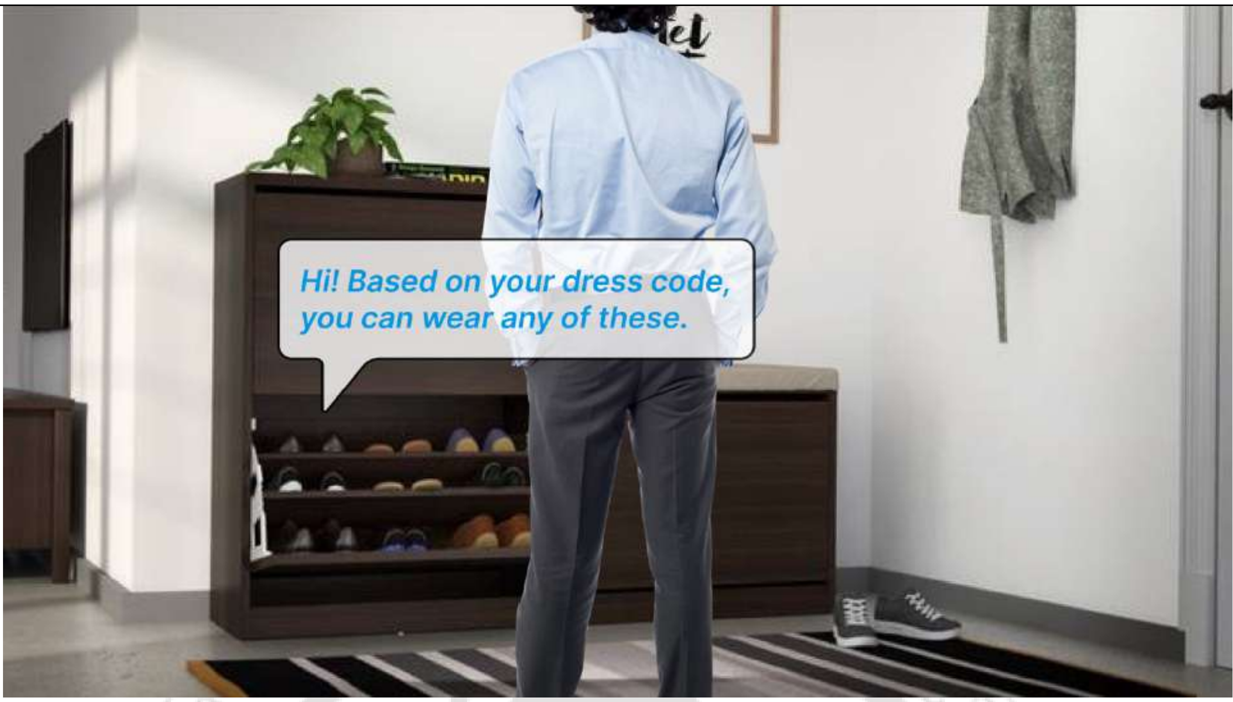
Functional Question: If smart products provide you with information on how they function like shown above, how would you feel?
Dysfunctional Question: If smart products do not provide you with information on how they function like shown above, how would you feel?

C17: Personalization

Example 17.1: If user is able to customize your smart products.

Functional Question: If you are able to customize your smart products like shown above, how would you feel?
Dysfunctional Question: If you are unable to customize your smart products like shown above, how would you feel?

Example 17.2: SH-PSS recommend you apparel based on your choices; e.g.: smart shoe rack recommends footwear.

TH-3294_196105005



Functional Question: If smart products recommend you apparel based on your choices like shown above, how would you feel?

Dysfunctional Question: If smart products do not recommend you apparel based on your choices like shown above, how would you feel?

C18: User friendly interaction

Example 18.1: SH-PSS greets you and have conversation with you.

Functional Question: If smart products greets you and have conversation with you like shown above, how would you feel?

Dysfunctional Question: If smart products do not greet you and have conversation with you like shown above, how would you feel?

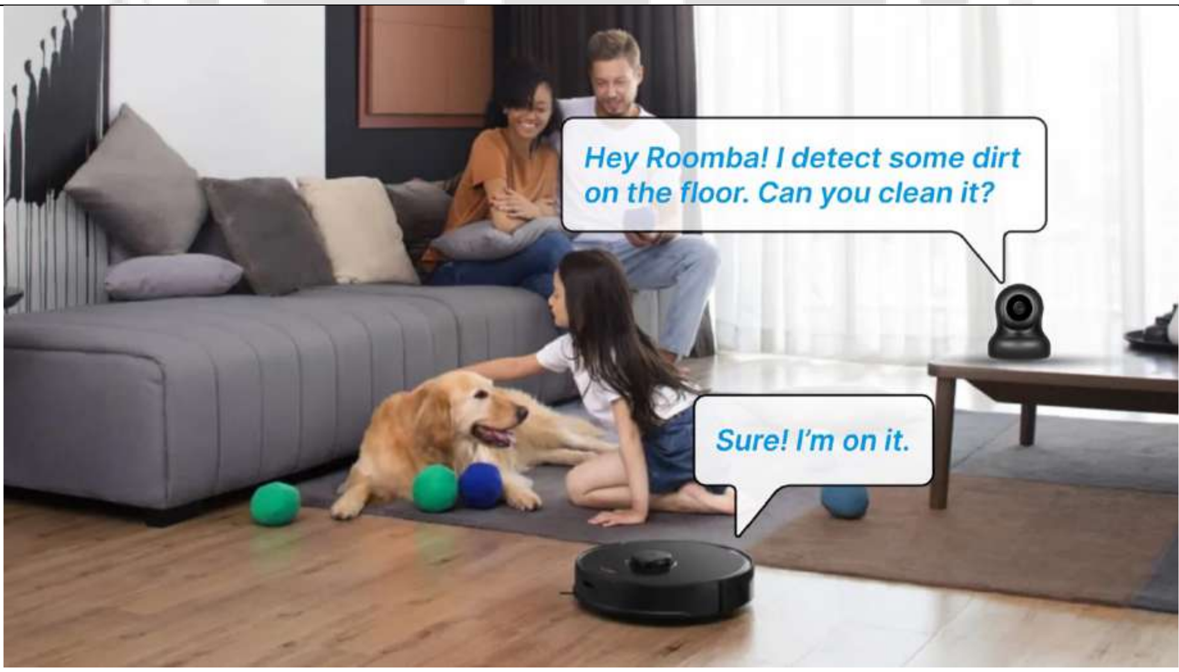
Example 18.2: SH-PSS detect the time and set mood accordingly; e.g.: smart speaker automatically plays ambient music when it is dinner time.

Functional Question: If smart products detect the time and set mood accordingly like shown above, how would you feel?

Dysfunctional Question: If smart products do not detect the time and set mood accordingly like shown above, how would you feel?

C19: Communication

Example 19.1: SH-PSS communicate with each other to solve problems; e.g.: smart camera detects dust on floor and tells smart vacuum cleaner to clean.



Functional Question: If smart products communicate with each other to solve problems like shown above, how would you feel?

Dysfunctional Question: If smart products do not communicate with each other to solve problems like shown above, how would you feel?

Example 19.2: SH-PSS communicate to get updates from each other.

Functional Question: If smart products communicate to get updates from each other like shown above, how would you feel?

Dysfunctional Question: If smart products do not communicate to get updates from each other like shown above, how would you feel?

C20: Co-operation

Example 20.1: SH-PSS cooperate with each other like smart speaker shares WIFI password to new devices by voice confirmation.

Functional Question: If smart products cooperate with each other like shown above, how would you feel?

Dysfunctional Question: If smart products do not cooperate with each other like shown above, how would you feel?

Example 20.2: SH-PSS works together to give user best experience; e.g.: smart headphones get connected with multiple device and switch between them seamlessly.

Functional Question: If smart products works together to give user best experience like shown above, how would you feel?

Dysfunctional Question: If smart products do not work together to give user best experience like shown above, how would you feel?

C21: Openness

Example 21.1: SH-PSS transfer Movies, TV shows or music with each other seamlessly.

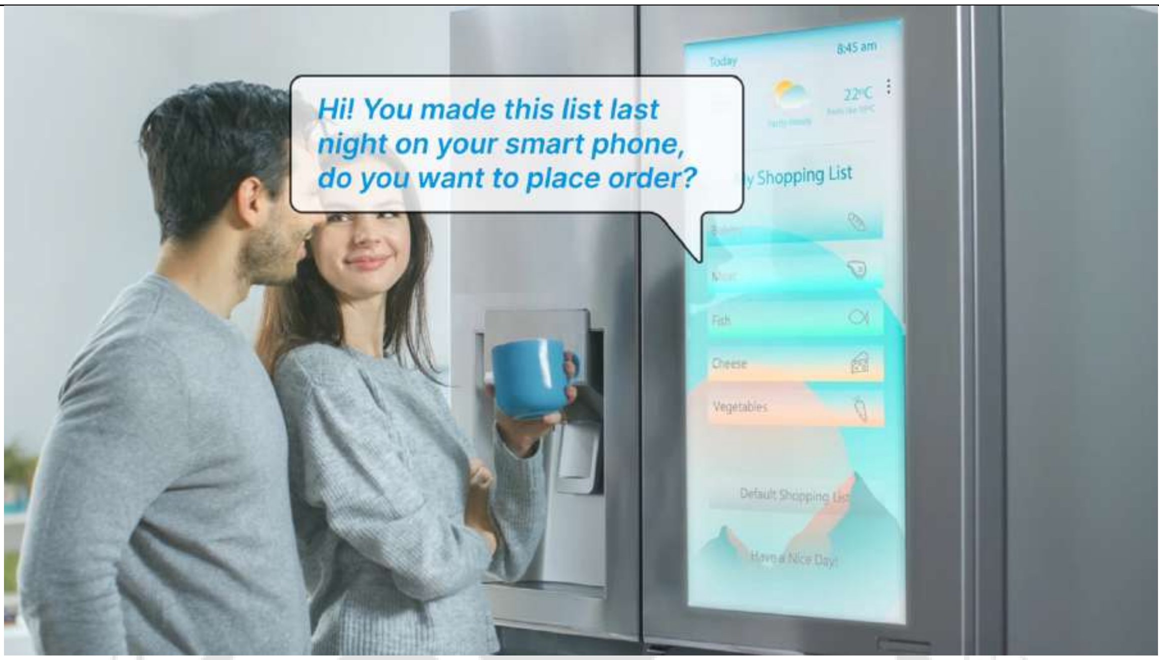
Functional Question: If smart products transfer Movies, TV shows or music with each other seamlessly like shown above, how would you feel?

Dysfunctional Question: If smart products do not transfer Movies, TV shows or music with each

TH-3294_196105005

other seamlessly like shown above, how would you feel?

Example 21.2: SH-PSS share your open data with other smart products.

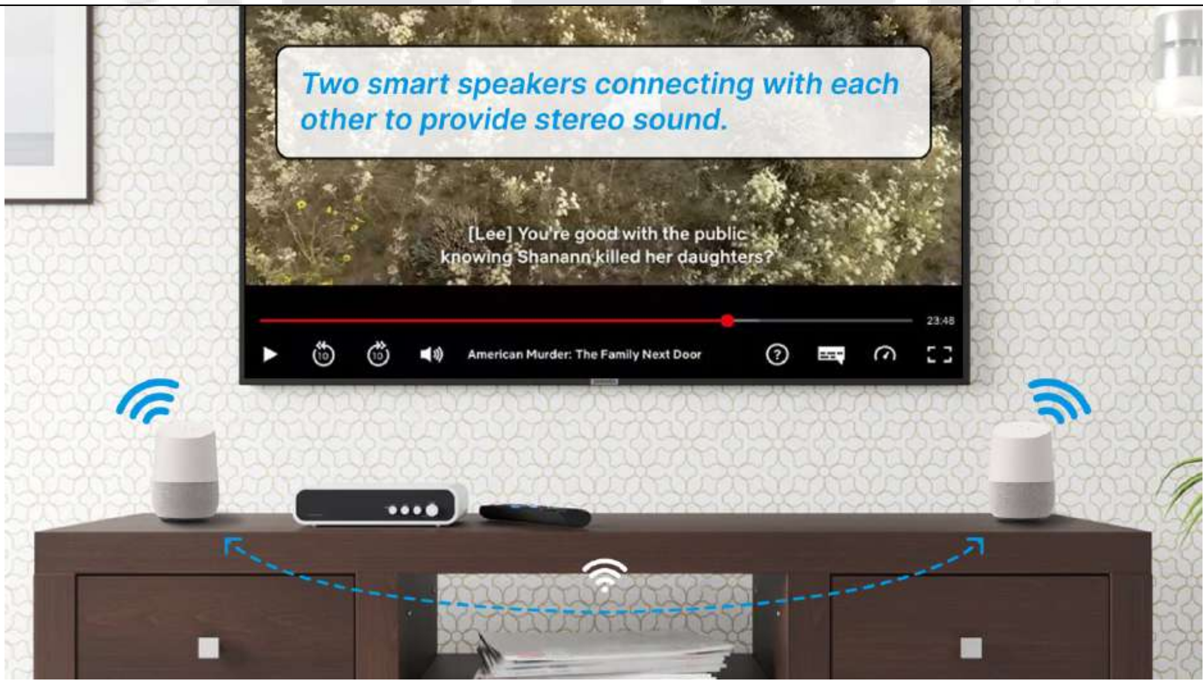


Functional Question: If smart products share your open data with other smart products like shown above, How would you feel?

Dysfunctional Question: If smart products do not share your open data with other smart products like shown above, how would you feel?

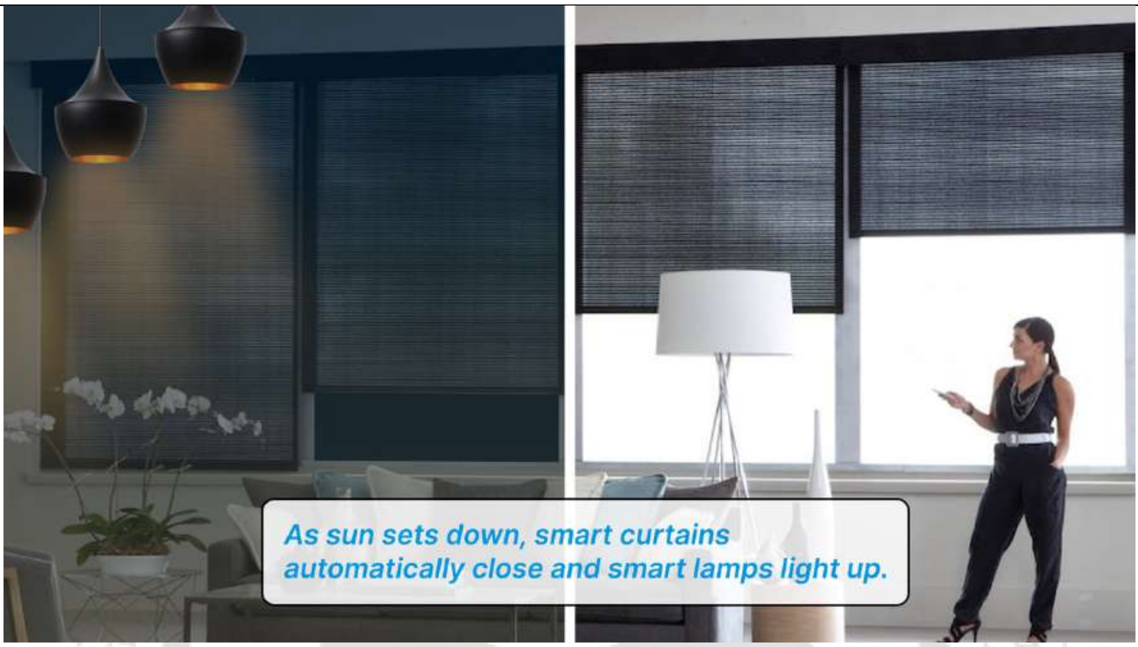
C22: Collaboration

Example 22.1: SH-PSS collaborate with each other to provide extra features; e.g.: two smart speakers connected with each other to provide stereo sound.



Functional Question: If smart products collaborate with each other to provide extra features like shown above, how would you feel?

Dysfunctional Question: If smart products do not collaborate with each other to provide extra features like shown above, how would you feel?

Example 22.2: SH-PSS collaborate with each other to provide extra comfort; e.g.: smart curtains automatically close after sunset and smart lamps lights up.

Functional Question: If smart products collaborate with each other to provide extra comfort like shown above, how would you feel?
Dysfunctional Question: If smart products do not collaborate with each other to provide extra comfort like shown above, how would you feel?

Appendix – B. Evaluation Sheet

	Extremely Unlikely	Unlikely	More or less Unlikely	Neutral	More or less likely	Likely	Extremely llikely
Ease of Use	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Usefulness	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Context Awareness	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Multi-functional	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Ability to Co-operate	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Personalization	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Openness	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7
Service-Dominant Design	☐ 1	☐ 2	☐ 3	☐ 4	☐ 5	☐ 6	☐ 7

ute of Technology

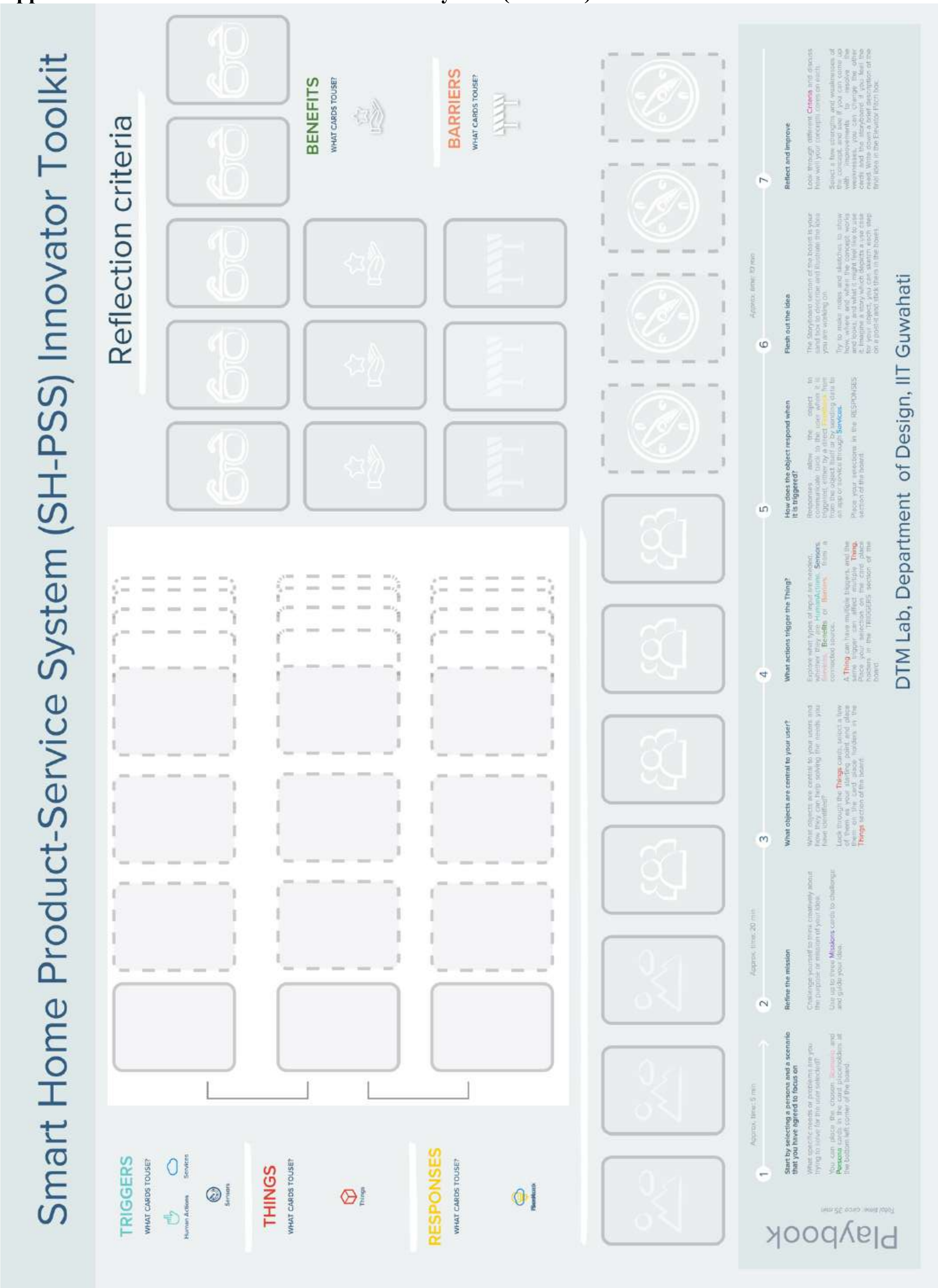
TH-3294_196105005

Appendix – C. Details of Expert Evaluators

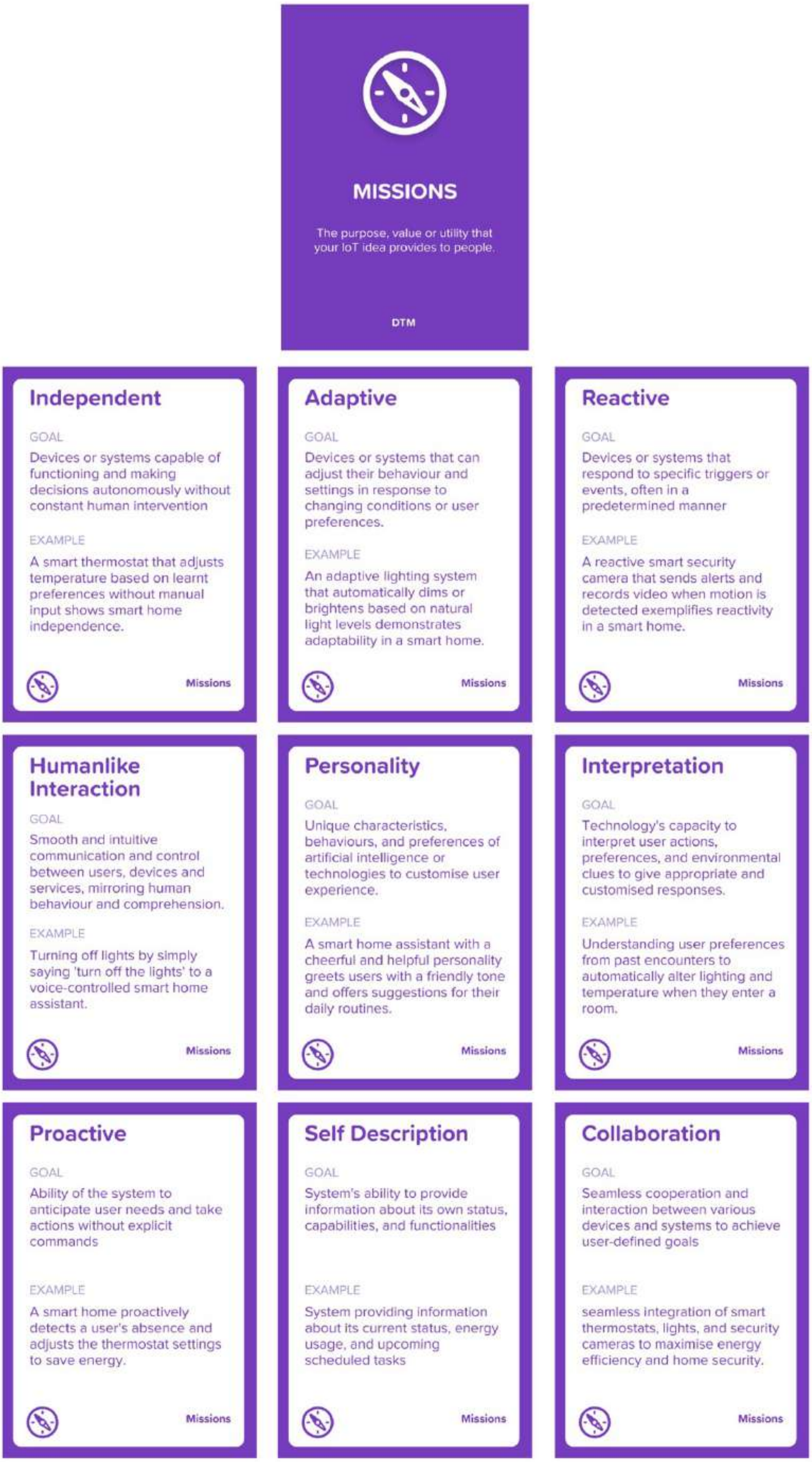
Name	Age (years)	Gender	Education Qualification	Current Organization Name and Location	Total Experience in Design Industry/ Academic (years)
Ashish Bhojane	42	M	MBA	Evolent Health	19
Yogesh S G	38	M	MBA	Shapoorji Pallonji	14
Pankaj Kuli	33	M	M.Des	Titan Company Ltd.	8
Sachin Adusumilli	32	M	M.Des	Sahasra Design House	7
Ankita Khante	29	F	M.Des	Samsung	6
Shreya Tembe	29	F	B.Tech (ECE)	Jio	6

TH-3294_196105005

Appendix – D. Smart Home Product-Service-System (SH-PSS) Innovator Toolkit

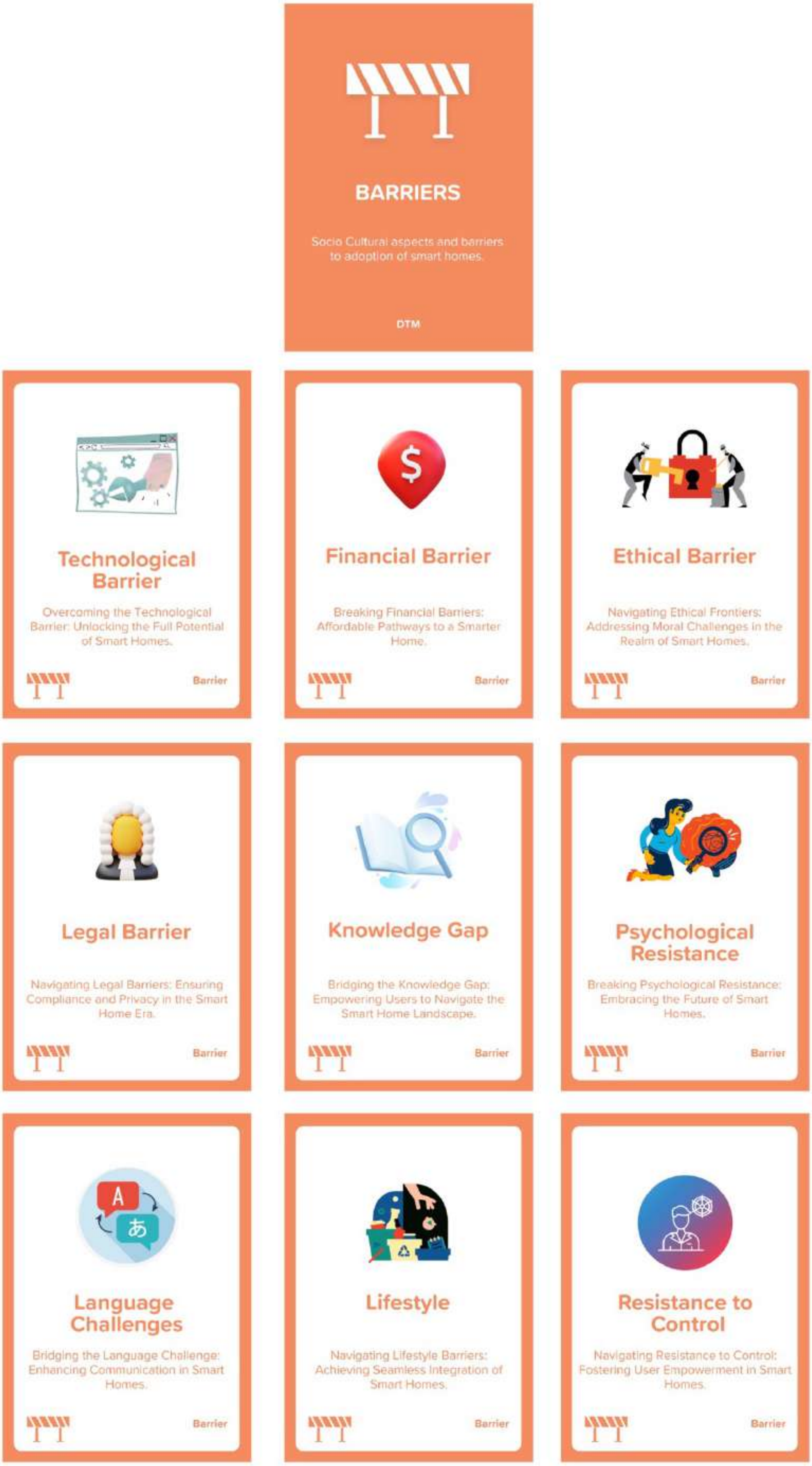


Appendix – E. Mission Card Tool



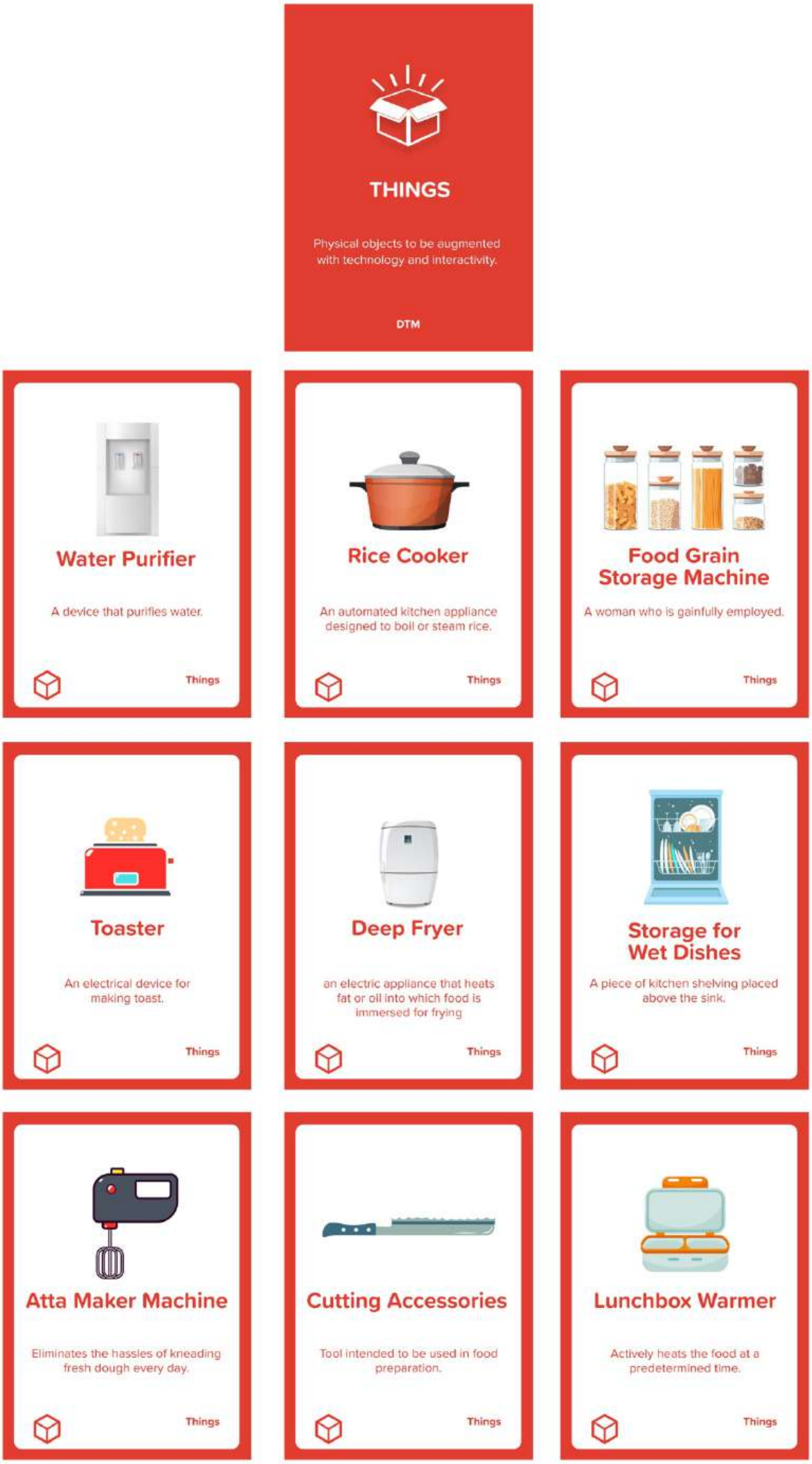
Appendix – F. Benefit Card Tool

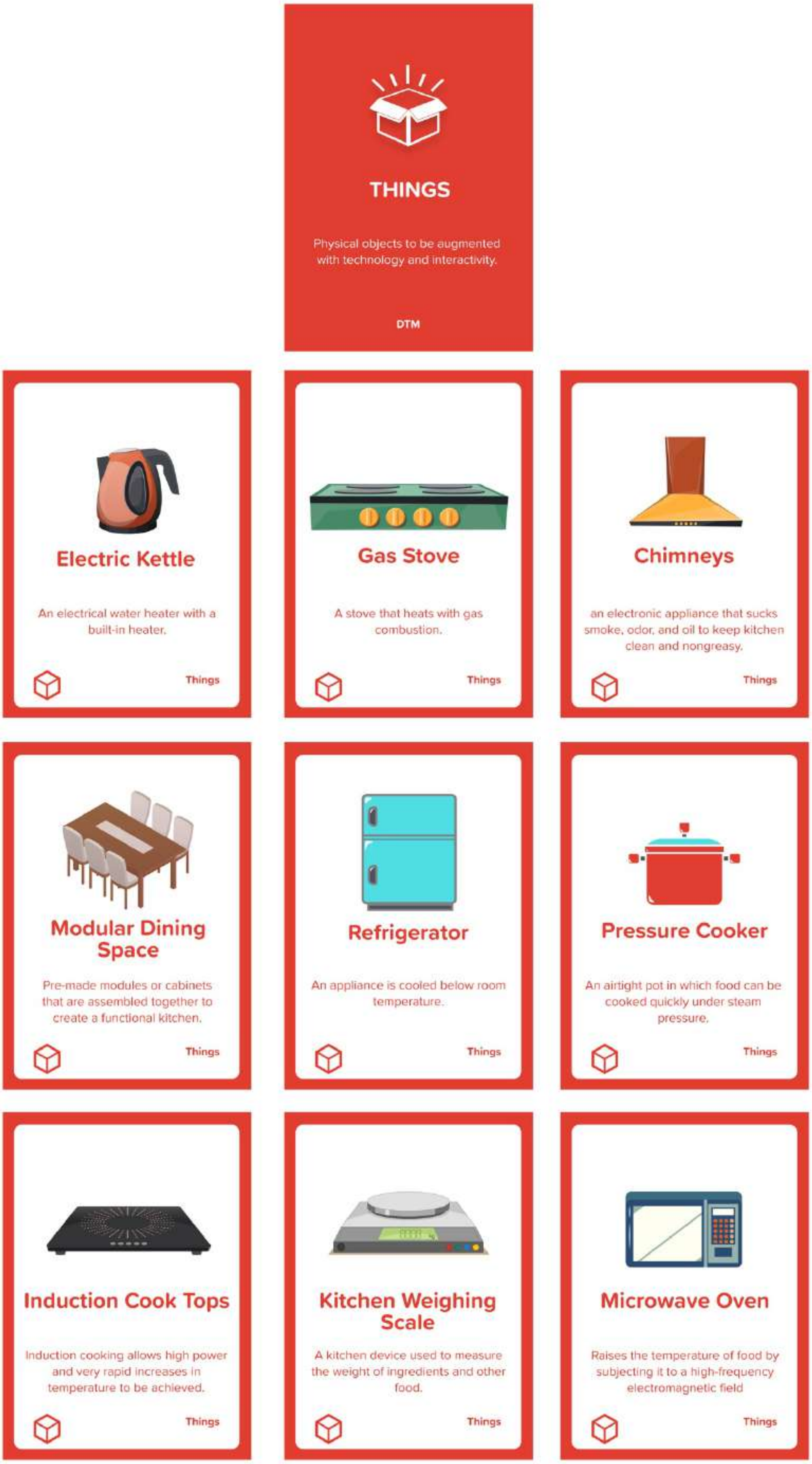
Appendix – G. Barrier Card Tool



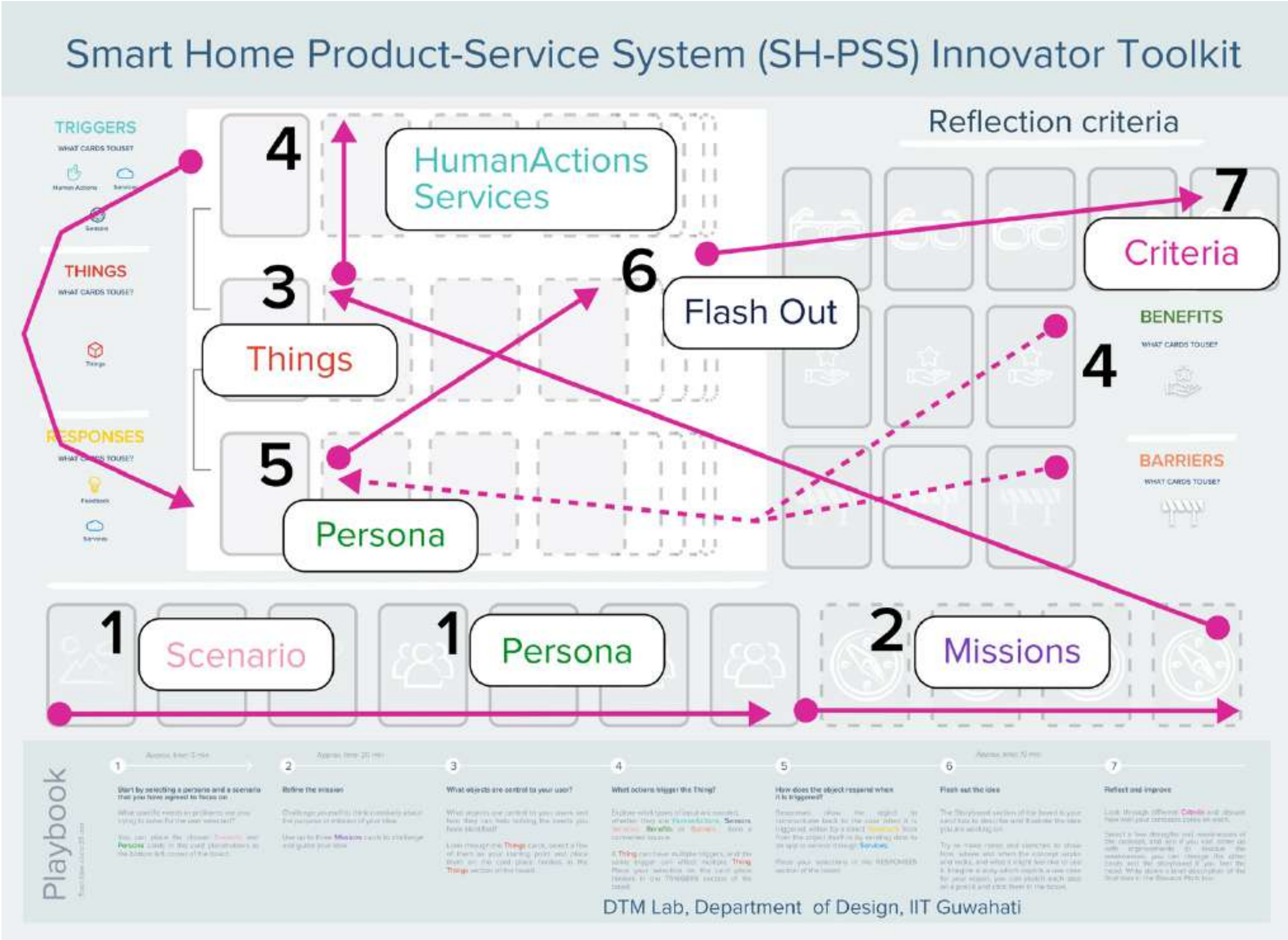
Appendix – H. Persona Card Tool

Appendix – I. Things Card Tool




THINGS
Physical objects to be augmented with technology and interactivity.
DTM
Electric Kettle
An electrical water heater with a built-in heater.
Things
Gas Stove
A stove that heats with gas combustion.
Things
Chimneys
an electronic appliance that sucks smoke, odor, and oil to keep kitchen clean and nongreasy.
Things
Modular Dining Space
Pre-made modules or cabinets that are assembled together to create a functional kitchen.
Things
Refrigerator
An appliance is cooled below room temperature.
Things
Pressure Cooker
An airtight pot in which food can be cooked quickly under steam pressure.
Things
Induction Cook Tops
Induction cooking allows high power and very rapid increases in temperature to be achieved.
Things
Kitchen Weighing Scale
A kitchen device used to measure the weight of ingredients and other food.
Things
Microwave Oven
Raises the temperature of food by subjecting it to a high-frequency electromagnetic field
Things

Appendix – J. Detailed protocol of experiments



	Activities
1	Start by selecting a **Persona** and a **Scenario** that you have agreed to focus on: What specific needs or problems are you trying to solve for the user selected? You can place the chosen Scenario and Persona cards in the card placeholders at the bottom left corner of the board
2	Refine the **Mission**: Challenge yourself to think creatively about the purpose or mission of your idea. Use up to three Missions cards to challenge and guide your idea.
3	What objects are central to your user? What objects are central to your users and how they can help solving the needs you have identified? Look through the **Things** cards, select a few of them as your starting point and place them on the card placeholders in the THINGS section of the board.
4	What actions trigger the Thing? Explore what types of input are needed, whether they are **Human Actions, Sensors, Services, Benefits or Barriers** from a connected source. A **thing** can have multiple triggers, and the same trigger can affect multiple things. Place your selections on the card placeholders in the TRIGGERS section of the board.
5	How does the object respond when it is triggered? Responses allow the object to communicate back to the user when it is triggered, either by a direct **Feedback** from the object itself or by sending data to an app or service through **Services**. (RESPONSES section of the board)
6	Flesh out the idea: The Storyboard section of the board is your sandbox to describe and illustrate the idea you are working on. Try to make notes and sketches to show how, where

	and when the concept works and looks, and what it might feel like to use it. Imagine a story which depicts a use case for your object, you can sketch each step on a post-it and stick them in the boxes.
7	Reflect and improve: Look through different **Criteria** and discuss how well your concept scores on each. Select a few strengths and weaknesses of the concept, and see if you can come up with improvements to resolve the weaknesses, you can change the other cards and the storyboard if you feel the need. Write down a brief description of the final idea in the Elevator Pitch box.

TH-3294_196105005

Appendix – K. List of Publications

Journal Publication:

Ganvir, L., & Kalita, C. P. (2022). Adoption of Socio-Cultural Aspects in PSS Design for Smart Home Products: An Integrative Review. *Archives of Design Research*, *35*(4), 7-29.

Conference Publication:

Ganvir, L., Kalita, P.C., (2020). User-Centric Product Design Strategy For Grocery Monitoring in Indian Context. *In: Digital Proceedings of TMCE 2020, 469-476*, at tmce.io.tudelft.nl/proceedings

Ganvir, L., & Kalita, P. C. (2021). Design Thinking Approach in Identification of Service Design Based on User Interface for Grocery Monitoring System in Indian Context. *In Design for Tomorrow—Volume 3: Proceedings of ICoRD 2021 (pp. 881-893).* Singapore:

Ganvir, L., & Kalita, P. C. (2023). Design of Smart Home Product Service System in Indian context. *International Conference on Research into Design. ICoRD 2023*. Springer, Singapore.

Ganvir, L., & Kalita, P. C. (2023). Design of Smart Home Product Service Systems (SH-PSS). *International Symposium on Industrial Engineering and Automation. ISIEA 2023*. University of Bozen-Bolzano.

Ganvir, L., & Kalita, P. C. (2023). Analysing Characteristics of Smart Home Product Service System through Kano Model Approach. *International Symposium on Industrial Engineering and Automation. ISIEA 2023.* University of Bozen-Bolzano.

Ganvir, L., & Kalita, P. C. (2023). Shaping Smart Home Product Service System (SH-PSS)Reflection Criteria Cards for Tiles Not Inventor Toolkit. *International Conference on Engineering & Product Design Education. E&PDE 2023*, Elisava Barcelona School of Design and Engineering. 10.35199/EPDE.2023.113

Ganvir, L., & Kalita, P. C. (2023). Usability testing to IoT Innovator Toolkit. *21st Humanizing Work and Work Environment (HWWE)*, IIM Mumbai. (Accepted, Scopus Indexed)

TH-3294_196105005