Strategic Selection and Integrative Perspective of Design Methods in Developing a Service System Design Framework with Special Reference to Domestic Plumbing

A Thesis

Submitted in Partial Fulfilment of the Requirements for the Degree of

Doctor of Philosophy

By

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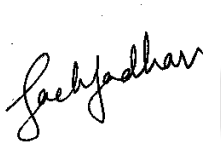
DECLARATION

I, Sachin Shivaji Jadhav, declare that the research work comprised in this thesis entitled **"Strategic Selection and Integrative Perspective of Design Methods in Developing a Service System Design Framework with Special Reference to Domestic Plumbing"** is my own work and carried out under the guidance of Dr. Pratul Ch. Kalita, at the Department of Design, Indian Institute of Technology Guwahati, Assam, India. It contains no materials previously published or written by another person or a significant proportion of material for the award of any other degree or diploma, except where otherwise indicated and due acknowledgement is made in the thesis. I also declare that the intellectual content of this thesis is the product of my own work.



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CERTIFICATE

This is to certify that the research work presented in this thesis entitled **"Strategic Selection and Integrative Perspective of Design Methods in Developing a Service System Design Framework with Special Reference to Domestic Plumbing"** has been carried out under my supervision and submitted by Mr. Sachin Shivaji Jadhav. This work submitted for the degree of Doctor of Philosophy is original and has not been submitted elsewhere for the award of any other degree or diploma.

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ABSTRACT

The prime inspiration of this research is to formulate a framework for strategic selection and integration of design methods for service development process in Product Service Systems (PSS) perspective. This research maps Design Thinking in PSS service development process. The effort has been experimented and successfully demonstrated with a case study of online domestic plumbing services in Indian context.

In recent years, the integration of products and services is a significant and growing trend. This phenomenon is due to the advancement of technology, information and competitive business environments. The potential of integrating products and services lies in improved efficiency, benefits customers and product and service providers. The studies related to this area are described mainly from the perspective of Design Management approach in Product Service System (PSS).

The Product Service System (PSS) concept focuses on selling functional results instead of the conventional sale of products. A unified approach for developing and delivering an integrated product-service offering is scarce. Researchers focused on integrating products and services as a significant objective. In addition, the proposed integration processes of products and services are numerous, but the detailed steps within each stage are missing. On the other hand, organizations and enterprises have lagged in understanding, knowledge and developing PSS business models. Moreover, PSS business models have been developing for business-to-business (B2B) sectors; but in the context of business-to-consumer (B2C) sectors it is often overlooked.

The overall objective of our research is to propose a PSS design framework with integration of design methods aligning strategic design management. This thesis focuses on the Product Service System (PSS), which is the core research area. A service system design framework from PSS perspective has been proposed, to which this thesis aims to contribute. It comprises three main phases. These are viz. PSS requirements identification and analysis, PSS designing and detailing and PSS test and implementation. A case example of domestic plumbing services in the Indian context demonstrates the proposed service system framework.

The PSS requirements identification and analysis phase involved activities viz. identification and analyses of customer requirements, design requirements prioritization, and plausible scenarios for domestic plumbing. The Design brief provides a structured statement that outlines

problem definition, goals, constraints, budgets, and timeline. Hence this approach was employed in defining the problem structure for domestic plumbing services. The PSS design and detailing phase emphasized the design thinking approach in developing an e-commerce business. It illustrated the application of design thinking through stakeholder mapping, service blueprint, data flow and wireframe techniques in developing e-commerce with the practical case of domestic plumbing services. The PSS test and implementation phase concentrated on the market launch of the domestic plumbing service system. It included benchmark study, B2C e-commerce business model development and SWOT analysis. It comprised website design and development and validated through the customers and expert users.

This thesis offers two main contributions in line with research and design viz.: (1) Service system design framework from PSS perspective inspired by design management. (2) service and system design for the domestic plumbing sector in the Indian context. This research provides knowledge to support designers working in the field of product service system design in e-commerce. Current research methodology, design methods and findings provide insights on how a service system design works for an e-commerce business model. It presents recommendations on how to build a service system design in this context.

The research presented in this thesis was conducted in India and considered only domestic plumbing as a case example. Therefore, the proposed service system process, developed e-commerce business model and strategies could have cultural and demographic influences. The future research trajectories may include more case studies of home services to generalize the proposed service system framework.

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Abbreviations used in this thesis

PSS	Product Service System
E-Commerce	Electronic Commerce
B2C	Business to Customers
B2B	Business to Business
FDI	Foreign Direct Investment
GVA	Gross Value Added
GDP	Gross Domestic Product
IBEF	Indian Brand Equity Foundation
NSDC	National Skill Development Corporation
USD	United States Dollar
IT	Information Technology
ITeS	Information Technology enabled Services
QFD	Quality Function Deployment
AHP	Analytic Hierarchy Process
ANP	Analytic Network Process
SWOT	Strength, Weakness, Opportunity, Threat
DFDs	Data Flow Diagrams
UI	User Interface
DIY	Do-It-Yourself
MCDM	Multi-Criteria Decision-Making
MCDA	Multi-Criteria Decision Analysis
IPS2	Industrial Product Service System
DEA	Data Envelopment Analysis
NPS	Net Promoter Score

Chapter 1

1 Introduction

The current research reported in this thesis focuses on the Product Service System (PSS), which is the core research area. A service system design from PSS perspective is proposed, to which this thesis aims to contribute. A case example of domestic plumbing services in the Indian context demonstrates the proposed service system design from PSS perspective. This chapter introduces the general background on the Product Service System (PSS), an overview of the service sector, e-commerce, home services and domestic plumbing. The chapter presents the research topics covered in this thesis, research aims, objectives and thesis outline.

This research has taken the multi-perspective such as viz. design management, business model, design thinking and service design. The prime inspiration of this research is the strategic selection and integration of design methods for a service system development from PSS perspective. In particular, a service process development in the context of B2C e-commerce. Therefore, the thesis can be understood through the following points,

- PSS is a strategic and comprehensive business model in our understanding. A business model that offers value to its stakeholders by adding a service to an existing or a new product. It is an effective integration of major entities of the system (products, services, infrastructures, networks and actors) aiming to achieve customer delight, higher revenues, sustainable relationships with customers and better environmental performance.
- A series of methods from different disciplines (e.g. strategic management, design management, engineering and technology, design thinking, service design, and information system) are combined to formulate a service process. It can provide knowledge support to designers and business managers involved in systems design, service design and product service systems.
- The tools and methods considered in the proposed service system design framework from PSS perspective for e-commerce are not new. They are well established methods and often used in management, design, information system, service design, and system design disciplines. The Prime contribution of the study is structured and systematic selection, flow and application of the methods in the Product Service System context inspired by design. Significant research contribution also lies in application of these methods in generating a service system design framework from PSS perspective for e-

commerce of domestic plumbing services. The consideration of the domestic plumbing services case example guides the pathway to the development of the service system design framework from PSS perspective.

1.1 Product Service System

In recent years, the integration of products and services is a significant and growing trend. This phenomenon is due to the advancement of technology, information and competitive business environments (Mont, 2002), (Baines et al., 2007), (Beuren et al., 2013), (Reim et al., 2015). The potential of integrating products and services lies in improved efficiency, benefits customers and product and service providers. With this phenomenon, companies can manage and enhance resource utilization and achieve a competitive advantage—nevertheless, product and service differentiation in the market. This part of the study describes mainly issues discussed and developed under research domain of Product Service System (PSS).

The strategic focus of several product manufacturers and service providers have been shifting from selling only products or services towards integration of both (Mont, 2002), (Goedkoop et al., 1999), (Baines et al., 2007). In addition, research on integrating products and services has been conducted in various disciplines, viz. sustainability, service science, business and design management, marketing, design, engineering and information system (Li et al., 2020). The concept of PSS has emerged from the field of sustainability to reduce environmental impacts due to the production and consumption of natural resources. At the same time, it allows companies to integrate products and services to achieve economic benefits and increase customer satisfaction.

From the management perspective, the Product Service System (PSS) is the most promising service-oriented business model (Baines et al., 2007) (Reim et al., 2015). As an effective and efficient business model, PSS gained attention among researchers due to its potential as an alternative business model. The basic idea of the PSS concept is not to sell products and services separately. In this approach, the consumer can use a product without ownership.

Within PSS literature, there are several types of PSS. Often these are described and range from a pure product to pure service. Several types of PSS are in between pure product and pure service, as shown in Figure 1.1. In PSS literature, the early contribution and widely accepted types of PSS were by the work of Mont (2002), Manzini and Vezzoli (2003), Tukker (2004),

and Baines et al. (2007). These are viz. product-oriented PSS, use-oriented PSS and result-oriented PSS.

- Product-oriented PSS: In this type of PSS, a product's sale is traditionally conducted with the additional benefits of services. Services such as viz. maintenance, repair, recycle and after-sale services. Product ownership is with the customer.
- Use-oriented PSS: In this type of PSS, the use or availability of the product is provided to the customer, for instance, leasing or sharing. Here, product ownership is not with the customer.
- Result-oriented PSS: The result or capability is provided to the customer instead of a product. To simply put, customized services or functional results are made available to the customers, for example, laundered clothes instead of selling a washing machine, a painted house instead of selling paint.

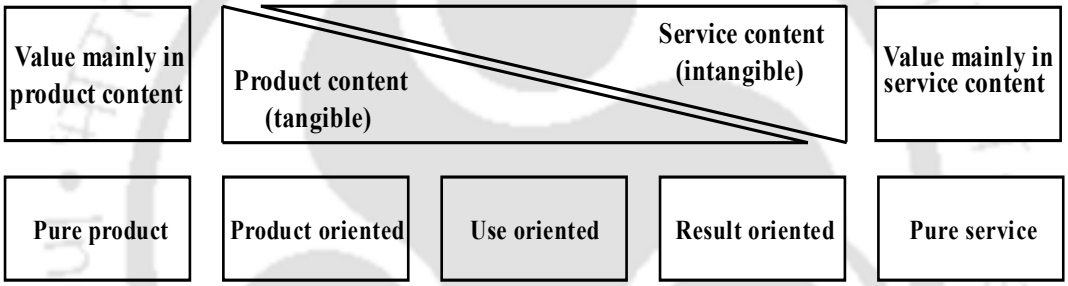


Figure 1.1: Types of Product Service System (source: Tukker, 2004)

Developing an integrated framework of products and services have exponentially increased and become an essential topic. This topic attracted researchers of various domain resulting in widespread PSS applications and benefits (Geum et al., 2011). Designing PSS solutions requires integrating tangible and intangible objects with a value addition (Vasantha et al., 2015). The design perspective of PSS emphasizes investigating customer behavior about products, services and technology (Morelli, 2002). On the other hand, globalization has brought new opportunities and challenges. Thus, innovation to create business value is the focal issue for organizations and companies (Lee & AbuAli, 2011). Innovation in the perspective of management is to develop customer-centric ideas. Innovative thinking is challenging for an organization due to lack of framework for strategic identification, selection and systematic application of design methods in a given PSS situation.

The popularity of PSS has increased substantially in recent years. The growing interest is reflected through the abundance of literature and studies related to PSS. At the same time, a unified approach for developing and delivering an integrated product-service offering is scarce (Maussang et al., 2009), (Beuren et al., 2013), (Sakao & Lindahl, 2015). For instance, Tran and Park (2014) mentioned that researchers focused on integrating products and services as a significant objective. The proposed integration processes of products and services are numerous, but the detailed steps within each stage are missing. A clear understanding of integrating the planning, developing, delivering, and using products and services is essential for PSS (Müller et al., 2010). On the other hand, organizations and enterprises have lagged in understanding, knowledge, and developing PSS business models (Mont et al., 2006). It has been observed that the PSS business models have been developing for business-to-business (B2B) sectors; but in the context of business-to-consumer (B2C) sector, there is a scarcity in PSS business models.

1.1.1 Service Design

The studies or research related to the design and development of services is still an emerging topic. Although, it has evolved in the last couple of decades into Service Design, Service Engineering and New Service Development. Service Design is a multi-disciplinary, customer-centric and participatory approach (Costa et al., 2018). In general, service design discusses integrating products, services, networks and actors' interfaces with the systems and processes (Wang et al., 2017) (Lee et al., 2019). Service Design covers not only the activities of a product lifecycle but also the customer activity services. It includes designing, specifying, measuring and operating with the product and service development. Service engineering deals with the systematic design and development of services through methods, tools and approaches (Wang et al., 2017) (Lee et al., 2019). Often, it represents a technical perspective. Service engineering focuses on services by maximizing the value and minimizing the environmental impacts. It involves service delivery, service creation and service consumption.

As a quest in developing sustainable market offerings, business organizers started looking into service design and design thinking (Tan et al., 2010a) (Andreassen et al., 2016). Since then, the significance of services has grown exponentially. Many manufacturing companies have shifted their focus from pure product orientation to product-service orientation (Marques et al., 2013). (Andreassen et al., 2016). Researchers focused more on the studies related to value creation and value-in-use. Why customers choose a particular service or solution may be

studied by understanding the processes that may affect customers experiences. It is also a matter of concern, how to provide better services through quality, convenience, and availability. These influenced the service design in prominence to create value for the customers through strategic design management.

The essential concerns for effective service development are, viz. customer requirements elicitation, customer-centric and a clear focus on service processes (Rapaccini et al., 2013). The unification of human and physical processes must be considered to maximize service value (Shimomura and Arai, pp-134. 2009). The design and development of service processes were adopted from traditional product development (Rapaccini et al., 2013). In comparison with the product development processes, service processes were ineffectively developed in the context of PSS.

1.2 Service Sector Overview

The service industry or service sector has played an essential role and contributed to the economies of the developed nations. Similarly, it plays a vital role in developing nations, such as China and India. The service industry is understood as wholesale and retail business, transportations and hotels, restaurants, logistics, finance, communication and information, consultants, real estate, social, insurance and banking, and personal and home services.

In India, the services sector enhanced in the 1990s. At the same time, economic reforms in the service sector led to privatization, Foreign Direct Investment (FDI) restriction minimization, reorganization of the approval procedures and many more (Mukherjee, 2015). Also, liberalization has made the pathway for multi-national companies to invest in India (Singh, 2014).

According to the economic survey reported in 2016-2017, about 53% of Gross Value Added (GVA) contributed to India's service sector (Subramanian, 2016). Despite a considerable contribution to economic growth, India's service sector contribution to total employment is only 28.6 %. In contrast with other countries, the share of the service sector in GDP and employment is almost equal, as shown in Figure 1.2. Although India's service sector growth is prominent, employment could be a concern and addressed as a research problem. This thesis also touches upon some aspects of employment in the business of domestic plumbing.

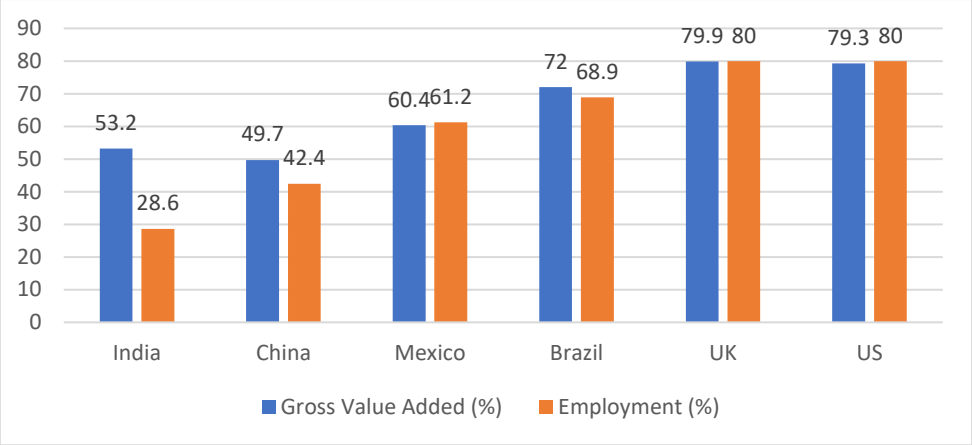


Figure 1.2: Share of the service sector in GDP and Employment (source: Economic Survey 2016-2017; www.equitymaster.com)

The E-Commerce sector has changed the perception of consumers with perceived value and quality of products and services. In response, business organizers and companies pursued creating innovative business models and seamless shopping experiences and innovative marketing strategies in this sector. The essential drivers in this sector are, viz. easy accessibility, range of product and services availability, a young population, urbanization multiple payment options (credit and debit), convenient and secured transaction, and many more. Figure 1.3 depicts India's e-commerce and retail sector overview, representing global industry, Indian industry, growth enablers, strengths and opportunities.

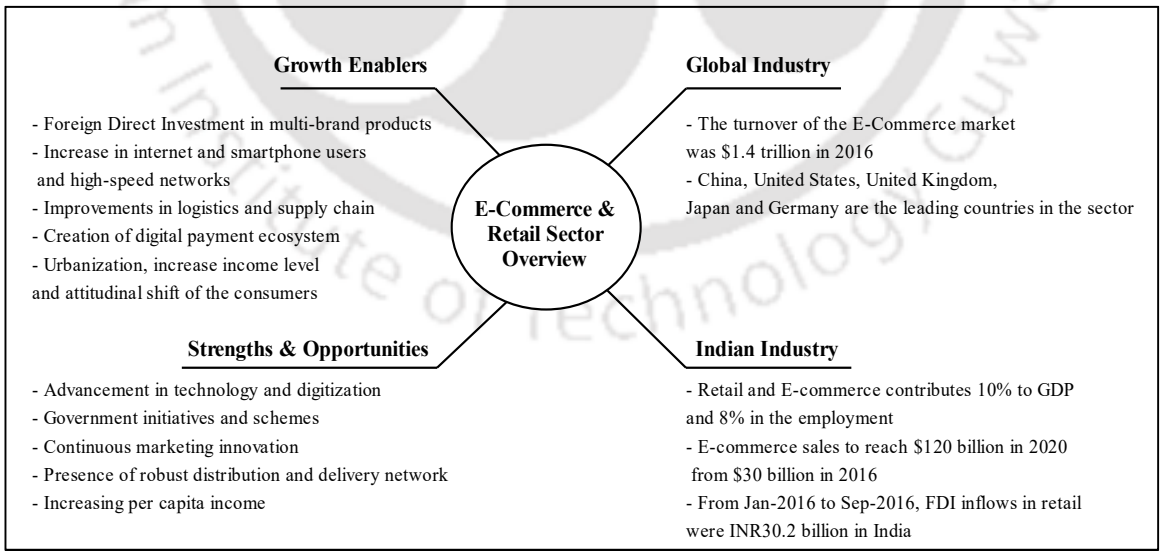


Figure 1.3: E-commerce & retail sector overview

(source: compiled from IBEF, 2016; Deloitte and Confederation of Indian Industry, 2017)

In the last decade, Information Technology (IT) grew globally. It transformed business processes along with creating efficient means of value chains based upon information exchange. India pursues information technology (IT), and Information Technology enabled Services (ITeS) with this opportunity. Supported by the Government of India, business organizers and young entrepreneurs developed innovative business models in this sector. It created efficient value chains, value networks and value propositions for business organizers and customers. In addition to customers usage of smartphones and Internet penetration, this sector disrupted traditional ways of business. Figure 1.4 illustrates the start-up sector overview in India, representing global industry, Indian industry, growth enablers, strengths and opportunities. The awareness and benefits among customers about conducting online business have increased substantially. Several business sectors, stakeholders, merchants, and retailers are entering and conducting commerce online. In addition, the Indian government initiatives and policies support stakeholders. For instance, the 'Digital India' initiative encouraging buyers and sellers for transactions and payments online and 'National E-commerce policy' for cross-border data flow of information.

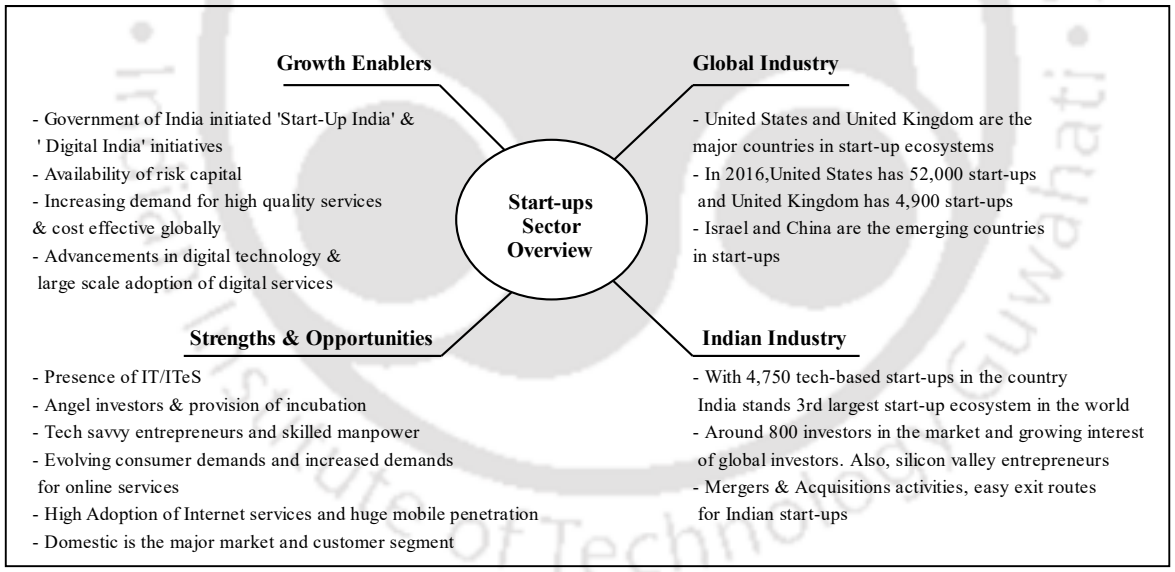


Figure 1.4: Start-ups sector overview

(source: compiled from IBEF, 2016; Deloitte and Confederation of Indian Industry, 2017)

1.3 E-Commerce

Electronic Commerce or E-Commerce includes conducting business transactions, sharing business information, managerial activities, selling products and services using the internet (Barnes et al., 2004) (G. Sharma & Lijuan, 2015) (Khan & Uwemi, 2018). These e-commerce

activities or functions are performed through websites. Unlike in traditional business, e-commerce allows to streamline business processes, offer products and services digitally, customize and personalized consumer service (Chang et al., 2003). Besides, e-commerce reduces space, workforce, paperwork, maintaining document archives, and reducing costs (Hosseini et al., 2020).

Moreover, e-commerce provides an opportunity for developing countries to enhance the social structure and economic growth and development. Therefore, e-commerce is growing rapidly and also aid opportunities in conducting business for creating values. Classification of e-commerce is based on the transaction between the actors, partners, or stakeholders (Mohapatra Sanjay, 2000) (Laudon & Traver, 2017). Initially, e-commerce was considered as an aid for conducting business. However, the growth of technology, internet speed and penetration changed functional e-commerce areas. Nowadays, enabling e-commerce becomes a strategic tool for business organizers, public sectors, retailers, financial services, tourism, logistics, and SMEs. Strategies are formulated to understand the dynamics of competition and adapt accordingly to sustain the competitive business environment. The business model refers to the firm's logic, and strategy refers to selecting a business model (Casadesus-masanell & Ricart, 2010). Therefore, firms' enabling e-commerce should identify and analyze external factors, internal resources, and core competencies.

Researchers and business organizers develop strategies through different approaches, such as game theory, resource-based view, and industrial organization theory (Casadesus-masanell & Ricart, 2010). The necessary steps in conducting a strategic planning process comprise of collecting a broad database, creative thinking analysis of data, identifying competitive advantages, defining gaps and understanding critical resources and skills (Thiradathanapattaradecha et al., 2017). Strategic planning is part of strategic management that connects planning with implementing a firm's vision, mission and objectives.

Strategic planning is to achieve a competitive advantage, communicate within and outside the business environment, sustain dynamic market conditions, and create values. As Bryson et al. (2018) suggested, strategic planning could be attained through the methodologies that conceptualize and operationalize differently. Besides, the variety of methodologies is resourceful as each provides insights into strategic planning.

1.4 Home Services and Domestic Plumbing Scenario

Traditionally, customers would find nearby or search for a reliable service provider to fix issues or repairs in their homes. Be it a plumber, electrician, cleaner, painter and many more. However, this scenario has changed to book or tap a service through the app or website platforms. To put simply in other words, many home services providers are available in the market, who can connect customers and required service providers through their website platform or the mobile app. Such on-demand services can influence the economy and eliminate the difficulty in finding a professional service provider.

On-demand services have grown significantly and are driven by technological advancements and changing customer requirements (Burg et al., 2019). In India, start-ups and the on-demand service sector have grown due to an economic boost. There is a niche market of on-demand home services. There are on-demand home services for installation and repair works in home. In addition, start-ups for various services viz. shifting furniture, events organization, health and wellness services are running online businesses. The fast adoption of online services during the Covid-19 lockdown and post-lockdown significantly drove the country's e-commerce sector. According to the latest report of 'India Brand Equity Foundation' the digital economy may reach US $ 800 billion by 2030 from 85-95 billion in 2020 (E-COMMERCE, 2021).

As per the report published in 2016 on Indian start-ups by NASSCOM and Zinnov pointed factors for the growth of start-ups, these are viz. ease of doing business supported by the Indian government; entrepreneurship and focused educational system; industry facilitation like corporate facilitators, mentoring, networking opportunities and funding support; promoting success stories of start-ups and university events (NASSCOM & Zinnov, 2016). In addition, the majority of the start-ups are based in Bangalore, Delhi-NCR and Mumbai. The emergent cities for start-ups are Hyderabad, Pune, Chennai and Kolkata. Moreover, total funding of USD 3.8-4.0 Bn has been raised in the Business-to-Business (B2B) and Business-to-Customer (B2C) sectors. Other alternate funding sources include crowdfunding, bootstrapping, peer-to-peer/business lending. In India, 85% of e-commerce companies offer B2C solutions. Start-ups focused on the niche categories of conducting an online business such as viz. fashion and retail, food and grocery, travel and hospitality, home and decor, healthcare, and consumer services like plumber, electrician and carpentry.

Table 1.1: Overview of some Indian home services companies (status as of May 2017)

Company	Types of service offerings	Investor/Partner	City
UrbanClap 2014	House cleaning, Beauty services, Interior designing and wedding photography	SAW Partners and Accel India	Ahmedabad, Bengaluru, Chennai, Delhi-NCR, Hyderabad, Kolkata Mumbai, Pune
LocalOye 2013	Tutors, home services, wellness experts	Tiger Global and venture fund Lightspeed Venture Partners	Bangalore
HouseJoy 2015	Pest control, beauty, AC repair, painting, movers and packers, Appliances repair, home cleaning electrical, plumbing, carpentry.	Matrix Partners	Bangalore Delhi Chennai Hyderabad Mumbai
Zimmber 2014	Ac servicing, Plumbing, Electrical repair services, Home Spa, Pest Control Services, Carpentry Services, laundry, Driver on-demand and Painting services	IDG Ventures India, Omidyar Networks	Mumbai, Pune, Delhi and Gurgaon
TaskBob 2014	Driver on demand, plumbing, carpenter, AC repair, appliance repair, pest control, car and Bike Cleaning	Orios Venture Partners, Mayfield Fund	Mumbai
Near 2014	Professional services for home needs, events and skills management, health and wellness,	Manish Vij and Anupam Mittal	Gurgaon

Today, families need on-demand services, thus giving on-demand service providers an opportunity of tying up with local retailers who can provide quick service. The provision of on-demand services is achieved through the website or app-based platforms. On-demand services cover many niche markets and customer segments, from online groceries to services like wellness experts, event management, tutoring and home services. For instance, start-up companies in India are Grofers, TinyOwl, Big Basket, LocalOye, PepperTap, Housejoy, Urbanclap, Zappon and many more. Table 1.1 shows some home service companies concerning service offerings and investors established in India's metro cities (Tier I).

The founders of the UrbanClap (now UrbanCompany) redefined the search or hiring of servicemen or local services in India (Arushi Chopra, 2017). They saw an opportunity in this unorganized sector of home services. They developed the business model emphasizing onboarding service providers, training the service provider, managing quality and standardized services. In addition, customers get assured services, payment options and reviews on services through their website platforms (Arushi Chopra, 2017) (Surie, 2020).

The potentials of home services sectors are reflected through investments capacities now and in the future (Galleher, 2020). These do not depend upon tangible goods. Moreover, these are well-positioned and not impacted by the economic downturn. Home services are successful

and operational based upon the demands and needs of their services. Customers use on-demand home services due to service convenience, quality and price.

According to 'The Passage' in an interview with the Housejoy CEO, India's on-demand service sector is a USD 20 billion-plus opportunity (Ebin, 2019). Altogether 97% of the market is unorganized. Hence, it is a vast market opportunity for offering home services online. In the on-demand service sector, business organizers and start-ups witnessing considerable potentials in the market, investments and intense competition (Inc42, 2015). At the same time, they are pushing many efforts on product/service differentiation, investments in technology, and expansion. Besides, transparency in pricing details and service quality could determine customer's preferences to choose on-demand services.

The internet penetration and use of smartphones among consumers and business organizers enabled several opportunities and challenges. Organizations from multi-national companies to small and medium enterprises are conducting online business through the internet. At the same time, opportunities and challenges arise for all the stakeholders in the business. Stakeholders involved in online business are consumers, producers, service providers, supply chain, logistics, delivery and distributors, payment partners, investors and developers. Opportunities for consumers include ease of ordering product/service, multiple options for selecting product/services, round the clock payment provisions, multiple payment options, easy return options, rating and reviewing product/service quality. Challenges for business organizers include: developing a sustainable business model, fostering trust in the consumers, use of advanced technology, data security and privacy maintenance, a system of network and infrastructures, steady workforce in place, delivery and distribution process modelling, product/service differentiation, competitive advantage, geographical expansion and many more. The following points are summarized as follows, based upon the discussions presented in this section related to home services in the Indian context,

- On-demand home services are operational only in urban and metro cities (Tier-I) of India.
- On-demand services can influence the economy and eliminate the difficulty in finding a professional service provider.
- India's on-demand homes services have a vast opportunity for conducting online business. In addition, it is an unorganized sector.

- Currently, on-demand business platforms offer several niche services. However, the realization of service quality could be compromised in a competitive business and geographical expansion.
- There is an opportunity to integrate traditional unorganized retail hardware shops of plumbing items in the ecosystem of online business in this sector.
- There is an opportunity to provide livelihood to plumbers by integrating them in a much better way in the ecosystem.

1.4.1 Domestic Plumbing Scenario

The rapid development in the housing and real estate sector has created an enormous demand for support services for maintenance viz. plumbing, carpentry and electrical. As real estate booms, several other sections gain importance. With more complex buildings being designed and constructed, there is a growing need for trained plumbers.

Several organizations, in partnership with the Indian government, initiated plumber training and skill development programmes. For instance, Pidilite Industries Ltd. and Indian Plumbing Skill Council (IPSC) jointly initiated the first plumbing skill development under the Pradhan Mantri Vikas Kushal Yojana (PMVKY) scheme (IIFL, 2014). Under this scheme aims to train and certify plumbers across India. These programs cover experts' seminars on plumbing practices, emerging plumbing trends, occupational hygiene, and safety instructions. As a result, 25,000 plumbers have been trained and planned to increase more institutions across India. Pidilite Industries Ltd. is one of the leading companies in business of adhesives, sealants, automotive chemicals, and construction products. The IPSC is an accrediting and certifying body partnered with National Skill Development Corporation (NSDC).

The Indian Plumbing Association (IPA) initiated the process of professionalization. However, plumbing apprentices work as helpers in urban cities with a practising plumber (Ranganathan, 2013). These apprentices learn plumbing skills as they worked on practical jobs. Plumbers concentrated more on conventional learning and there is lack of professional training including plumbing codes, and certification programs. Therefore, the service provided by the plumbers were subjective and challenging to regulate.

Recently, CPET university, situated in Ahmedabad, India, has started offering theoretical subjects and practical sessions related to plumbing services. These courses are offered for students pursuing a Bachelor of Construction Technology through a plumbing design studio. It

includes planning and designing sustainable plumbing services, preparing digital architectural and plumbing system models. Plumbing is not merely fixing up a tap. According to the study titled 'Skill Assessment and Anticipation Study' conducted by the Ministry of Skill Development and Entrepreneurship, Government of India, the plumbing sector has a high proportion of unskilled workers (Alam et al., 2021). Several institutions like Indian Plumbing Association and Indian Plumbing Skill Council have initiated professionalization of plumbers through training and certification courses (Ranganathan, 2013). There is an opportunity to connect skilled plumbers and customers through online platforms. There is a need to develop a business model to meet the service demand in the domestic plumbing sector with skilled manpower. This thesis efforts to address a part of this issue.

1.5 Research Questions, Research Aim and Objectives

The basic purpose and research questions of this research moves around the convergence map of issues viz. Product Services Systems (PSS), service process, online services and e-commerce, strategic design management and design methods. Based on the research gaps identified and recognition of research need, the following research questions have been formulated.

Research Questions

Research Question 1: What is the strategic selection and integrative perspective of design methods to develop a service process from the Product-Service System design in the context of strategic design management?

Research Question 2: How do integrative perspective of design methods complement and function in synergy in developing a service system design from PSS perspective for domestic plumbing services?

Aim

Our research aims to study product service system design in the context of design methods and design management.

Overall objective

The overall objective of our research is to propose a service system design framework from PSS perspective with integration of design methods aligning strategic design management. To address these challenges following were the specific objectives of the research,

Specific Objectives

Objective 1: To formulate a Service System Design framework for structured and systematic selection, flow and application of the methods inspired by strategic design management.

Objective 2: To formulate a Service System Design strategy through e-commerce in domestic plumbing services in the Indian context.

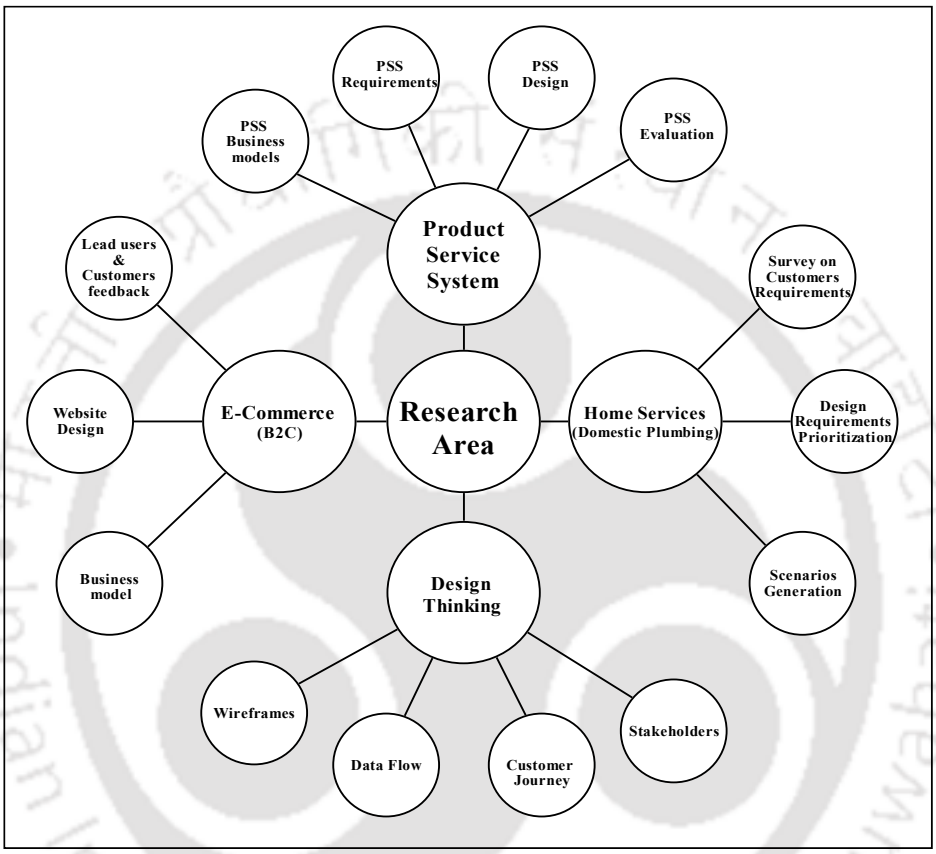


Figure 1.5: Research areas covered in the thesis

The broad research areas considered in the current research are Product Service Systems (PSSs), home services, design management, design thinking and e-commerce. The research areas presented in this thesis is depicted in Figure 1.5.

1.6 Thesis Outline

The research reported in this thesis is composed of five chapters. The following are the chapter summaries. The five chapters break up followed in this thesis is illustrated in Figure 1.6.

Chapter 1 – Introduction: The research topics and areas of the current research were presented in this chapter. These are viz. Product Service System (PSS), service design, service sector, e-commerce, homes services and domestic plumbing.

Chapter 2 – Literature Review: The literature surveyed on research areas of Product Service System (PSS), design methods, design thinking and strategic design management presented in chapter 2. Inferences on literature review topics were reported.

Chapter 3 - Research Methodology: This chapter explains the methodology of the study performed for the current research. It proposes the service development process in PSS.

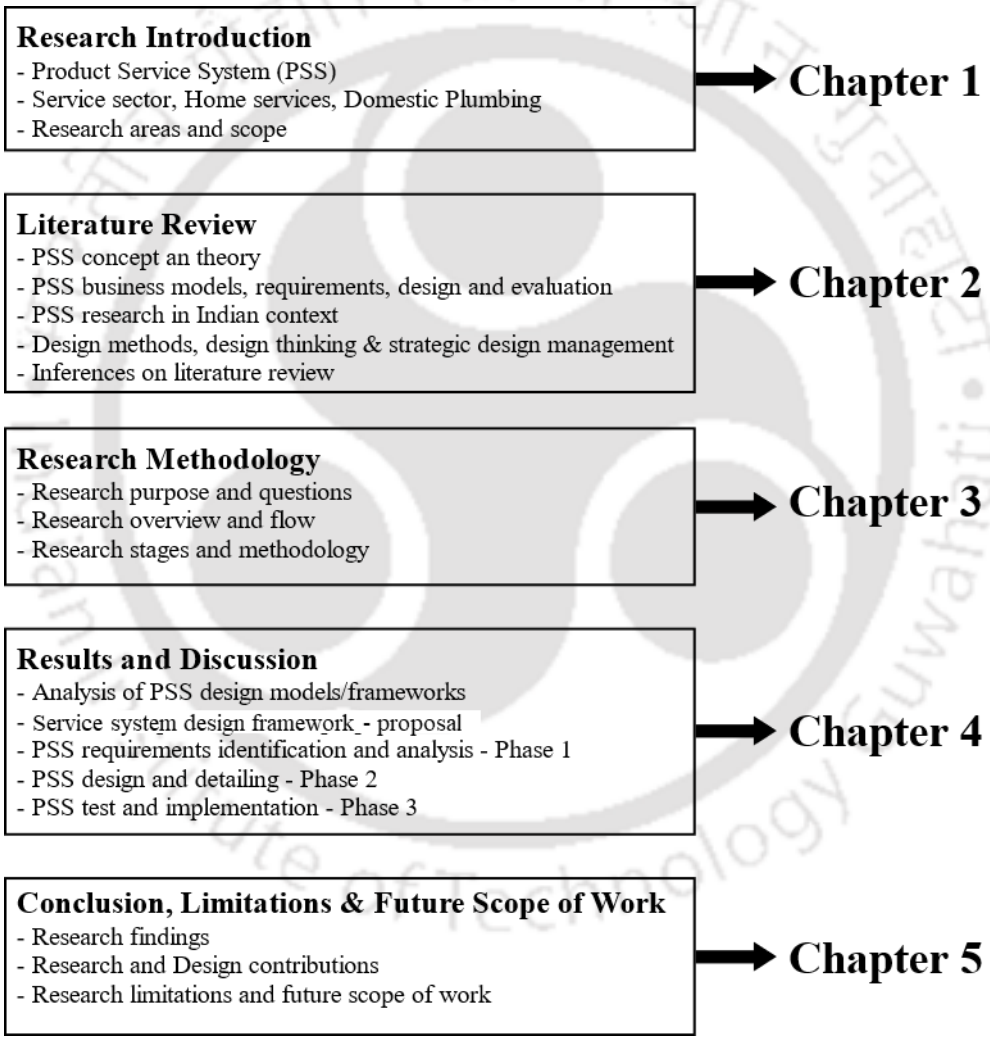


Figure 1.6: Chapters break up followed in the thesis

Chapter 4 - Results and Discussion: This chapter provides user behavior study, prioritization of design requirements and scenarios on domestic plumbing services in the Indian context.

Besides, it illustrates the application of Design Thinking through stakeholder mapping, service blueprint, data flow and wireframe techniques in developing e-commerce with the practical case of domestic plumbing services. The business model development of B2C e-commerce through the benchmark study is addressed in this chapter. The website (www.fixplumbing.in) has been developed following the structured proposed framework for PSS service design. The developed e-commerce business model of domestic plumbing services is validated through the expert users and e-commerce website of domestic plumbing services through the customers.

Chapter 5 – Conclusion, Limitations and Future Scope of Work: This chapter provides a summary of consolidated outcomes of the current research. Research findings, contributions, limitations and future scope of work were discussed.

Appendix: There are five appendixes included in this thesis. Appendix 1 consist of questionnaires for the study of consumer behavior related to domestic plumbing services**.** Appendix 2 presents descriptive statistics of the Chi-Square test and One-Way ANOVA test results. Appendix 3 consists of questionnaires for experts on design requirements for domestic plumbing services. Appendix 4 provide expert's-based decision matrixes pairwise comparison of design requirements for domestic plumbing services. Appendix 5 consists of questionnaires for customers and expert users about the feedback and opinions of understanding and implementing the B2C e-commerce website.

Chapter 2

2 Literature Review

This chapter aims to advance our understanding of Product Service System (PSS) literature for developing and implementing the service system design framework. Systematic literature review was conducted on research areas of PSS, design methods, design thinking and strategic design management. Design research and research design has gone hand-in-hand in this study. This study is inspired by various Design Research Methods (DRM) discussed by Blessing and Chakrabarti, 2009 (Blessing & Chakrabarti, 2009). Section 2.1 comprises review on Product Service System research areas, these are viz. PSS concepts and theory, PSS business models, PSS requirements, PSS design, PSS evaluation and PSS research in Indian context. Section 2.2 presents theoretical background and foundations on design methods, design thinking and strategic design management. Section 2.3 briefs inferences on literature review chapter.

2.1 Product Service System (PSS)

The methodology adopted for the literature review was using a structured keyword search with the term 'Product-Service System'. EBSCOhost, Scopus, Google Scholar and Elsevier databases were used for articles search. Figure 2.1 illustrates the number of articles reviewed in the PSS research areas. Initially, the term 'Product-Service System' was searched in the titles, abstracts and keywords. Then limit was applied to obtain the most cited (greater than 5) articles on PSS.

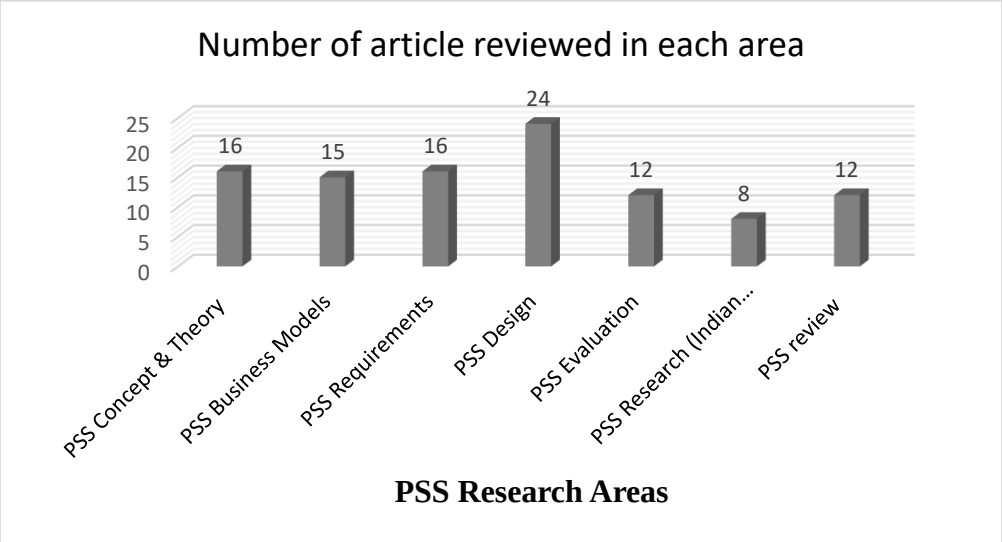
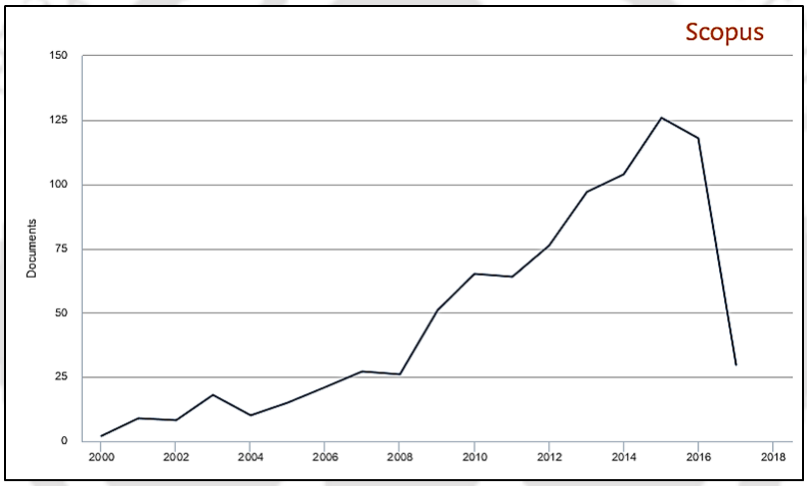
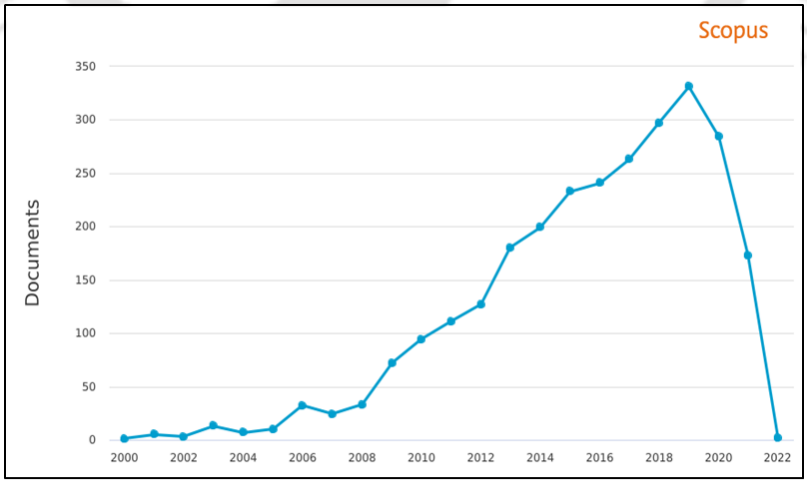


Figure 2.1: Number of PSS publications reviewed

After reviewing abstracts of more than 284+ articles on PSS, combined with search string business models, requirements, design and evaluation, we reviewed 145 scientific articles on PSS for content analysis. The Mendeley software was employed for managing the references and for the citations of the articles. Most of the PSS articles were published in the Journal of Cleaner Production. PSS articles can be found in the Springer, Taylor and Francis and Emerald Insight links. Scopus database presents abstract and citation information of scientific articles covering a wide range of fields and domains in contrast with Google Scholar and Web of Science. The search with the term "Product-Service System", Scopus generated 837 documents, status as of May 2017 and 2735 documents as of Sept 2021. Figures 2.2, 2.3, 2.4 and 2.5 depicts PSS publication distribution over years, document types, subject area and country.



(a) Status as of May 2017



(b) Status as of Sept 2021

Figure 2.2: PSS publications over the years: (a) status as of May 2017 (b) status as of Sept 2021 (Source: Scopus database)

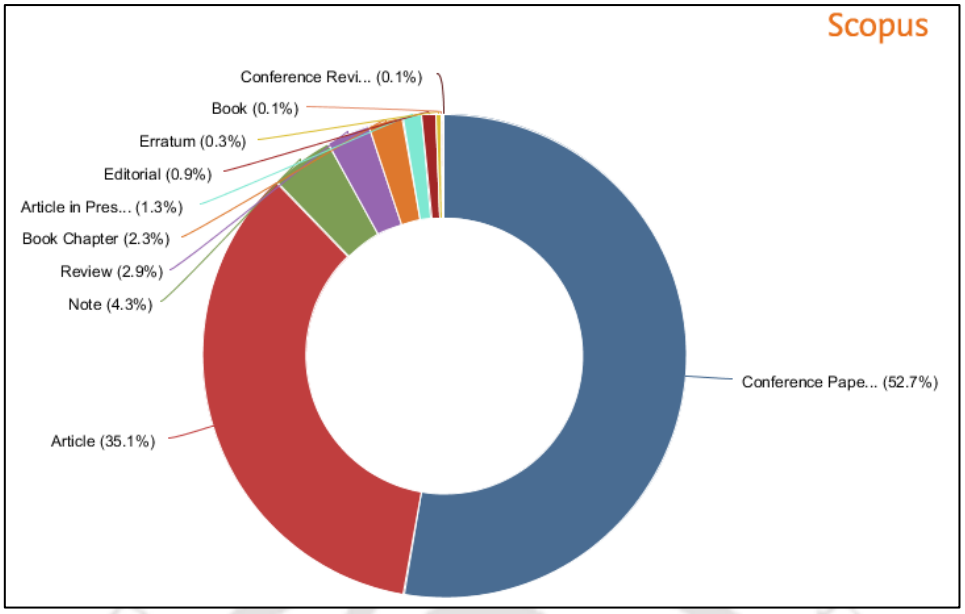


Figure 2.3: PSS publications document types

(Source: Scopus database)

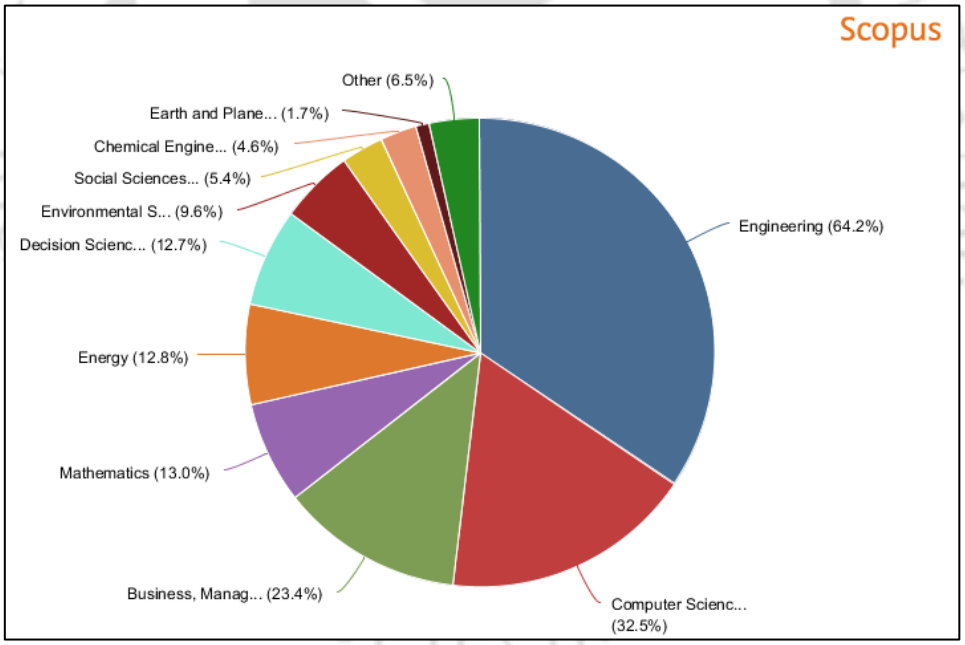
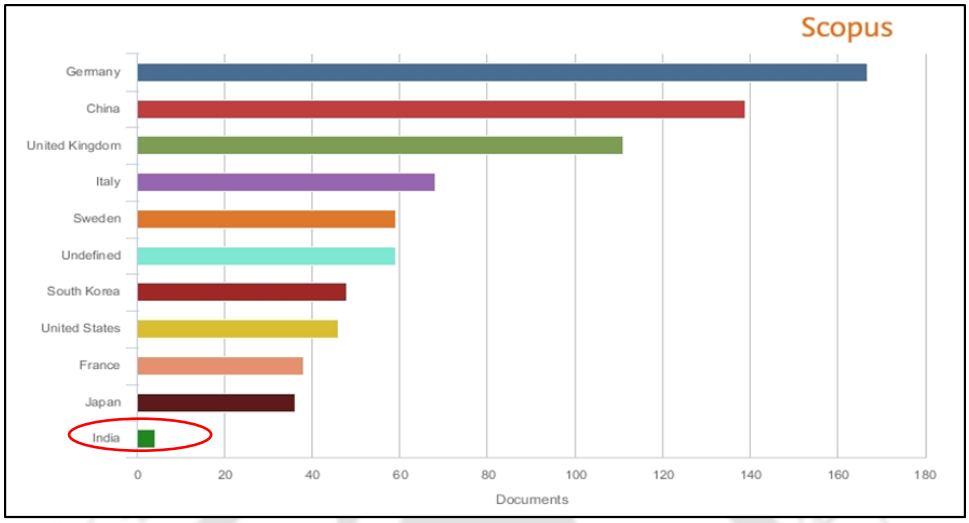


Figure 2.4: PSS publications subject area

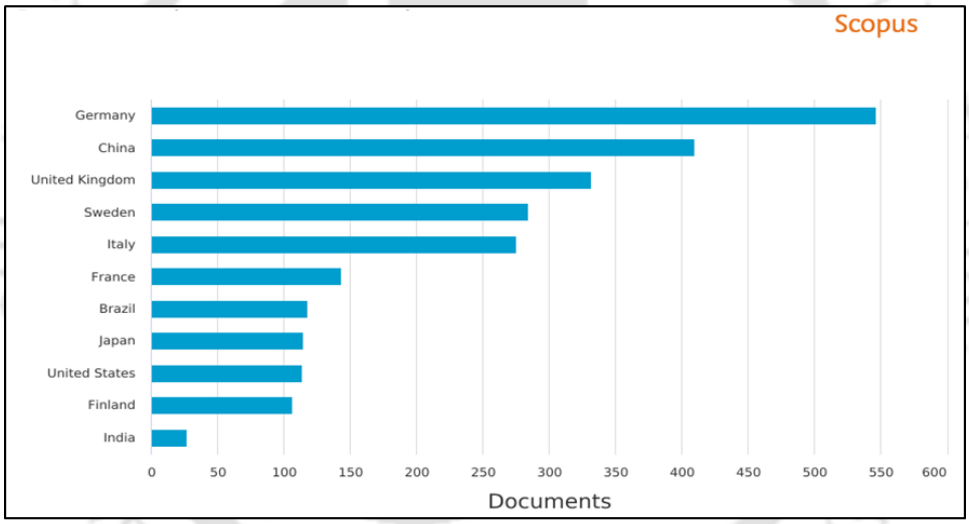
(Source: Scopus database)

It has been observed in Figure 2.2 that the publications on the PSS research area has been increased exponentially during 2011 to 2017 and trend is continuing till date. Figure 2.5 shows the comparison of PSS publication distribution over the country during 2017 and 2021. It has

been observed that in 2017, the PSS publication in India were eight and as of 2021, it is twenty-six.



(a) Status as of May 2017



(b) Status as of Sept 2021

Figure 2.5: PSS publications distribution over the country: (a) status as of May 2017 (b) status as of Sept 2021

(Source: Scopus database)

2.1.1 PSS Concept and Theory

Since 1999 PSS concept and theory development started from an environmental perspective then moved towards a business perspective. It is essential to know why this novel idea of PSS proposed and what are the theoretical foundations. Hence, this section briefs the early contribution to the PSS concept and theory. The studies on PSS by Goedkoop et al. (1999),

Mont (2002), Tukker (2004) and two EU-wide projects (eco-efficient producer services and SusProNet) contribute to the understanding of PSS concept and theory (Li et al., 2020).

A first report describing Product Service System (PSS) potentials were documented in the Dutch Policy on Environment and Economic (Goedkoop et al., 1999). Sustainable production and consumption patterns concerns were addressed in the report. As a result, it was meant to encourage manufacturers and companies to formulate policies and strategic options for business growth and minimize environmental impacts. It appears in emphasizing theoretical foundations and ten case studies.

Mont (2002) clarified the concept of PSS in terms of PSS elements, characteristics, benefits and barriers. What does PSS mean for actors (consumers, producers and service providers) involved in the PSS? For consumers, PSS is the use of functional results from a product or service. For producers and service providers, a responsibility of designing a closed-loop system along with consumers' involvement. The ultimate goal of PSS for these actors is to reduce environmental impacts on the product's lifecycle consumptions.

In the study conducted by Manzini & Vezzoli, (2003) an example of a washing machine is presented to understand the distinct characteristics between the traditional business system and PSS. A customer buys a product (washing machine) to fulfil his needs in traditional product sales or business models. In this case, to clean clothes in the house. In contrast, the PSS business model allows a customer to rent/lease a product (washing machine) to meet his end needs. In this case to rent washing machine to clean clothes. Besides, customers can also buy a service for a limited period from a service provider. Here, the service provider determines required equipment's and methods to meet customer needs. In traditional business sales, the customer retains ownership of a product and is also responsible for storage and maintaining it. In contrast, the PSS business model allows a company or service provider to retain ownership of a product and be responsible for maintenance. From a business perspective, Meier et al. (2010) highlight how industries are transitioning more towards service business through Industrial Product-Service Systems (IPSS2). The following are the purpose mentioned in PSS literature to propose the PSS concept,

- Environmental resource consumption and management have been transitioned from a pollution control approach to cleaner production. Cleaner production refers to an enhancement of industrial processes and products. It aims to reduce pollution and waste generation by re-designing industrial processes and products at a system level.

Radical change is needed at the consumption level of products and services towards dematerialized consumption, besides the need for system innovation by defining customer requirements, defining companies and stakeholders' roles and relationships. Thus, the PSS concept is proposed to fulfil these, which is promising and achievable (Manzini & Vezzoli, 2003).

- The sustainable PSS concept is different from cleaner production concepts, design for the environment and eco-design (Roy, 2000). Such concepts aim to reduce environmental impacts by a factor of 4 with standard quality of services. The sustainable PSS concept provides end-use functions to meet essential needs by considering socio-technical systems, such as public libraries and transport services.
- Several approaches and concepts were developed on how to address sustainable production and consumption issue in the 1990s. These issues were mainly due to increasing population and consumption (Mont, 2002). Thus, a Product Service System (PSS) concept has emerged from sustainability to enhance services instead of products. The PSS is looked at as a strategy for dematerialization and minimalism.
- Change in the environmental policy and law of product consumption encouraged manufacturers to develop sustainable products and services (Maxwell & van der Vorst, 2003).
- Theoretically, the result-oriented PSS type of business model lies in the interests of the producer and consumer in reducing the lifecycle costs. Besides, a system is considered an initial step to fulfil customer demands rather than the product itself. It requires the design of a system with factors 4-10. These benefits indicated the EU to advance in PSS development (Tukker, 2004).

As observed in PSS research, various terminologies are named that are related to the PSS concept. Such as 'Servitization', 'Industrial Product-Service System', 'Functional Sales', 'Integrated Product-Service Offerings', 'Total Care Products' (Baines et al., 2007) (Beuren et al., 2013). However, the goal and objective of these terminologies are the same.

The definitions provide a substantial understanding of any research topic (Baines et al., 2007). As in this PSS research, there are several definitions for a PSS. PSS definitions are mentioned from different perspectives, such as traditional marketing, service marketing and product management (Morelli, 2002). Therefore, we considered the most cited definition for a PSS as a reference and are tabulated in Table 2.1: PSS definitions

Table 2.1: PSS definitions

Author(s)	Definition
Goedkoop et al. (1999)	PSS is defined as "a marketable set of products and services capable of jointly fulfilling a user's need. The product/service ratio in this set can vary, either in terms of function fulfilment or economic value".
Mont (2002)	PSS is "a system of products, services, supporting networks and infrastructure that is designed to be: competitive, satisfy customer needs and have a lower environmental impact than traditional business models".
Manzini and Vezzoli (2003)	"a PSS can be an innovation strategy, shifting the business focus from designing physical products only, to designing a system of products and services which are jointly capable of fulfilling specific client demands".
Tukker (2004)	"PSS can be tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs"
Maussang et al. (2009)	PSSs as systems made up of service units and physical objects. The physical objects are functional entities that carry out the elementary functions of the system, the service units are entities that will ensure the smooth functioning of the whole system
Tan et al. (2010)	"PSS is a shift from a product orientation to service orientation, where instead of the product itself, the activity and knowledge associated with the use of the product is perceived to be of more value to the customer".

According to these definitions, PSS is an innovative, strategic and comprehensive business model in our understanding and from strategic design management perspective. A business model that offers value to its stakeholders by adding a service to an existing or a new product. Besides a whole system (products, services, infrastructures and actors) designed to provide functional results to customers.

Mont (2002) presented five main elements of PSS for understanding and designing PSS. These are products, services or a combination of products and services; services; product usage; maintenance service; and revalorization service. The PSS development has interactions and relationships between several elements that need to be considered (Maussang et al., 2009). These are viz. partners and organization of the enterprise, benefits for PSS provider and user, environmental and social considerations, encourage the use of PSS and system life cycle phases. Moreover, Vasantha et al. (2012) review on PSS design methodologies, presents a broader perspective of elements involved in the PSS. Such as requirements, stakeholders, environment, support objects, life cycle stages, processes and evaluation criteria (Vasantha et al., 2012).

Roy (2000) mentioned four types of PSS, these are viz. result services, shared utilization services, product-life extension services and demand-side management. Besides, discussed these in contribution to sustainability. However, widely accepted types of PSS were proposed

by Tucker (2004). Tukker (2004) presented eight types of PSS business models grouped under three main categories of PSS. The three main categories of PSS are product-oriented services, use-oriented services and result-oriented services, as depicted below in Figure 2.6.

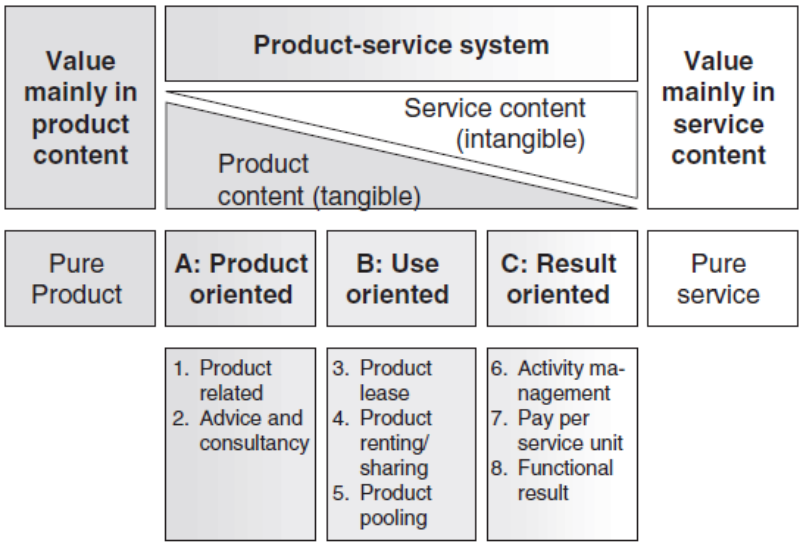


Figure 2.6: PSS categories (Source; Tukker, 2004)

The first category of PSS, Product-oriented services, consists of Product-related and Advice and consultancy types of PSS business models. In this first category of PSS, the business model concentrates on selling products with added services. Use-oriented services are the second category of PSS comprised of Product lease, Product renting/sharing and Product pooling types of PSS business models. Here, the business model is about product ownership. The provider has ownership of the product and is made available for users on a rent basis. Result-oriented services consist of Activity management, Pay per service unit and Functional result types of PSS business models. In this third category of PSS, the user and provider have agreements on the result of the service. PSS business model from use-oriented (product renting/sharing and pooling) and result-oriented (functional result) agree from a sustainability perspective to develop and implement PSS.

The PSS concept can minimize environmental impacts of consumption and benefits consumers, manufacturers, government and society. For consumers, PSS provides a choice of service selection, reduces the responsibility of product maintenance, ownerships, storing and disposal, multiple payment options, product and service customized offers, involvement in designing a

product and learning environmental impacts of consumptions (Mont, 2002) (Baines et al., 2007).

For manufacturers, PSS enhances market opportunities with added services, continuous information flow and customer preferences that improve relationships (Mont, 2002). A manufacturer, companies or producer is responsible for their product and services in recycling and minimizing resources through lifecycle (Baines et al., 2007). Moreover, manufacturers can reduce the cost by their innovative use of technology, energy and resources in delivering value-in-use. As PSS is more service-oriented, optimization can be achieved in packaging and delivery processes (Manzini & Vezzoli, 2003).

For government and society, PSS aid in formulating policies to encourage sustainable lifestyles and in understanding stakeholders' networks and relationships. Baines et al. (2007) pointed out that adoption of PSS reduces material resources in production and public pressure on environmental concerns. For example, Sweden and Netherlands have been promoting sustainable businesses. PSS might be a promising and strategic option for economic growth (Meier et al., 2010).

The successful examples of PSS implementations were mentioned in the PSS literature (Roy, 2000) (Baines et al., 2007) (Beuren et al., 2013). For instance: Xerox, price per copy; Parkersell, UK based organization providing lighting system solutions; Electrolux, pay per wash and laundry system; Mobility, Switzerland based organization providing vehicle sharing; Castrol, lubricant service packages; Whirlpool, water purifying system installation in the consumer house who pays value every month; Call a Bike, a German-based company providing a bike lending system.

Reviewing the literature, the authors mention barriers and challenges for adopting PSS (Mont, 2002) (Baines et al., 2007). Consumer acceptance of a ownerless product consumption can be a barrier to PSS adoption (Mont, 2002). Manufacturers concern would be the change in organization practices internally and externally, which facilitate time and money (Morelli, 2002) (Baines et al., 2007). PSS design involves products, services and other supporting elements that involve the expertise of different domains (Morelli, 2002). For example, product design needs expertise from product developers and technicians that includes materials and dimensions. In contrast, service design needs expertise from marketing, service providers and managers. These could be barriers for PSS design and development, which requires co-creation and continuous involvement of all stakeholders. Goedkoop et al. (1999) mentioned, the

business model of companies' value proposition entirely lies in product quality control. In contrast, service providers could directly contact the clients, not the technical sale of products (Goedkoop et al., 1999). These could be the reasons for companies or service providers might not accept the PSS. A list of articles reviewed for the PSS concept and their subjective descriptions tabulated in Table 2.2.

Table 2.2: List of articles reviewed for PSS concept and their subjective descriptions

References	Subjective descriptions
Goedkoop et al. (1999)	The first Uauthor publication on Product Service System concept, PSS scope, characteristics and driving forces, ten examples of PSS, quantitative analysis of PSS
UNEP (2002)	PSS theory and practices
Roy (2000)	PSS theoretical background discussed, outlined four types of PSS
Mont (2002)	PSS concept clarification, functional economy discussion, PSS benefits, barriers, elements and classifications
Morelli (2002)	Exploration of methods for PSS, PSS design and management process, service design and management model presented
Manzini and Vezzoli (2002)	Use of strategic design approach, sustainable product-service system development, PSS elements and characteristics
Maxwell and Vorst (2003)	Development of sustainable product-service system, two case studies, criteria for optimizing sustainability in product and services
Tuckker (2004)	Presented eight types of PSS, PSS categories, value elements of PSS
Tuckker and Tischner (2006)	PSS research directions and agenda, a transition towards sustainable PSS, PSS review
Aurich et al. (2006)	Presents technical service design process, lifecycle-oriented design, a framework for the technical PSS, properties and functions of technical services, process modularization and case study
Morelli (2006)	Methodologies and operational tools for developing PSS, actors network identification, PSS structure representation
Baines et al. (2007)	PSS literature review, PSS features, PSS applications, PSS benefits and barriers, PSS tools and methodologies, research challenges and future scope in PSS
Maussang et al. (2009)	PSS design methodologies, PSS elements, functional block diagram representations and scenarios
Meier et al. (2010)	PSS in the industrial context, industrial challenges, Industrial PSS framework, business models of Industrial PSS, risks and uncertainties in Industrial PSS

2.1.2 PSS Business Models

Due to increased competition and to sustain in the business environment, organizations finding alternative ways to conduct business. Barquet et al. (2011) point to PSS as an alternative and innovative business model, because PSS includes products with services as a system to fulfil customer's needs (Barquet et al., 2011). Often business model is discussed and mentioned within the PSS literature. Therefore, this section reviews PSS with an emphasis on business models.

The most widely cited review articles on the PSS business model concept were Zott et al. (2011) and Reim et al. (2015). Zott et al. (2011) reviewed the business model concept in the

academic literature and mentioned that: The business model concept has been developing according to the researchers' interest such as viz. e-business and utilization of information technology, strategic issues, innovation and technology management in the organizations. The analysis of the business model concept is different from product, service, industry and network. Business model is about emphasizing how a firm does business and creates value. It is a system-level and holistic representation of a firm's business; the activities of an organization and relationship with its client's concerns. Business models explains about value capture and value creation (Zott et al., 2011). Reim et al. (2015) investigated and classified the business models related to PSS topics. They suggested operational-level tactics which could be considered in the implementation of the PSS business model. Their operational-level tactics include contracts, marketing, networks, product and service design and sustainability operational tactics (Reim et al., 2015).

Within PSS business model literature, the organizations and enterprises have lagged in structuring knowledge in development of PSS business models (Mont et al., 2006). Moreover, PSS business models have been developing for business-to-business sectors and overlooked the business-to-consumer sectors. Besides, information about shifting from traditional business models to PSS business models is limited (Barquet et al., 2013b) (Adrodegari et al., 2017). The comprehensive PSS business model that describes product-service offerings in the PSS literature is limited (Gaiardelli et al., 2014). The organizations' prime challenge is identifying the required changes in their business logic (Barquet et al., 2013b). More recently, the authors mentioned that PSS business model understanding and implementation into practice are needed from a design management perspective. Studies related to planning and ideation of business models within the PSS literature are also limited (Adrodegari et al., 2017) (Kwon et al., 2019). The changes required in shifting towards a PSS business model are driven by product and services development, production, marketing and distribution (Barquet et al., 2013b). Business logic is the common point in both the traditional and PSS businesses. Hence, the business model concept is appropriate to discuss, describe and employ in PSS.

A product-service system (PSS) is "a system of products, services, infrastructure and network support that continually strives to be competitive, satisfy customer needs and result in less environmental impact than traditional business models" (Mont, 2002). This definition characterizes a PSS as a comprehensive business model. The literature asserts that how a company creates and captures value through integrating products and services is the essential

tactic to consider when designing and implementing the PSS business model. Moreover, it is essential to consider how an organization or business organizer creates value for its customers? Who are the customer segments that benefit a value from a business model? What are the internal and external activities of an organization? How to interface and maintain relationships with clients? What are the costs incurred to create and produce value? What are the financial benefits obtained from a value? For instance, Barquet et al. (2011) identified and classified PSS business model characteristics. Besides, the PSS characteristics need to be addressed for implementing the PSS business model. Their study was based on the literature review, considering three types of PSS and nine business model elements. Further, characteristics of PSS are sorted with nine elements of the business model.

Barquet et al. (2013) proposed the framework for adopting PSS by employing the business model concept. The framework consists of three parts viz. business context, PSS types and the PSS characteristics. Literature review and case study method were employed to develop a framework for the PSS business model. Further, this methodology was deployed into four stages viz. the identification of characteristics and typology of PSS, the investigation of business model concepts, the development of the framework and the framework's application utilizing a case study. The study conducted by Barquet et al. (2013b) a machine tool manufacturer's case was illustrated using the proposed framework to identify opportunities for PSS adoption (Barquet et al., 2013b).

Gaiardelli et al. (2014) focused on the value proposition business element and proposed a product-service offering classification model. It is insisted into consideration for B2B and B2C domains. The Product-Service (PS) offering classification model and its dimensions are derived from the literature. In their study, the PS offering model consists of three dimensions such as viz. PS offering orientation, the focus of the PS offers, and interaction between the customer and the PS provider. To illustrate the application of the proposed PS offering classification model, a case study of the heavy truck industry was considered (Gaiardelli et al., 2014).

Applying the business model canvas approach to PSS, Adrodegari et al. (2017) developed a two-level hierarchical framework. The first level includes the perspective of the business model to provide a holistic PSS business model. The second level includes specific variables that describe each business model's dimensions and are associated with managerial challenges (Adrodegari et al., 2017). The specific variables are related to the nine elements of the business

model. For instance, the business model's value proposition element consists of specific variables viz. value for the customer, creation of value, product ownerships and service offerings. A set of predefined building blocks and morphological analysis by Kwon et al. (2019) investigated the PSS business model's possible patterns. Their study includes the nine elements of the business model derived from Osterwalder and Pignuer. The morphological chart identified strategies for each element of the business model. A hairdryer manufacturer case study was employed to demonstrate the modelling benefits of business modelling using the proposed morphological chart.

Service design methods and approaches have been utilized in PSS business models. Lay et al. (2009) proposed a framework that provides the classification of new service-based business concepts. In their study, authors believe that the framework acts as a structured tool in designing new service-based business concepts of business-to-business manufacturing markets (Lay et al., 2009). An exploratory survey conducted by Adrodegari et al. (2015) proposed a framework to identify the types of PSS business models in understanding the shift toward a service-oriented business model (Adrodegari et al., 2015). The business that refers to functional sales is service-oriented. A framework developed based on the business model canvas approach and survey results are of qualitative. Besides, their study was limited to specific sectors such as automation, transportation and machinery. Prendeville and Bocken (2017) analyzed the service design role in facilitating a sustainable business model. An exploratory study was conducted in their research through a literature review to illustrate five case studies. The case studies include B2B, B2C markets, as well as start-ups (Prendeville & Bocken, 2017). However, the research lacks into considering nine elements of the business model in the cross-case analysis.

Nevertheless, there are some constraints to business model innovation. First, regulatory norms constitute support from legislation and societal institutions to enhance the development of sustainable business. Second, market and financial constraints include market risk, stakeholders' value and awareness of sustainable products/services among customers. Third, behavioural and societal constraints include attitudes within the organization, value proposition and perception of customers. Other barriers to business model innovation are competitive pressure, cost structures and technology utilization within business environments (Holtström et al., 2019). Table 2.3 represents some of the case studies mentioned in the reviewed article on PSS business models.

Table 2.3: Case studies considered in the PSS business model

References	Case study
Mont et al. (2006)	Leasing of baby prams.
Lay et al. (2009)	Multiple case studies were considered that provide product-related services.
Barquet et al. (2013)	A machine tool that produces pressure forming and plastic bag machines was employed to demonstrate the proposed framework.
Xing and Ness (2016)	Soniclean, a small-sized firm operational in Australia as a supplier of Ultrasonic cleaning products and equipment, was considered a case example.
Adrodegari et al. (2017)	An automation solutions supplier named KINE was undertaken as a case study for production processes such as material handling, welding, measuring and packing.
Prendeville, and Bocken (2017)	Five case studies presented: laundry services, clothing and apparel, mobile technology, furniture and telecommunications.
M. Kwon et al. (2019)	A hairdryer product case example was employed to demonstrate business modelling in South Korea.
Holtström et al. (2019)	Apparel (sportswear) retailer business model development.

2.1.3 PSS Requirements

With the increased competitiveness in the business environment, products and services requirements determine what companies supply. Therefore, decision-makers or designers must practice co-creation in fulfilling needs and demands. PSS concepts include the involvement of customers in the design process. In the initial studies on PSS design and development, researchers considered PSS requirements as a vital phase. It shows the significance of requirements in PSS. For example, the proposed design process of PSS, by Morelli (2002), includes exploring functional requirements in the problem phase.

Moreover, the design activity in the PSS design process must include defining the requirements (Morelli, 2006). Aurich et al. (2006) proposed technical service design, and their first step includes identifying customer demands. Customers express their experiences and provide feedback on the usage of services, which could be extracted using technical resources to meet customer demands (Aurich et al., 2006). However, a systematic process of describing customer demands was missing in their proposed technical service design process. Therefore, the designer's initial step of the PSS activity must cover customers' needs, expectations and other stakeholders in the PSS life cycle (Maussang et al., 2009).

The PSS requirements are diverse based upon their characteristics and features (Song, 2017). In other words, PSS are heterogeneous because PSS includes tangible (product, physical) and intangible (service) requirements. In contrast with tangible requirements, intangible requirements are more difficult to elicit and prioritize. PSS requirements have several stakeholder's perceptions and experiences that are difficult to capture. Here, decision-makers

or designers have to convert into product and service design characteristics. PSS involves several stakeholders and has different value propositions, which may cause conflicts between requirements (Song, 2017).

Within the PSS requirements literature, the significant studies are related to extracting, understanding, translating and prioritizing customer requirements. Moreover, some of the studies also cover challenges faced while identifying requirements, understanding information requirements, organizational requirements and analyzing PSS requirements.

Several methods and approaches have been utilized in PSS requirements identification and elicitation (Shimomura et al., 2018) (Song, 2017). Such as questionnaires, interviews, surveys, ethnography, personas and scenarios. Researchers developed their methodology for PSS requirements such as Requirements Diagram (Durugbo et al., 2010); Requirements template or checklist (Müller et al., 2010); Industrial customer activity cycle (Song et al., 2013); Requirements Data Model (Berkovich et al., 2014). Kimita and Shimomora (2014) suggest that designers must emphasize customers' requirements rather than benchmarking strategy in developing integrated products and services.

Often customer's express needs and demands in non-technical characteristics, which could not be utilized directly in the PSS design. To address this issue, researchers used several methods for requirements conversion (Song, 2017), such as Quality Function Deployment (QFD), fuzzy mapping, support vector machine and combination of rough set theory with multi-criteria decision analysis.

A graphical modelling language named Systems Modelling Language (SysML) was presented for analyzing PSS requirements (Durugbo et al., 2010). It helps in representing a combination of products, data, people and facilities as a system. Durugbo et al. (2010) presented a requirement diagram for the types (product-, use- and result-oriented) of PSS with the case example in the automotive industry. Furthermore, Durugbo et al. (2010) argue that the proposed requirement diagram can aid in initial requirements traceability during system design. Nevertheless, decision-makers can explain the rationale during the design process. However, SysML is notations for systems and a visual representation but not a methodology, which could be challenging to accept in the research community.

A checklist of requirements was proposed by Müller et al. (2010). This checklist could aid in PSS planning and development. The presented checklist is retrieved from the literature on

product, service and information technology development. The requirements checklist was grouped under lifecycle activities, values, actors, contracts, business and operation models, structure, behaviour, services, technical artefacts, information and communication (Müller et al., 2010). However, defining all these requirements with PSS components is challenging.

Geng et al. (2011) proposed a PSS planning framework to translate customer requirements into product-related and service-related engineering characteristics. The PSS planning framework was deployed into following phases: first, a fuzzy pair-wise comparison approach employed to determine initial importance weights of engineering characteristics; second, Data Envelopment Analysis (DEA) method to generate final weights of engineering characteristics; third, fuzzy Kano's questionnaire was used to categorize engineering characteristics into Kano's attributes. Kano attributes refer to changing customer satisfaction and are classified into attractive, must-be, one dimensional, indifferent and reverse attributes (Geng et al., 2011). However, the limitation of this proposed PSS planning framework is the use of the Analytic Network Process (ANP) approach. The ANP approach is complex when there are large numbers of criteria or characteristics in pairwise comparisons due to dependency relationships.

To address industrial customers' requirements elicitation and prioritization, Song et al. (2013) proposed a framework consisting of two functional parts. The first functional part is Industrial Customer Activity Cycle (I-CAC) for requirements elicitation. This proposed model consists of industrial product lifecycle activities such as before, during and after usage. It comprised of activities analysis, stakeholder's mapping and relationships, customer value identification and construction of hierarchical structure for industrial product-service system requirements. In the second functional part, requirements prioritization was carried out by integrating Rough Group and Analytic Hierarchy Process (AHP) methods. These methods can effectively address subjectivity and vagueness in the requirements prioritization. The proposed methodology can be effective for customer requirements elicitation and prioritization. There are limitations, such as adjustments of expert's judgement when pair-wise comparison matrix fails in the consistency test. It is an iterative process and time consuming and requires more application-based studies to validate.

Raja et al. (2013) conducted and exploratory study to understand customer satisfaction using integrated product-service offerings and the value-in-use (Raja et al., 2013). Value-in-use is regarded as the customer's outcome and impacts for the integrated products and services. In their study, the Repertory Grid technique from psychology was employed to collect interview

data. From this technique, the authors defined attributes of value-in-use, such as access, contract, administration, conveniences, cost, environment, delivery, relational dynamic, knowledge, quality of improvement, range of offering, risk, service orientation, support system and inventory management. Then, Honey's procedure utilized for analyzing the collected data and identified impacts on the attributes of value-in-use. As a result, access and relational dynamic could influence customer satisfaction (Raja et al., 2013).

Berkovich et al. (2014) proposed a requirement data model and named as RDMod. It appears to be addressing requirements for PSS at different levels of abstraction, such as goal, system, feature, function and component level of abstraction (Berkovich et al., 2014).

A context-based customer requirements extraction that could influence the PSS design was proposed by Nemoto et al. (2015). The concept of context refers to the interactions in-between person, product or computer. In their study, the context-based activity of the requirement analysis process comprised three steps. First, designers develop a social scenario by extracting contextual elements from environmental attributes (social trends, economic circumstances, technology direction and public consciousness). Similarly, designers develop a persona from customer attributes (personalities, knowledge, skills, and relationships) in the second step. These environmental and customer attributes are regarded as invariables and long-term. Finally, in the third step, designers extract some environmental and customer states elements to elaborate on product/service use. Environmental states consist of season, temperature, weather and location. Customer states are health conditions, humour and behaviours. These environmental and customer states are regarded as variables and short-term. Authors argue that by analyzing these contexts and scenarios, designers can identify customer requirements. However, this context-based activity ultimately depends upon designers' knowledge and experience in identifying customer's needs.

Shimomura et al. (2018) proposed a methodology to identify customers' orientations and requirements in designing PSS (Shimomura et al., 2018). It integrates approaches of the topic analysis, persona and scenario. The method comprised of following steps: collect data about customers' requirements with open-end questionnaire; Latent Dirichlet Allocation (LDA), which is a topic model to analyze a potential topic, estimates topic rate and cluster the document; then classify the topics based on topic rates; construct the personas followed by scenarios development to clarify the context; finally, analyzing the scenarios to describe each personas requirement (Shimomura et al. 2017). It applied for testing in the urban development

project to improve the downtown area. However, requirements selection and repetition among the clusters were missing in their study.

More recently, the challenges faced while identifying requirements in the PSS context was explored by Nilsson et al. (2018). Challenges that need to be addressed for setting requirements of product-service offering development are identification and inclusion of stakeholders' aspects throughout product-service offering lifecycle; requirements structure and communication with the design team; prioritization of requirements. The other major challenge is to consider less trendy and informative requirements into the development process (Nilsson et al., 2018). Nilsson et al. (2018) identified these challenges from literature review and interviews with three manufacturing companies.

To sum up, the requirements identification and analysis have been considered essential phases in PSS design. On the contrary, existing studies lack requirements identification and testing within PSS research (Nemoto et al., 2015). The requirements engineering process includes elicitation, analysis, documentation and validation. A clear understanding of integrating the planning, developing, delivering and using products and services is essential for PSS design (Müller et al., 2010). To effectively implement PSS, requirements elicitation and prioritization must be included in the PSS design process (Vasantha et al., 2015).

2.1.4 PSS Design

The significant studies in Product Service System (PSS) are most related to the design of integrated solutions. To put it in simple words, most of the studies in PSS advances the design and development of combining products, services, networks and infrastructures. This section provides an overview of PSS design and the design processes presented in the literature.

The design of PSS has evolved from product orientation (Engineering design) to customer orientation (Service design). Tan et al. (2010b) mentioned the different types of services spanned between engineering design and service design (Tan et al., 2010b). As shown in Figure 2.7, these are viz. design for serviceability (product use services), design for supportability (product life services) and design for service (customer activity services). Design for serviceability or maintainability covers the activities of repair, maintenance and warranty of the product. The essential concerns in the design for serviceability are: adapting to the several changes in the lifecycle, continuous development of products and integrating maintenance information. Design for supportability includes the activities related to the after-sales of the

product. It covers installation, training, auxiliary input, documentation, availability and customer consultation. Design for supportability provides value to customers and manufacturers essential resources and competencies. Design for service covers not only the activities of a product lifecycle but also the customer activity services. It includes designing, specifying, measuring and operating with the product and service development.

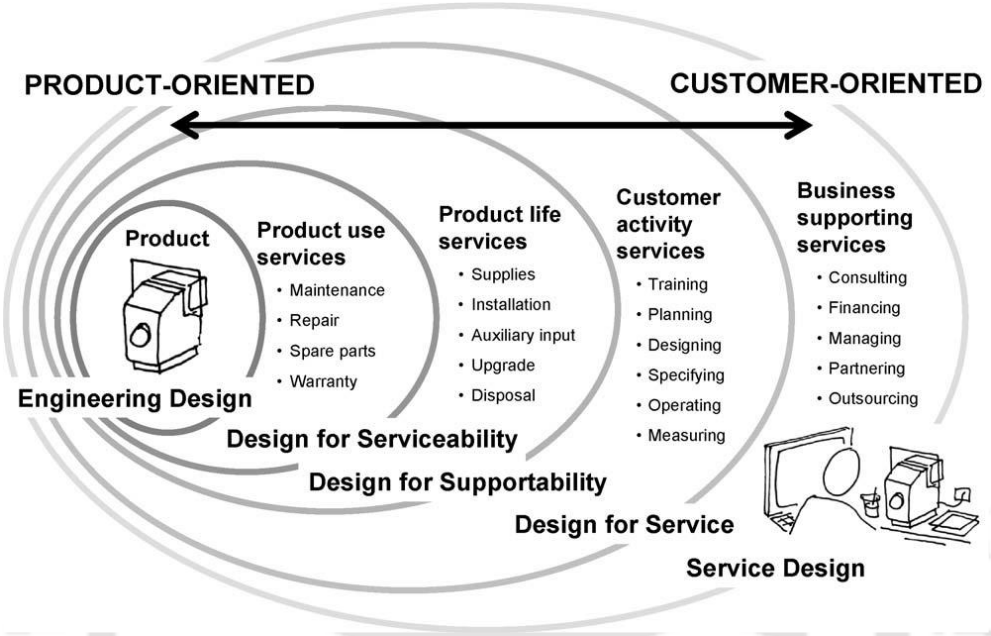


Figure 2.7: PSS development approaches with types of services (Source: Tan et al., 2010)

Aurich & Fuchs, (2004) proposed an integrated design process that constitutes product-related technical service design. They developed a process model based upon modularization. Their study combines the product design and service design processes and demonstrated using the investment goods industry as the case example (Aurich & Fuchs, 2004). As shown in Figure 2.8, the proposed technical service design process includes demands identification, feasibility analysis, concept development, service modelling, realization and service testing. The authors suggest that the exchange of design information between design activities could enhance the success of integrated solutions. The three functions of technical service considered in their study were support functions (inspections, maintenance and repair for customers), requirements fulfilment (contracting and teleservice for customers) and information procurements (experiences, expectations or suggestions from customers).

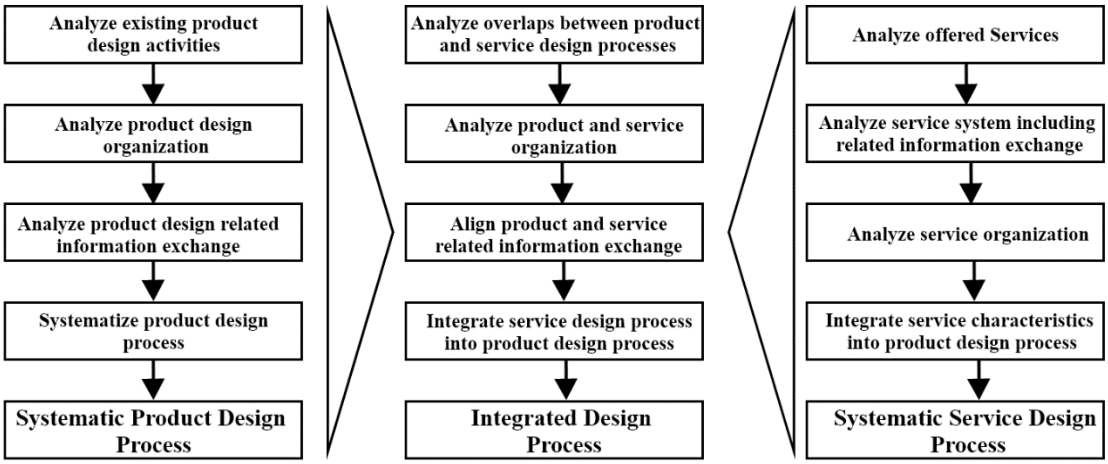


Figure 2.8: PSS technical service design process (Source: Aurich & Fuchs, 2004)

Morelli (2002) proposed the PSS design process that supports the development of services. They adapted the logical sequence in the concept development phase proposed by Ulrich and Eppinger (2000) to develop services. It consists of two spaces or dimensions, as illustrated in Figure 2.9; a problem space where functional requirements are identified and a design space where solutions are proposed.

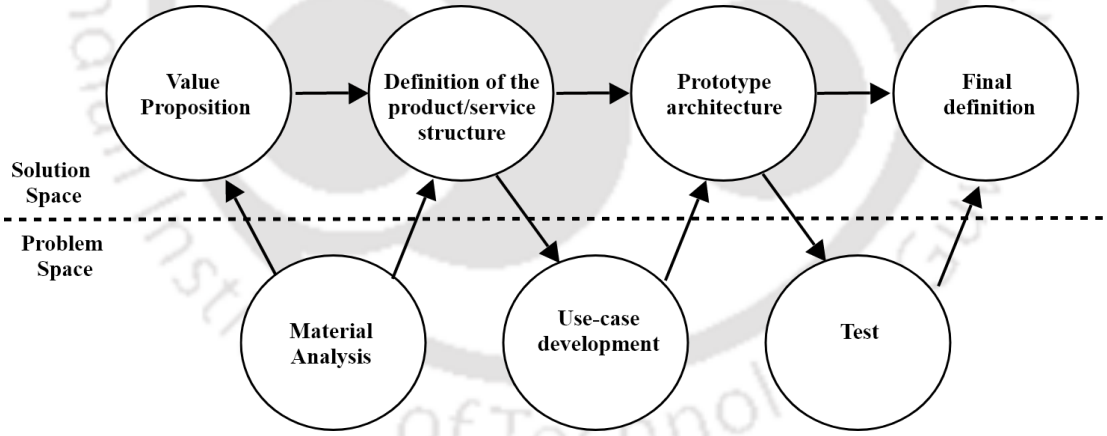


Figure 2.9: Design process for the development of service (Source: Morelli, 2002)

Alonso-Rasgado et al. (2004) coined Total Care Products (Functional Products) for integrated solutions. According to them, Total Care Products are an integrated system that constitutes hardware and support services (Alonso-Rasgado et al., 2004). The provider of functional products offers a support system to the customers to keep hardware operational. Here, support systems are services. The proposed design of a service support system for a functional product

is illustrated in Figure 2.10. It consists of five stages: concept generation, identification of sub-systems, integration of sub-systems, service system modelling, testing and implementation.

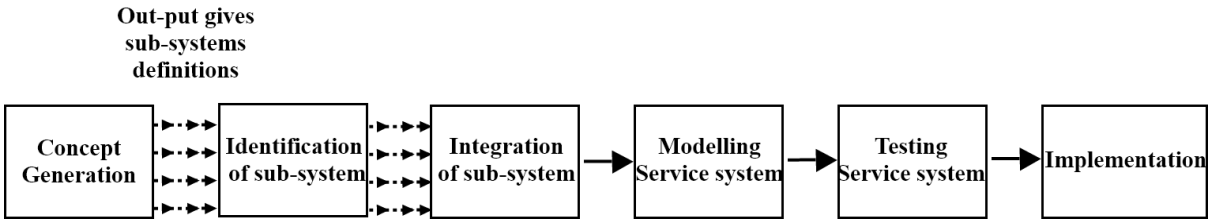


Figure 2.10: Design process of service support system for a functional product (Source: Alonso-Rasgado et al. 2004)

The product design process for services begins with collecting customer needs, prioritizing requirements and developing concepts (Alonso-Rasgado et al., 2004). Alonso-Rasgado et al. (2004) suggest that concept generation of a functional product should involve customers in the design process. Functional product concept generation is a continuous iterative process. It involves customers and providers exploring product potentials and customer expectations simultaneously. The authors mentioned that four sub-systems could be identified in the identification and integration of sub-systems. These are viz. planning operations, product maintenance, data storage and decision-making, and service processing. Modelling service systems can be achieved by using computational models. Here, the functionality of the service system is tested. The criteria considered were time taken for the service, the quality and the information flow. The functional products testing includes determining the service system outputs for the given inputs. The implementation stage involves extensive testing and training.

A service is defined as “an activity that changes the state of a service receiver” (Shimomura et al., 2009) (Shimomura and Arai, 2009). The contents and channels are the realizations of a service that changes receivers’ state. Usually, contents are material, energy and information. Whereas channels are transportations, amplify and control service contents (Shimomura et al., 2009) (Shimomura and Arai, 2009). Therefore, service engineering focuses on services by maximizing the value and minimizing the environmental impacts. It involves service delivery, service creation and service consumption. They stated that a set of parameters could represent a receiver’s state change as Receiver State Parameters (RSPs).

Shimomura et al. (2009) proposed the view model. It handles functions and attributes to represent RSPs. For developing PSS, the authors proposed a unified representation scheme by extending the service blueprint, as depicted in Figure 2.11. It consists of three stages, such as

customer value identification, service content designing and service activity designing. The proposed methodology was demonstrated using an example of an elevator operation service. The Quality Function Deployment (QFD) method was employed in their study to evaluate a service.

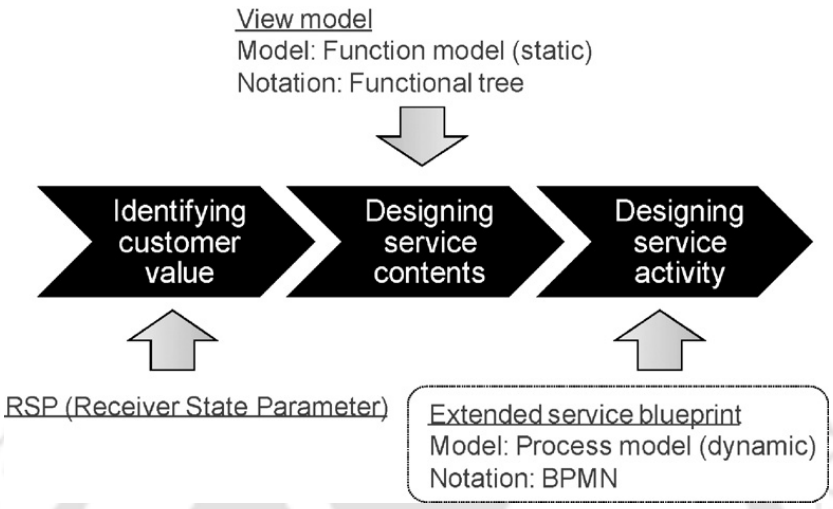


Figure 2.11: Receiver state parameter, view model and extended service blueprint (Source: Shimomura et al., 2009)

Sakao et al. (2009) developed a prototype for developing a service and named it a 'Service Explorer'. It can help designers in describing and operating design objects (Sakao et al., 2009). The authors argue that a service must be designed based upon customer satisfaction, value and receiver's state change. Therefore, they developed a service model that constitutes flow model, scope model, scenario model and view model. Figure 2.12 illustrates the four sub-models and relationships among them. Flow model (who) identifies the agents between a service provider and receiver of a service. Scope model (what) specify the range of service between a service provider and receiver. The scenario model (why) is for representing the receiver's behaviour and property. The scenario model can be developed using the Persona method. The persona method identifies imaginary target users and consists of demographic and psychological data. View model (how) represents the service elements relationships.

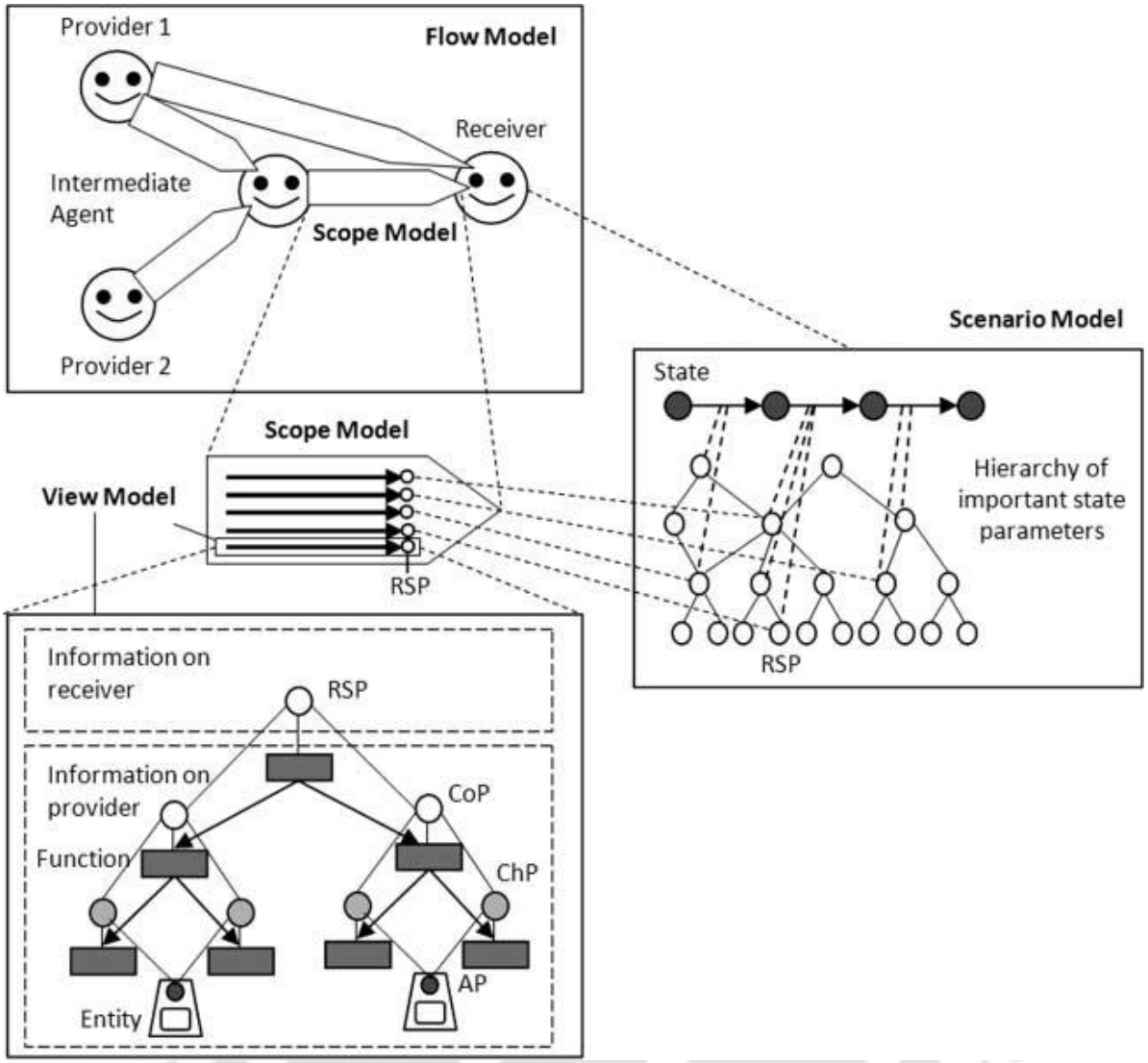


Figure 2.12: The four sub-model of service and their relations (Source: Sakao et al. 2009)

Sustainable trends in servitization have progressively increased over the last couple of decades. Developing a service process model is essential for academic and business organizers. As a design practice and research area, service design has developed into a design-led approach to service innovation (Yu and Sangiorgi, 2018b). Literature indicates that service innovation is more about improved customer experience, processes and actions (Fließ and Kleinaltenkamp, 2004), (Lee, Chen and Trappey, 2019). It involves human actors, physical resources/technologies and processes (Chen and Cheng, 2012) (Costa et al., 2018). The study on the new service development process by Froehle and Roth, (2009) includes resources and a process-oriented framework. Resource-oriented new service development practices emphasize

developing intellectual, organizational and physical resources. At the same time, process-oriented new service development emphasizes design, analysis, development and launch.

Within design communities, Service design is conceptualized as design-centred contributions to service innovation based on a human-centred perspective and creative methods (Yu and Sangiorgi, 2018a) (Wetter-Edman et al., 2014). Service design was influenced by emotional design, design thinking and contextual design. Yu and Sangiorgi, (2018a) argues that design impacts on product innovation are generally related to the attributes of physical objects, while design impacts on service innovation require different dimensions. Service design has also been examined as a set of collaborative and cross-disciplinary activities for service innovation (Patrício et al., 2011).

Vasantha et al. (2010) reviewed PSS design methodologies and presented a maturity model. The presented maturity model describes the concerns in the PSS domain and analysis of PSS methodologies (Vasantha et al., 2012). As a result, among twenty dimensions in the maturity model, the PSS literature most emphasises the three areas. These are viz. design process of integrating product and services, planning and designing lifecycle phases and defining PSS and elements. The authors suggest that other dimensions need substantial consideration and development. These are detailed requirements analysis and prioritization, stakeholders' definitions and involvement in the design process, creation of PSS business models, PSS evaluation, and PSS monitoring and implementations issues.

2.1.4.1 Existing PSS Design Models/Frameworks

Through the literature review, we searched for publications focused on the design and development process in PSS. In particular, PSS design models or frameworks proposed a structured plan of actionable to provide designers in developing new PSS. Table 2.4 shows the summary of existing design models for a PSS development. Table 2.5 briefs purpose/rationale, methods and case studies in designing and developing the existing PSS design models.

Developing an integrated framework of product and services have exponentially increased and become an essential topic. This is due to the research interest in academia, widespread PSS application and benefits (Geum et al., 2011). Globalization has brought new opportunities and challenges. Thus, innovation to create business value is the focal issue for organizations and companies (Lee & AbuAli, 2011). Innovation in the perspective of management is to develop

customer-centric ideas. Innovative thinking is challenging for an organization due to a lack of considering methodology and tools systematically.

Bertoni et al. (2013) mentioned three prime routes for PSS development: First, the accumulation of service operation into product development. Second, the development and management of tangible products result from accessible services to the offering of modified products. Third, enhancement of methods, tools and approaches from another domain in developing PSS (Bertoni et al., 2013). The development of a PSS model involves the participation of several actors (Morelli, 2006). Its effectiveness is based on ideas, vision, perceptions and shared values. This design activity includes target goals, expected results and problem-solving criteria. As a result, the designer has to identify the actors involved in the network, develop possible scenarios, use cases, sequence of actions, a PSS requirement and organizational structure of a PSS. In addition, management tools to represent a PSS through tangible products, intangible services, logical links and sequences. Sakao et al. (2009) mentioned the importance of servitization in their study. Sakao et al. (2009) also highlighted the trend of shifting from the consumption of physical products to solution-based services. The concept of combining products and services as a whole system attracted attention in academia and industrial applications. This concept is named Total Care Products, Functional Sales and Product Service System in literature (Sakao et al., 2009).

Table 2.4: Existing PSS design models/frameworks

Author(s) & Year	Descriptions
(Morelli, 2006)	The methodological approach is proposed in designing PSS for designers. Author addressed the role of designers in defining attractive and practical PSS. Author proposed methods to define a mapping of actors (companies, institutions, and end-users) involved in the PSS, requirements, and structure of a PSS, PSS representation, and a blueprint.
(Sakao et al., 2009)	A software application prototype naming ‘service explorer’ was developed to support designers in describing, operating design objects, and generating new ideas in the conceptual phase.
(Kindström & Kowalkowski, 2009)	A four-stage framework for the service development process is constructed. This framework is based on market sensing, development, sales, and delivery. The developed framework is related to manufacturing sectors and focused on product development and sales.
(Maussang et al., 2009)	The proposed methodology is based on functional analysis to support engineering designers for the development process of PSS as a whole system.
(Geum et al., 2011)	The framework is based on technological interfaces and consists of five steps in three main stages. The first stage is the structural determination of ‘what to plan’; the second stage is the functional determination of ‘how to plan,’ and the third stage is road mapping.
(J. Lee & AbuAli, 2011)	Systematic thinking and PSS design methodology are proposed based on the dominant design concept for products and processes.
(C. H. Lim et al., 2012)	A structured tool is proposed for companies to visualize the PSS process.

(Berkovich et al., 2014)	A requirement data model (RDMOD) is proposed for describing types of requirements and relations in PSS. This proposed model helps structure the requirements, enable traceability, and for finding conflicts.
(Hussain et al., 2012)	A framework is proposed for designers in developing PSS conceptual design through the system-in-use data.
(Y. S. Kim et al., 2013)	A comprehensive framework for the blood donation PSS case is illustrated of PSS design methods and process. This process consists of four steps into a comprehensive framework: value modeling, service activity design, service interaction, and experience management.
(Ana Paula Bezerra Barquet et al., 2013a)	The business model concept's practical use as a foundation to develop a framework and implement product-service systems. The developed framework was based on the literature review. Also, it aims to guide the company on three variables: business context analysis, PSS type selection, and PSS characteristics definition.
(Rapaccini et al., 2013)	A maturity model is proposed for manufacturing companies that offer product services. The maturity model is a roadmap or direction for improvement to a specific domain.
(Marques et al., 2013)	The design methodology, as a parallel sequence of activities for product and service development. The proposed methodology consists of four phases: organizational preparation, planning, design, and post-processing.
(Bertoni et al., 2013)	A representation tool named Lifecycle Value Representation Approach (LiVReA) for designers in enabling value information into visual features is proposed. This approach utilizes color-coded 3D CAD models.
(Tran & Park, 2014)	The proposed design methodology for PSS involves customer co-creation, business model, and organizational structure. Besides, this methodology is generic and applicable to different types of PSS. Its generic approach aid in designing PSS effectively for practitioners and designers. The types of PSS available in the literature are product-oriented, use-oriented, and result-oriented.
(Zine et al., 2016a)	A conceptual framework of the PSS design process is proposed for machine tools—moreover, PSS implementation issues concerning the Indian machine tool business context.
(Pezzotta et al., 2015)	A five-stage framework of service engineering is proposed for designing and assessing integrated product service. Idea, value, process, simulation, and monitoring are the five stages of the product-service engineering framework.
(Muto et al., 2015)	A PSS design guideline is proposed for designers in managing the PSS design process.
(Joore & Brezet, 2015)	A Multilevel Design Model is proposed for analyzing and describing the PSS design process.
(Trevisan & Brissaud, 2016)	The modeling framework is proposed for product engineers and service designers, where integrating product and service models is challenging in PSS design. Also, to support the detailed phases in this context.

The shift towards PSS from the traditional sale of products depends on developing PSS capabilities, which is different from the traditional manufacturers' perspective (Rapaccini et al., 2013). In contrast, the service processes are under-designed and ineffectively employed in the business context with product development processes. The trend of product differentiation is shifting towards service differentiation by integrating product-services (Marques et al., 2013). This is the new competitive advantage for organizations. Through integrating products and services into a whole system provides added value to the product-service life cycle.

Tran and Park (2014) pointed out that the existing PSS design methodologies have limited industrial application. It is due to the ability to explain the design process and practical guidance

to PSS designers (Tran & Park, 2014). Trevisan and Brissaud (2016) mentioned that the PSS design and development processes proposed in the literature follow the combination of product and service engineering steps. However, the proposed methodologies converge towards the three phases, such as the strategic phase, product/service design phase and implementation phase. The strategic phase constitutes identifying needs, defining requirements, strategic analysis with PSS conceptual design and selection. The product/service design phase includes concept development, embodiment design, detailed sub-systems and testing (Trevisan & Brissaud, 2016).

Table 2.5: Existing PSS design models/frameworks purpose, methods and case examples

Author & Year	Purpose/Rationale	Methods/Tools/ Approaches	Case Study
(Morelli, 2006)	The designer's role in designing PSS plays a crucial role. The PSS design process needs to consider product design aspects, communicational, economic, and social aspects.	IDEFO (Integration Definition for Function Modelling), Service Blueprint.	TeleCentra project (development of a neighborhood center, development of a physical and virtual office)
(Sakao et al., 2009)	The practical and efficient service activity design with products utilizing computer systems is missing in the literature of PSS concepts.	Service CAD & Service Explorer (Flow, View, Scope and Scenario models)	Manufacturing business- selling washing machine, pay per wash, and cleaning washing machine.
(Kindström & Kowalkowski, 2009)	Literature on new service development processes addresses, employs and focuses only on the service life cycle's development aspects (idea generation, concept development, and pilot studies).	In-depth interviews and Focus group	Manufacturing Companies located in Sweden
(Maussang et al., 2009)	Engineers focus on the design of tangible products and their interactions with other objects. However, the associated technical services part is neglected.	Functional analysis, Functional block diagram, Scenario	Helium-based refrigeration case
(Geum et al., 2011)	Nowadays, products and services are combined as an offering to the customers. However, this integration is achieved through manufacturing-originated methodologies, i.e., strategic planning of product development.	Quality Function Deployment (QFD), Structural determination, Functional determination, and Road-mapping	Dell customization, U-Healthcare, Xerox case, Automatic teller machine, RFID-based service, Water purifier
(J. Lee & AbuAli, 2011)	Systematic thinking and PSS design methodology based on the concept of dominant design for products and processes is challenging for companies.	Innovation matrix, Space Mapping and Quality Function Deployment (QFD)	Pressure-sensitive technology and self-adhesive solution for consumer products
(C. H. Lim et al., 2012)	The significant four components of PSS are products, services, dedicated infrastructure, and network provider. Understanding these four components and their relationships is complex in the PSS process context. A systematic tool for visualizing this context is missing.	PSS Board (Extended service blueprint)	A car-sharing scheme, a management document solution, and a precise spraying solution

(Berkovich et al., 2014)	An integrated requirement engineering (RE) that constitutes hardware, software, and services in the PSS context is missing.	Workshops, expert interviews, and Documents analysis	Production of electrical appliances (Washing machine and dryers)
(Hussain et al., 2012)	Industries need to close the design loop through product-in-use data into PSS conceptual design for the PSS literature.	Interviews, Ethnography	Laser job shop.
(Y. S. Kim et al., 2013)	To identify and analyze the economic, ecological, and experience value of blood donation.	Value mapping, Context-based activity model, Service Blueprint	Blood donation
(Ana Paula Bezerra Barquet et al., 2013a)	The utilization of business model concepts in developing the PSS for companies is challenging, and the information is also limited in the PSS literature.	Literature review, Business model concept	Machin tool
(Rapaccini et al., 2013)	In contrast, the service processes are under-designed and ineffectively employed in the business context with product development processes.	Workshops, In-depth interviews,	Company A (Sell spare parts for household appliances) Company B (Printing services) Company C (OEM-Printing Equipment's)
(Marques et al., 2013)	Service development methodologies are few compared to product development methodologies. Besides, in the context of PSS, development methodologies provide little attention to service and are complex.	Workshops, CAD 3D by CEIIA	Mobile Care Vehicle
(Bertoni et al., 2013)	The visualization and representation of PSS to optimize value provision of a physical product, from the conceptual phase to the system lifecycle, are limited in the literature.	Workshop, semi-structured interview focus group, Ethnographic and protocol analysis	Aerospace manufacturing industry.
(Tran & Park, 2014)	The methodologies developed for PSS were domain-specific and hence resolved issues in a particular project. Also, it does not represent differences in PSS types and provides guidelines to practitioners and designers.	Customer co-creation, Business model, and Organizational structure	Sanitary project of IDEO.ORG
(Zine et al., 2016a)	The availability of the PSS design process for machine tools in literature is limited.	Exploratory surveys, In-depth interviews.	Indian machine tool business context.
(Pezzotta et al., 2015)	The methods, tools, and service engineering models have been adopted from traditional engineering, business, and computer science for designing and developing product-service systems.	Service CAD and Service Explorer (Flow, View, Scope models, & service blueprint, Business Process Modelling Notation)	The repair workshop of a truck company
(Muto et al., 2015)	Although several PSS design methods and evaluation tools were developed in the PSS literature, a practical framework of the PSS design process for designers in managing substantial design activities or criteria is missing.	Software Engineering Methods and Theory	Software support service for automobile parts
(Joore & Brezet, 2015)	The design or innovation model is missing based on the three demands. Provide insights into developing a physical product or PSS and developing societal changes.	The cyclic iterative design approach and hierarchical system approach	Sustainable Transportation

	Provide insights about the relations between the functional and operational issues, also socio-technical and societal problems. Providing the design process or transition process can be described consistently and mutually comparable, resulting in structuring future design-based initiatives.		
(Trevisan & Brissaud, 2016)	Lack of tools for guiding the detailed PSS design process. In other words, a roadmap for the PSS concept selection to the detailing in solution definition.	Modeling Techniques (result and system models), Functional analysis, Process model, Service Blueprint, and IDEFO model	Pneumatic energy delivery for a manufacturing company (Compressors used for refrigeration system)

2.1.5 PSS Evaluation

The sustainable or effective Product Service System (PSS) depends upon the evaluation phase. This phase is a complex activity because PSS development involves many variables (Vasantha et al., 2015). Researchers focused on measuring and assessing customer needs, product/service requirements, PSS solutions, implementation and performances within the PSS evaluation literature.

About customer requirements evaluation, Song et al. (2013) proposed an industrial customer activity cycle to capture customers' requirements which could be vague and subjective (Song et al., 2013). Their study integrates rough set theory and analytic hierarchy process approach for evaluating PSS requirements. Geng et al. (2011) emphasized PSS planning evaluation by mapping customer requirements to engineering requirements. Engineering requirements consist of product-related and service-related engineering characteristics. A series of approaches were used in their studies, such as the Analytic Network Process, Quality Function Deployment, Data Envelopment Process and Fuzzy Kano's questionnaire (Geng et al., 2011).

Xing et al. (2013) proposed a value assessment model for product-service development. In their proposed value assessment model, measures of technical performances, cost and environmental impacts were considered. The net present value and lifecycle assessment approaches were utilized. In the study conducted by Xing et al. (2013) a solar heating system was considered to demonstrate the proposed value assessment model. Authors argue that it supports selecting and evaluating several product-service developments (Xing et al., 2013). However, the value assessment model is only applicable to the product-oriented type of PSS.

To assess sustainable PSS, Chou et al. (2015) argue that criteria of customer perception, social impact or value and employee perception are missing in measuring the performance of a PSS solution (Chou et al., 2015). To address these concerns, the authors developed multiple criteria of specifications in a hierarchical structure. They defined the efficiency of sustainable PSS as the ratio of product-service value and sustainable impact. Product-service value could be measured by the category of customer and employee perceptions. Similarly, the sustainable impact could be measured by working conditions, cost and consumption. The factors of customer perception category are tangibles, interactions, sustainability and prices. In contrast, commitment falls under the employee perception category. The assessment of a sustainable PSS considers environmental and socio-economic issues along with employee's perceptions.

Lee et al. (2015) focused on measuring the PSS functional performances through a system dynamics approach. In general, system dynamics comprise conceptualization, formulation, testing and analysis (Lee et al., 2015). Based upon these, the authors proposed an analytic scheme of PSS functional dynamics that consist of five steps. Lee et al. (2015) defined PSS functional dynamics as "The functional performance of PSS over time, depicting how the PSS functions and changes over time". In their proposed analytic scheme, the first step is to identify the functional structure of PSS, which is achieved by drawing a functional dependency network of PSS. The second step is to identify intensifying and weakening factors of each function. The third step covers specifying key policy issues, that could be achieved using a causal loop diagram. The fourth step is analyzing the functional dynamics of PSS. Assessing the functionality of PSS and setting the goal and strategy of the firm is the fifth step. However, their study restricts only to the economics of PSS functional performances.

From the viewpoint of customers and providers, Yoon et al. (2012) present an evaluation method for designing a PSS. It involves quantitative and qualitative approaches and is demonstrated using a car-sharing service example. The evaluation factors considered in their study are expected value, intention to adopt and preferred use of service. The evaluation factors for providers are economic, political and technological feasibility, environmental and relationships with competitive providers. Service model feasibility tests and survey methods were employed to present an evaluation guideline for designing a new PSS. The results highlighted that minimizing the usage of car rate could reduce the consumption of fossil fuel, the number of private cars could be reduced by an increase in the number of customers opting for car-sharing services (Yoon et al., 2012).

To validate the performance of a car-sharing service model, Alfian et al. (2014) used simulation techniques and fuzzy classification. The objectives in their study were to provide the best service to customers and maximize the income for car-sharing service providers (Alfian et al., 2014). The criteria for service providers are profit per day, utilization ratio and acceptance ratio. Service models include destination service (round trip, one-way, undeclared) and relocation technique (static inventory balancing, static shortest time, rebalancing). The simulation results highlighted those service models offering the round trip, one-way and static shortest time is the best service to customers. However, the limitation of their study is that considering few relocation techniques and comparison with existing transportation is missing.

In service engineering, contents and channels are the fundamental concepts of services (Shimomura et al., 2008). The functional and entity importance, which are the service's structural elements, could be measured quantitatively. Therefore, Shimomura et al. (2008) proposed a service evaluation method using Quality Function Deployment (QFD) and demonstrated using a cloth washing service. The method consists of seven steps, such as (i) establishing the importance of receiver's state by analytic hierarch process; (ii) creating a service quality table which will be similar to the QFD; (iii) structuring the receivers state parameters and obtaining importance; (iv) obtaining the content of parameters, which is parameters that change in receiver's situational; (v) considering indirect interactions using the DEMATEL method; (vi) obtaining service channel parameters; (vii) deploying the service functions.

An integrated service evaluation framework and a service process model was proposed by Watanabe et al. (2012). The service process model was developed for car-rental service and bike-rental service. In their proposed service process model covers elements such as consumer, organization, natural resources and environment. In addition, a simulation tool to evaluate service processes was presented quantitatively (Watanabe et al., 2012). Determining the meaningful activities of different stakeholders in the simulation process was not considered in their study. To evaluate a PSS, Sun et al. (2012) proposed a product-service performance method. They mentioned that the interrelationship between PSS provider and receiver is referred to as product-service relationships (Sun et al., 2012). Product-Service relationships were described based upon product-service network and product-service chain. The factors considered in their study were time, cost, quality, stability and reliability to measure the product-service performance.

Kimita et al. (2009) proposed a method to measure customer satisfaction in the early stages of PSS, which could aid designers in comparing PSS design solutions (Kimita et al., 2009). To achieve this purpose, the authors proposed two models: the view model and the satisfaction-attribute function (Kimita et al., 2009). The view model is about identifying the customer's state after experiencing the product or services. At the same time, the satisfaction-attribute function was used to quantify customer satisfaction. The satisfaction-attribute function is expressed through regression analysis from survey data. The function parameters considered in their study were expectations, quality and satisfaction. Here, designer's emphasize customer expectations and utilize them in the iterative design process at the conceptual stages. However, customer importance could change over time. Customer's product and service experiences may differ from the competitive advantage available in the market. Their proposed method restricts considering a single case study to express customer satisfaction.

Table 2.6: PSS evaluation perspectives, methods and case studies

PSS evaluation perspective	PSS evaluation methods	Case example	References
Customer requirements	Rough set theory and Analytic Hierarchy Process	Air compressors system	Song et al. (2013)
Customer requirements	Analytic Network Process (ANP). Quality Function Deployment (QFD), Dara Envelopment Process, fuzzy Kano's questionnaire	Metering pumps and related services	Geng et al. (2011)
Customer satisfaction	Questionnaire survey, non-linear function	Domestic in-flight service	Kimita et al. (2009)
Customer acceptance	System dynamics (functional dependency network and casual loop diagrams)	u-healthcare system	Lee et al. (2015)
Product-Service performance	Survey, Product-Service network and chain	Aviation product and related services	Sun et al. (2012)
Service assessment	Simulation	Rental services (car and bike)	Watanabe et al. (2012)
Service assessment	Questionnaire, QFD, DEMATEL	Cloth washing service	Shimomura et al. (2008)
Service assessment	Service model feasibility test, questionnaire	Car sharing service	Yoon et al. (2012)
Service assessment	Simulation techniques and fuzzy classification	Car sharing service	Alfian et al. (2014)
Sustainability	Questionnaire	Conceptual	Chou et al. (2015)
Sustainability	Net Present Value and life Cycle Assessment (LCA)	Solar heating system	Xing et al. (2013)

Table 2.6 represents the evaluation of PSS perspectives, methods and case studies in the literature. Here we can interpret that most of the evaluation or assessment was adopted from the customer perspective, although PSS design involves several stakeholders. Moreover, the

methodology applied in evaluating PSS studies were questionnaire, survey and multi-criteria decision-making methods.

2.1.6 PSS Research in the Indian Context

This section reviews PSS research or studies related to PSS in the Indian context, with the special emphasis to PSS business models, requirements, design and evaluation. We searched the studies or work related to PSS in the Scopus database with the keywords "Product-Service System" AND "India". As a result, 26 documents were found and published as journals, conferences and book chapters (status on September 2021). Eight articles were shortlisted and downloaded to analyze PSS research in the Indian context, after reviewing all the article titles and abstracts. Table 2.7 shows research articles that discuss PSS within the Indian context, emphasizing business models, requirements, design and evaluation.

Table 2.7: PSS research contributions and topics discussed in the Indian context

References	Research contributions	Product Service System (PSS)			
		Business model	Requirements	Design	Evaluation
Sharma and Garg (2010)	A model was proposed to understand the attributes that affect the performances of automobile service centers.			X	
Datta and Roy (2011)	A conceptual framework was presented to address operations strategies in performance-based contracts for manufacturing companies.			X	
Zine et al. (2014)	A hybrid PSS business model was proposed to incorporate value co-creation based upon customization and personalization.	X			
Zine et al. (2016)	A conceptual framework was proposed for the PSS design of machine tools in the Indian context.			X	
Gupta et al. (2015)	A methodology was presented on how to optimize stakeholders' needs to have a sustainable PSS.		X		
Sharma and Kumar (2016)	A methodology was proposed to evaluate PSS offerings based upon the product and service value dimensions.				X
Anand et al. (2019)	A business model was proposed to the Indian car sector based upon the PSS and circular economy.	X			
Banerjee and Punekar (2020)	A process design developed for agricultural machinery			X	

'X' denotes the topics discussed in PSS business models, requirements, design and evaluation

Zine et al. (2014) addressed the customization and personalization for a machine tool with the PSS business model perspective. They proposed a framework on these two issues based upon a hybrid PSS model and co-creation activities. In their proposed framework for machine tools, PSS design comprises of business model and engagement model. Besides, the authors argue that the framework benefits customers, providers and other stakeholders. Benefits for customers are offerings in terms of flexibility and options to customize service requirements (Zine et al., 2014). Whilst benefits for provider and other stakeholders are in terms of knowledge co-creation, based upon customer loyalty and experience.

In contrast with a traditional business model for a car, an alternative business model was suggested that relies on the concept of eco-leasing (Anand et al., 2019). The concept of eco-leasing has emerged from eco-innovation, which is a process to develop products, services and processes. It benefits to customers, organizations and reduces environmental impacts. However, the proposed business model is limited to the conceptual stage in their study.

Sharma and Garg (2010) addressed the after-sale services of the automotive service centre in the Indian context. The automotive sector involves several stakeholders, variants and models, infrastructure, after-sales services and customer demand (Sharma & Garg, 2010). The purpose of their study was to identify interrelationships and critical success factors associated with automotive service centres. The critical success factors were identified through Interpretive Structural Modelling and MICMAC analysis. The authors emphasize enhancing the performance of automotive service centre. Authors argue that the use of technology and employee training are the enablers to improve the performances of automotive service centres and meet customers' needs.

Datta and Roy (2010) addressed the operational strategies for performance-based contracts in the manufacturing sectors for procuring service equipment. As a result, based upon two case studies, the elements that aid in understanding the operations strategy are organizational readiness, performance assessments and contract definitions, which delivers performance-based service contracts (Datta & Roy, 2011). However, for effective service delivery process, which includes service networks and relationships of stakeholders, is missing in their study. A conceptual framework of the PSS design process was proposed for machine tools—moreover, PSS implementation issues concerning the Indian machine tool business context (Zine et al., 2016b). Banerjee and Punekar (2020) developed a process for designing agricultural machinery. In addition, services related to agricultural machinery are based upon sustainability-

orienting design approaches. The process includes five stages viz. strategic product analysis, exploration of opportunities, designing system concepts, and product and system design (Banerjee & Punekar, 2020). However, the proposed process design is qualitative. In addition, the process visualization is complex, time-consuming and requires multi-domain knowledge.

Gupta et al. (2015) utilized a multi-objective genetic algorithm to address the selection of product, service or combination of both. In their study, they proposed a methodology, which is comprised of three equations (Gupta et al., 2015). These equations help maximize profit and social impact functions and minimize environmental functions. To demonstrate the proposed methodology, car manufacturing in the Indian context was considered. However, the proposed mathematical solution has some assumptions and it is in a conceptual stage.

The fuzzy analytic hierarchy process is one among the multi-criteria decision-making methods. It is a systematic process and comprises of set theory and hierarchical structure. Sharma and Kumar (2016) utilized this approach to rank and prioritize quality proportions of products and services with a case example of public transportation. Data were collected from the two stakeholders (public transport providers and equipment suppliers). As a result, the proportions or dimensions of product quality are reliability, durability, features and performance (Sharma & Kumar, 2016). Similarly, the proportion or dimensions of service quality are reliability, assurance and performance. However, process of identification of these product and service quality dimensions is missing in their study.

The majority of the articles reflected the manufacturing and automotive sectors for PSS research in the Indian context. The methodologies for PSS business models were based upon literature review, co-creation theory and comparative analysis. Whereas for PSS design, several approaches and methods were used. Such as Interpretive Structural Modelling (ISM) tool, case study approach, exploratory survey, interviews and Lifecycle assessment approach. Subsequently, articles covering PSS requirements and evaluation are less and methodologies used were multi-objective genetic algorithm and Fuzzy analytic hierarchy process, respectively. Table 2.8 shows the summary of PSS articles reviewed in the Indian context.

Table 2.8: List of PSS articles reviewed in the Indian context

Authors and date	Case example	Methods/Tools/Approaches	Remarks
Sharma and Garg (2010)	Automotive service centers	Interpretive Structural Modelling (ISM) tool	Stakeholders mapping is missing
Datta and Roy (2011)	Manufacturing sector	Literature review and case study approach	Service networks and defining stakeholders' relationships is missing
Zine et al. (2014)	Machine tools	Co-creation theory (involvement of customers and other stakeholders in the design aspects)	Cultural differences and influence may affect or change the stakeholders' requirements
Zine et al. (2015)	Machine tools	Exploratory survey and interviews	The proposed framework is in the conceptual stage
Gupta et al. (2015)	Car manufacturing sector	Multi-objective genetic algorithm	Mathematical solution based upon assumptions. Quantitative studies are needed to validate the proposed equations
M. G. Sharma and Kumar (2016)	Public Transport sector	Fuzzy analytic hierarchy process	How to identify product and service quality dimensions are missing
Anand et al. (2019)	Car eco-leasing	Literature review and comparisons between traditional and suggested business model	The study provides only a conceptual stage
Banerjee and Punekar (2020)	Agricultural machinery	Lifecycle assessment approach and satisfaction-based approach	The study is qualitative, the process visualization is complex, time-consuming and requires multi-domain knowledge

In the Indian context, the studies related to PSS are minimal. There are no comprehensive academic PSS studies conducted and reported in an Indian context. In addition, there is a lack of PSS research examples related to business-to-consumers markets in India.

2.2 Design Methods, Design Thinking and Strategic Design Management

The theoretical background and foundations related to design methods, design thinking and strategic design management are presented in this section. A series of methods from different disciplines are discussed, these are viz. strategic management, design management, engineering and technology, design thinking, service design and information system design.

2.2.1 Method of User Behavior Study in PSS

User behavior data is required to enhance the design activities, such as target customer identification, idea generation and information content generation (Kim et al., 2018). Increased mobile networking allows marketers to understand and interact with customer behavior (Rust & Huang, 2014). Moreover, this trend has changed customers' roles from isolated to connected,

from unaware to informed and passive to active (Blazevic & Lievens, 2008). Customer behavior includes several factors viz. gender, age, occupation, living environment and cultural background (Zhao et al., 2010). These factors determine the uncertainty of customer behavior. Therefore, it is beneficial to understand customer behavior to deliver and fulfil needs. Studies on customer behavior use quantitative and qualitative methods such as surveys, in-depth interviews and focus groups.

From literature, studies have shown that utilizing user behavior data could improve the design activities for service organizations (Ordenes et al., 2014) (Lim et al., 2018). Various attributes of user behavior in PSS may be analysed from the perspective demographic profiles of the user. It enhance the customers' experience, contexts, requirements and customization in a specific market segment (Ordenes et al., 2014) (Zhao et al., 2010). Service organizations can transform insightful information for strategic market planning (Huang & Rust, 2013). Ordenes et al. (2014) indicated that customer feedback could be utilized to gain customer experience information. Lim et al. (2018) used customer data to generate information contents and design service concepts in Product Service System (PSS).

2.2.2 Multi-Criteria Decision Making for PSS

The PSS design must concentrate on customers and their requirements for realizing value in a PSS (Mourtzis et al., 2016). The evaluation of customer satisfaction supports the PSS design. Hence, Multi-Criteria Decision Making (MCDM) methods were employed in the early stages of PSS design.

In literature, the publication and citation for Analytic Hierarchy Process (AHP) are higher than other MCDM (Promentilla et al., 2018). Other MCDM tools are viz. TOPSIS, i.e. Technique for Order of Preference by Similarity to Ideal Solution by Yoon (1987), PROMETHEE, i.e. Preference Ranking Organization Method for Enrichment Evaluations by Brans et al. (1986). In comparison with other MCDM techniques, AHP is a simple technique and incorporates quantitative and qualitative criteria into a hierarchical decision structure.

T. L. Saaty (1980) developed the Analytic Hierarchy Process (AHP), which is a systematic process and widely used method for multiple criteria decision analysis (MCDA). This process involves problem structuring and integrating the inherent subjectivity of decision preferences. Its applicability to the Industrial Product-Service System (IPS2) on eliciting and assessing requirements evaluation was demonstrated by Song et al. (2013). They integrated AHP and

Rough Group methods for subjectivity and vagueness in the IPS2 requirement evaluation process to an air compressor system case. The AHP has modelling and evaluation phases (Orellano et al., 2019). The modelling phase, which involves goals, criteria and alternatives, is structuring the problem into a hierarchy. Whereas, evaluation phase is for the pairwise comparison of elements into a hierarchical structure. An ordinal scale is used for pairwise comparison. Orellano et al. (2019) used the AHP as a multi-criteria decision-making method in the early stages of PSS design. In their case study of safety clothing systems, five value dimensions are considered as criteria's. These are viz. economic, environmental, relational, social and functional.

To support decision-making for PSS design concepts and the integration of customers and providers value was proposed by Rondini et al. (2017). A two-step assessment method was illustrated through the Importance Performance Analysis (IPA) method. The first step consists of the Weighted Pugh matrix approach for recombining concepts. The second step consists of the TOPSIS method for quantification. Moreover, QFD with Thurstone's Law of comparative judgements methods integrated for prioritizing customer requirements in the early phases of PSS (Haber & Fargnoli, 2019). The application of these methods was demonstrated in the healthcare sector to understand customer needs and expectations. A customer survey was employed in their proposed approach for market analysis, followed by the Kano model to filter the customers' requirements. Then, defined receiver state parameters (positive or negative effect on the receiver) and PSS characteristics. Lastly, Thurstone's Law of comparative judgements defines importance levels and QFD for prioritizing PSS characteristics.

Rating of engineering characteristic performance in PSS development was conducted by (Geng et al., 2010). The PSS conceptual design of a horizontal drilling machine as a case example was considered in their study. They emphasized the QFD technique in translating customer requirements into product-related and service-related engineering characteristics. QFD-ANP model was utilized in determining the initial importance weights of engineering characteristics. Data Envelopment Analysis (DEA) approach was used for determining the final weights of engineering characteristics (Geng et al., 2010).

The service development process includes various activities and essential factors in its life cycle. Concept selection is one such significant activity. Lee et al. (2012) proposed a systematic approach for evaluating new service concepts. In their study, the suggested approach consists of integrating AHP and Rough set theory in four phases. First, a hierarchical AHP model was

developed, incorporating strategy, market, finance, technology and implementation to evaluate new service concepts. Second, pairwise comparison constructed and importance weights were obtained from experts. Third, combined individual judgements into group judgements followed by prioritizing new service concepts as the fourth phase. A study on video game service was considered for the illustration of the aforementioned proposed approach. Huang and Hsu (2016) examined the service quality of international distribution centres. As a result, five service requirement attributes were considered essential in their study. These are viz. handlings of damaged cargos, the correctness of shipping orders, punctuality, storage spaces and transportation routes. In addition, five service operations attributes are viz. consolidation & deconsolidation, cargo stowage & discharge, delivery scheduling, logistic processing and business inquiry. QFD and fuzzy AHP techniques were integrated to translate service requirement attributes into service operations attributes (Huang & Hsu, 2016).

The previous studies show that multi-criteria decision-making methods are employed in PSS requirements, design and evaluation. These methods are utilized in PSS requirements evaluation, prioritizing customer requirements, concepts selection, rating engineering characteristics, evaluating new service concepts and service quality assessment. The AHP is the most common multi-criteria decision-making method employed in PSS literature. Other MCDM methods such as TOPSIS, ELECTRE, VIKOR and PROMETHEE are less common (Rondini et al., 2017). However, a limited empirical study has been conducted on elicitation and prioritization of design requirements in the early phase of PSS. This thesis attempts to address this issue.

2.2.3 Scenario Planning

Scenario planning is considered for strategic planning and policymaking in descriptions, scripts and contents (Dong et al., 2013) (Amer et al., 2013). Besides, developing scenarios is essential for plausibly exploring future uncertainties. It is considered a management technology profoundly utilized by decision-makers and managers of an organization to analyze future possibilities. Scenario planning is a form of exploration but not forecasting and analysis of scenarios highlights future prospects (Quiceno et al., 2019).

The journal ‘Futures’ and ‘Long Range Planning’ publish many academic and practitioner articles on applying scenario planning toward management research problem-solving areas (Page et al., 2010). The roots of scenario planning are in military strategy studies (Bradfield et al., 2005). In the 1960s, Herman Kahn was an early founder of scenarios and he promoted the

idea of 'thinking the unthinkable and used scenario as a tool for business predictions. Since 1960, scenario planning has become popular with prominent business and scenario development at corporate, national, public and private institutions. The use of scenario planning has grown substantially from management science, Rand Corporation, Shell and Stanford Research Institute (Quiceno et al., 2019). As Kiely et al. (2004) noted, scenario planning is also employed in the service sector. Organizations like British Airways, Electrolux and United Distillers, with the service element, used scenarios to anticipate the future and aid strategic planning (Kiely et al., 2004). Lindgren and Bandhold (2009) show the emphasis of scenario planning in corporate strategy. Scenario planning is a strategic perspective for anticipating and adapting to change in today's uncertain business environment.

Scenario planning is an alternative to forecasting (Derbyshire & Giovannetti, 2017) (Amer et al., 2013). Scenario planning focuses on unexpected but plausible outcomes that represent a break from the past. Forecasting emphasizes continuing trends, most likely pathways to estimate uncertainties, as in the recent past. The work of scenarios presents a set of plausible futures for an organization resulting from uncertainties. In scenarios, uncertainties are explored, whereas forecasting identifies the most probable future and estimates uncertainties (Amer et al., 2013).

Scenario planning is a design method employed in strategic planning by anticipating uncertainties in business environments (Lindgren & Bandhold, 2009) (Derbyshire & Giovannetti, 2017). The objective in the context of scenario planning is to create plausible future events. Börjeson et al. (2006) indicated that the scenario development process consists of generating ideas, gathering data and integrating, and checking the scenario's consistency in a given situation (Börjeson et al., 2006). The standard approach to scenario planning is intuitive logic and the development process includes eight stages (Derbyshire & Giovannetti, 2017). These eight stages are viz. (i) set the agenda, (ii) determine the driving forces, (iii) cluster the driving forces, (iv) define the cluster outcomes, (v) impact/uncertainty matrix, (vi) frame the scenarios, (vii) scoping the scenarios and (viii) develop the scenarios. There are different approaches to create scenarios (Page et al., 2010) (Bishop et al., 2007). However, they all have a common starting point, i.e., identifying the critical focal issue, processes, time scale and driving forces of change and trends. User behavior can provide essential information on customers' experience, requirements, contexts and demographic data to define focal issues and processes in this context.

2.2.3.1 Scenario Planning Approaches

In the literature, several methods and techniques were reviewed and described for scenario planning. Nevertheless, all share and aim at identifying drivers of change and trends. The drivers of change and trends have multiple influences on current situations and the business environment. A recent study on the current state of scenario development by P. Bishop indicates, scenario development is the heart of future studies. Scenario planning approach proposed by Lindgren and Bandhold (2009), Peter Schwartz (1991), overview studies on scenario planning methodologies outlined by Bradfield et al. (2005) and Amer et al. (2013), which are briefed below in more detail.

Bradfield et al. (2005) presented the origins and growth of scenarios from the literature. Various methodologies are classified into three schools of techniques for scenario planning (Bradfield et al., 2005). Techniques are viz. Intuitive-logics models, La Prospective models and Probabilistic Modified Trend models. These techniques aim to develop a strategy in an ongoing activity associated with the organization, a more effective policy with the strategic decisions and tactical plans. The scenario perspective for these models is descriptive or usually normative. The tools used in Intuitive-logics models are brainstorming, system dynamics and stakeholder analysis. While morphological analysis, Delphi technique, structural and actor analysis are used for the La prospective models. Trends impact and cross-impact analysis are applied for the Probabilistic Modified Trend models. Further, Bradfield et al. (2005) mentioned that the significant differences in these scenarios lie in scenario teams and expert participation in designing the scenario.

Amer et al. (2013) summarized scenario planning and discussed several other techniques for developing scenarios. Their study comprised the three primary scenario development techniques mentioned by Bradfield et al. (2005). However, their review of literature on scenarios also includes quantitative scenario planning methods. Such as viz. Interactive cross-impact simulation, Interactive future simulations, Trend impact analysis and fuzzy cognitive map-based scenario planning approach. Besides scenario selection, how many scenarios are to be developed and how to validate scenario planning is also discussed. As a result, a combination of qualitative and quantitative techniques could help develop robust scenarios. An appropriate number of scenarios to be developed for a project is 2 - 5 and for the validation of scenarios, internal consistency and plausibility are the essential aspects (Amer et al., 2013).

Lindgren and Bandhold (2009) proposed the scenario planning process in five stages viz. Tracking, Analyzing, Imaging, Deciding and Acting. However, preparation and pre-requisites for the process are the pre-stages. Lindgren and Bandhold (2009) suggest identifying the purpose and focus on the rationale for developing scenario planning. Scenario planning could be developed for different purposes for an organization. The different kinds of scenario planning might be for: Risk consciousness or a need of renewal on old business; a paradigm shift on new business; business/concept development; and strategy development/organizational development (Lindgren & Bandhold, 2009).

In the pre-stages, the purpose of scenario development, the focal question, time horizon is defined and the mapping of the organization's past and present is known. The tracking stage identifies the trends, uncertainty related to a project and drivers of change in the surrounding environment. These factors influence the outlined focal question about the future. Methods to identify these factors are viz. media scanning, focus group, experts' panel and the Delphi technique. The analyzing phase depicts the descriptions of identified factors individually and interrelationships between the trends. The imaging stage is about creating visions. Visions provide meaning, identity, belief, guidance and inspiration for a project of an organization. Meaningful visions must be supported by strategies, goals and actions of the organization. The deciding stage is to integrate the information identified from the previous steps and move towards the vision. Looking at the advantage of opportunities, core competencies and avoiding threats, decision-makers could finalize strategies. The deciding stage methods are viz. strategies versus life cycle and competitors, cross-impact analysis and causal loop diagrams. The Acting stage is to put the strategy into actions or follow-up continuously the scenario planning process.

According to Peter Schwartz, the scenario planning process consists of eight steps in developing the scenarios (Schwartz, 1991). Identifying the focal issue or decision is the first step. This step begins the process by thinking 'inside out' rather than 'outside in'. Listing the key factors that influence decision-makers choice on the focal issue or decision is the second step. The key factors are customers, suppliers' competitors and many other local environments that characterize success or failure. The third step comprises of listing the driving trends in the macro-environment. The driving trends influence the key factors from social, economic, political, environmental and technological perspectives. The next step is to rank these key factors and driving forces by importance and uncertainty. The fourth step aims to identify the

essential and uncertain two or three factors or trends. According to Schwartz (1991), selecting the scenarios by logic is vital for the scenario planning process. As a result, this fifth step could be helpful in the presentation form as a spectrum (one axe or trend), matrix (two-axis or two trends), or volume (three-axis or three trends). The sixth step is to present the narrative from scenarios and has to be simple and dramatic. These can be achieved by considering interactions between factors and trends identified in steps one and two in different scenarios. The seventh step is to imagine the plausible scenario by returning to the focal issue or decision. The last step is to identify indicators and signposts that unfold the imagined future. These indicators and warning signals must be identified carefully and imaginatively by spending more time. One has to act accordingly to the strategies which reflect a competitive advantage for an organization.

2.2.3.2 Why Scenario Planning

With rapidly changing measures and uncertainty, it is beneficial for decision-makers and designers to adapt and anticipate future events. The scenario approach is one of the tools that support such decision making. The Scenarios help strategy development, innovation, risk management, visioning and executive learning in new and old businesses (Lindgren & Bandhold, 2009). Scenarios play two essential roles. First, risk management; the latter is creativity and sparkling new ideas. Scenarios enable strategies and decisions to be analyzed against possible futures (Bishop et al., 2007). Scenario planning has the potential of providing various benefits. Multiple examples of scenario planning from practitioners worldwide suggest that scenarios are helpful for strategic thinking. One has to be prepared for future challenges about the political, economic, social and technological factors involved in the business environment.

2.2.4 Design Brief

Design brief is recognized to achieve greater clarity of the design problem, design opportunity and design direction (Blyth and Worthington, 2001). In literature, the briefing is referred to as creative brief, marketing brief, project brief or innovation brief (Dewulf et al., 2012) (Phillips, 2004) (Parkman, 2010). Defining a design brief has become an integral part of the design process (Dewulf et al., 2012). Phillips, (2004) defined design briefs as “A document that outlines the strategic direction for creative development, covering the specific task at hand, the communication objectives and strategy, and any elements that the executions must contain”. Ryd (2004) discusses the importance of the client’s briefing for a construction project. More

specifically, design brief documents act as information carriers during the design and production phases (Ryd, 2004). However, designers and design managers should make an effort to study design briefs. It is a combination of a business plan and a creative design strategy (Phillips, 2004). The successful briefing shows the experience, skills and knowledge of the design team. Design brief is about comprehensive communication, strategic objectives for all the stakeholders involved in the project. Therefore, the design brief expresses the client brief in terms of user requirements, stakeholder map, design opportunity, design intent and design direction to the design management team.

2.2.5 Design Thinking

Design thinking as a problem-solving approach had made a significant contribution in business, management, product design and practice (Liedtka, 2015). Design thinking is a well-established iterative design process that offers an approach to innovation and problem-solving (Micheli et al., 2019). Design thinking is a consistent, coherent, distinctive and management practice. It first appeared in the book title 'Design Thinking' by Peter Rowe in 1987. Initially, it had a limited application to architecture, but later applied in business practices by innovation consulting firm IDEO.

Further, design thinking expanded to the design of services, strategies, education and other social systems by Tim Brown. According to Tim Brown, design thinking is defined as "bringing designers' principles, methods, tools and approaches to problem-solving." Thomas Lockwood, a design practitioner in business, defined design thinking as "a human-centred innovation process that emphasizes observation, collaboration, fast learning, visualization of ideas, rapid concept prototyping, and concurrent business analysis." Consulting firms like IDEO and Continuum, academics like the Stanford Design School, The Rotman School, The Darden school described the process and tools of design thinking practice (Liedtka, 2015). Liedtka (2015) mentioned that the most common design thinking tools are viz. visualization, ethnography, mind-mapping, prototyping, co-creation and field experiments. Customer journey, empathic design and personas are also some of the methods included in design thinking (Andreassen et al., 2016).

Tim Brown published one of the most popular article entitled 'Design Thinking' in Harvard Business Review (Brown, 2008). It mentioned that design thinking for innovation happens in three stages. These three stages are viz. inspiration, ideation and implementation. Inspiration stage deals with identifying the problem or opportunity that leads to solutions. Ideation is about

generating, developing and testing ideas. The implementation stage is for visualizing and a path to market launch. The design process is iterative and a system of spaces but not a predefined series of steps. According to Brown (2008), a design thinker's personality profile should include the following characteristics: empathy, integrative thinking, optimism, experimentalism and collaboration. A designer must emphasize the customer's needs, have innovative thinking with alternative solutions and work with other domains.

In the context of service innovation, design thinking is used to create effective and efficient solutions for organizations and create value for customers by designing experience-centric services (Jaaron & Backhouse, 2018). Jaaron and Backhouse (2018) mentioned that organizations adopt service design and design thinking to enhance service innovation. According to Andreassen et al. (2016), identifying all the stakeholders, understanding customer's demands and representing the service are the three prime aspects of design thinking. The design thinking approach in developing the service process often provides value to the customers. It is based upon the experience-centric as the core of service design, where customers come first and the organization second. The adoption of design thinking to manufacturing industries, enterprises, service sectors depend on many attributes. The attributes of design thinking explored by Micheli et al. (2019) are viz. customer co-creation, problem-solving, interdisciplinary collaboration, ability to visualize, iteration and experimentation, abductive reasoning, creativity and innovation.

2.2.5.1 Design Thinking in Product Service System (PSS)

In many organizations, the prime challenge is how to deliver value to their customers through experiences (Lille et al., 2012). This challenge is tackled by developing the services and complementing the service offerings. Besides, a perspective of the designer's approach is required in the development of a product-service system. Design thinking is a human-centred approach to stimulate innovation in several business processes, including the development process. Rosa et al. (2016) indicated that the design thinking approach could be helpful and support generating ideas and concepts of PSS. Significantly few researchers employed a design thinking approach in supporting the PSS development.

Henze et al. (2011) constructed a PSS framework of methods, techniques and tools based on the design thinking approach. They reviewed three case studies to conceptualize how the collaborators' network should be structured to develop a PSS. The collaborators' network in the framework consists of service design network, service organization network and service

experience network. (Henze et al., 2011) investigate how the design consultants use the design thinking approach in implementing a product-service system for organizations. As a result, design consultants identify the difficulties, the necessary skills, tools, designer's role and characteristics of changing the organization.

The comparison of the design thinking process and PSS design process was presented by Rosa et al. (2017). Their study was based upon a corpus linguistic approach and frame semantic elements. As a result, design thinking could be seen as a complementary entity to the PSS design process. In other words, design thinking supports the conceptual design, stakeholders understanding and opportunity identification in the PSS design process (Rosa et al., 2016). Scherer et al. (2016) utilized design thinking and business analytics to enhance the PSS design model for companies. Their proposed PSS design model uses design thinking to understand customers' needs and satisfy their emotional requirements based on their resources and constraints (Scherer et al., 2016).

Pieroni et al. (2016) developed a framework for manufacturing companies to transform traditional products to PSS business models through the design thinking process (Pieroni et al., 2016). West and Nardo (2016) described a process by integrating service design tools with design thinking. This process was examined to PSS context based on two case studies (West & Nardo, 2016). More recently, Carvalho et al. (2020) proposed a methodological framework that constitutes the design thinking structure. The design thinking structure is comprised of observation, ideation, prototyping, test and implementation. This proposed framework is for a PSS solution in enabling the treatment of organic waste (Carvalho et al., 2020).

The application of design thinking is applied in product and service development in the markets of Business-to-Business (B2B), Business-to-Customers (B2C) and Business-to-Governments (B2G). For instance, companies utilizing design thinking are P&G, Pfizer, Nokia, Apple Inc. and Intel (Scherer et al., 2016). To enhance experience-based innovation, a design thinking approach is employed in leading enterprises like Samsung, IBM and SAP (Rosa et al., 2016).

The design thinking approach helps develop a product, process and business model innovation (Micheli et al., 2019) (Liedtka, 2011). Innovation is a broad concept and could be achieved by implementing a novel idea, creating value for some stakeholders. A fundamental element of design thinking is human-centred design (Hendricks et al., 2018) (Trischler et al., 2019). The early design stages are concerned with applying in-depth user research, stakeholder engagement, visualization of process and empathy design to explore the needs of the end-users.

Previous studies shows that the design thinking approach has been applied in product design, branding design, service design and other areas such as information systems design (Brown & Katz, 2011) (Vetterli et al., 2016) (Trischler et al., 2019). According to the firm IDEO, leading practitioners of the design thinking process mentioned that it is a system of overlapping spaces. The design thinking process is not a sequence of orderly steps. A system of overlapping spaces includes inspiration, ideation and implementation. The function of inspiration space is to find alternate solutions for a problem. The ideation process is all about generating, developing and testing ideas. Implementation is to launch the ideas and solutions into peoples' lives. The design thinking process is iterative that loops back through the inspiration, ideation and implementation spaces. Hence, these are mentioned as spaces rather than sequentially orderly steps. The design thinking approach can generate new and innovative products, services and systems based on these studies.

Design thinking is a well-tested approach that enables organizations to see the world through the eyes of their customers (Vetterli et al., 2016). A human-centered design toolkit, which is a field guide developed by IDEO. It aid public sector organizations, who could adapt design thinking to their problem-solving activities (Trischler et al., 2019). Liedtka (2011) identified essential tools and practices of the design thinking approach and demonstrated the two managers' cases; managers who are, in effect, successful design thinkers. Micheli et al. (2019) addressed the most influential applied models of design thinking. The design thinking model developed by IDEO includes inspiration, ideation and implementation. The design thinking model developed by Stanford Design School includes empathy, define, ideate, prototype and test. The design thinking model developed by IBM consists of understanding, explore, prototype and evaluate. The models mentioned above tend to start from initial exploration to understand the problem to be clarified. Then move onto an ideation stage to generate possible alternatives. In closing, all conclude with an implementation and testing phase based on prototyping and iteration.

2.2.6 Stakeholder Mapping

A stake is an authority, right, responsibility, ownership, knowledge, capacity, interest, influence or contribution. A stakeholder is an individual or group having a stake. Edward Freeman defines a stakeholder as "any group or individual who can affect or is affected by the achievement of the organization's objectives." Stakeholder analysis or stakeholder mapping has evolved to identify and analyze stakeholders' interests and actions. Assessing stakeholders

for any project of an organization is an essential step in strategic analysis (Freeman et al., 2010). The quality of a system is improved by the selection and involvement of appropriate stakeholders. Selecting and involving the appropriate stakeholder plays a significant role in improving the development and quality of a system. Hujainah et al. (2018) mentioned that stakeholder identification in the project development is a reason for producing a successful system (Hujainah et al., 2018).

In PSS literature, the terminology used to refer to the stakeholders are viz. partner(s), actor(s), a player(s), network(s), customers/users, government and local providers, society and service provider (Fernandes et al., 2019). In general, stakeholders are broadly classified into internal stakeholders and external stakeholders. Therefore, the designation of stakeholders in the PSS literature is not homogeneous. The studies on the PSS design and development process significantly includes the identification of stakeholders. For example, Morelli (2006) developed a design exploration process for an early PSS design and development incorporating stakeholders. It mainly focused on understanding and combining service networks. In particular, Actor-Network Map illustrating stakeholders involved in a system along with direct and indirect relationships. Ginige et al. 2018 explored broadly and categorized stakeholders in the context of societal challenges. These stakeholders are grouped into national and local governments, international organizations, community, civic society, private and corporate sectors, academic and professional associations. The purpose of exploring stakeholders in their study is to identify how individuals/organizations influence, benefit or effects societal challenges (Ginige et al., 2018).

Kim et al. (2011) discussed the design support tools for PSS. Their study considered stakeholder activity design in the lifecycle analysis for stakeholders' identification and relations. Stakeholder activity design can be generated by independent design tools such as stakeholder modelling (Kim et al., 2011). Tan and McAloone (2006) identified strategies that could be used in the development of PSS. These strategies are based upon the continuous lifecycle improvements of tangible products and intangible services. Actor-Network Map utilized to understand the stakeholders' involved in the emerging PSS. As with the design and development of PSS, stakeholders' context, needs and value, the social and technological possibilities guide an organization in creating a good PSS solution (Tan & McAloone, 2006).

Gilles and Christine (2016) investigated the identification of stakeholders in developing a PSS solution for the showerhead case study. The stakeholders identified in their case study were

regarding security, traceability and maintenance, and economic and social issues (Gilles & Christine, 2016). In the context of healthcare, Yip et al. (2014) identified and grouped stakeholders based upon different levels in the operations of a PSS. These levels are business environment, system, product and service delivery. Stakeholder identification and mapping support integrated solutions, i.e. PSS is based on partnerships among organizational networks (Yip et al., 2014).

To sum up, the stakeholder system map benefits the visualization of stakeholders involved in the design and emphasizes interrelations. Stakeholder analyses are essential because of the increasingly interconnected nature of the world (Ginige et al., 2018). Stakeholder's analysis or mapping would aid in designing specific knowledge of who has a stake and why. Selecting and involving the appropriate stakeholders are considered one of the significant factors for producing a successful system. Accordingly, to succeed in a project, one has to identify stakeholders with their power, influence and interest, followed by prioritization of the essential stakeholders in the system. Finally, mapping of each stakeholder in the power versus interest matrix has to be carried out to recognize what motivates them from the system.

2.2.6.1 Stakeholders Identification and Mapping methodology

Bryson (2004) presented fifteen stakeholder identification and analysis techniques and grouped them into four categories, such as viz. (i) organizing participation (ii) creating ideas for strategic interventions (iii) building a winning coalition around proposal development, review and adoption (iv) implementing, monitoring and evaluating strategic interventions. With the specific to project management, Missonier and Loufrani-Fedida (2014) investigated stakeholder analysis and engagement. Further states that what to observe in the stakeholder network, how and when to observe them (Missonier & Loufrani-Fedida, 2014). In their conceptual approach, stakeholder analysis is comprised of five stages and three stages of stakeholder engagement. The five stages of stakeholder analysis are viz. (i) identifying and analyzing stakeholder relationships (ii) identifying stakeholders' interests (iii) assessing stakeholders influence (iv) identifying controversies and (v) analyzing the effects of controversies on stakeholder networks. Problematization, mobilization, interest and enrolment are the three stages of engagement.

Stakeholder mapping determines who have a positive and negative influence on an effort. In addition, who is most affected by an effort. To summarize the characteristics of stakeholders, Ginige et al. (2018) mentioned that tables or charts aid in the group or prioritize the

stakeholders. Stakeholder analysis is conducted employing power vs interest or influence vs importance matrix or grid. Figure 2.13 depicts the stakeholder mapping in terms of power vs interest.

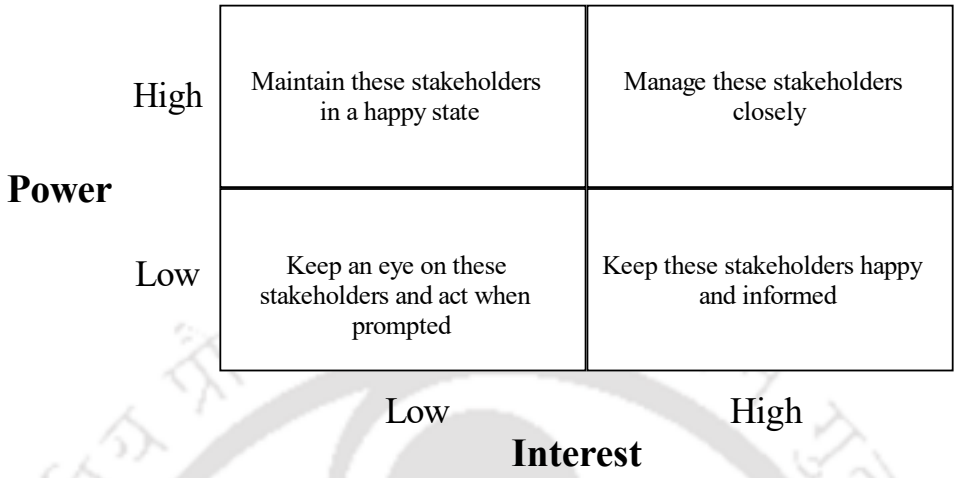


Figure 2.13: Power – Interest matrix

Stakeholder management researchers used the power vs. interest matrix for several objectives. For example, Bryson (2004) used a power vs. interest matrix in determining the stakeholders' interest and power to address the issue, stakeholders' coalition encouragement or discouragement and information on how to convince stakeholders perspectives (Bryson, 2004). Freeman et al. (2010) used a power vs. interest matrix to understand the company's environment. Ackermann and Eden (2011) used a power vs. interest matrix for enabling managers to manage stakeholders. The stakeholder mapping of power vs. interest represents stakeholders concerning the power (low or high) and their interest (low or high) in the project (Ackermann & Eden, 2011). The type of relationship with stakeholders that needs to establish is shown in Figure 2.13. For instance, stakeholders having high power and high interest, the relationship would be of closely managing the stakeholders. Identified stakeholders in the project activities with low power and high interest must be kept informed about the project decisions. This matrix provides a strategy for effective communication between various stakeholders.

2.2.7 Service Blueprint

Sustainable trends in servitization have progressively increased over the last couple of decades. Service design has developed into a design-led approach to service innovation (Yu & Sangiorgi, 2018a). Service innovation is more about improved customer experience, processes,

and actions (Fließ & Kleinaltenkamp, 2004) (Lee et al., 2019). It involves human actors, physical resources/technologies and processes (Chen & Cheng, 2012) (Costa et al., 2018). The study by (Froehle & Roth, 2007) on the new service development process includes resources and a process-oriented framework. Resource-oriented new service development practices emphasize developing intellectual, organizational and physical resources. In contrast, process-oriented new service development emphasizes design, analysis, development and launch. Service design is conceptualized as design-centred contributions to service innovation within design communities based on a human-centred perspective and creative methods (Wetter-Edman et al., 2014) (Yu & Sangiorgi, 2018b). Service design was influenced by emotional design, design thinking and contextual design. Researchers (Yu & Sangiorgi, 2018b) argues that design impacts on product innovation are generally related to the attributes of physical objects, while design impacts on service innovation require different dimensions. Service design has also been examined as a set of collaborative and cross-disciplinary activities for service innovation (Patrício et al., 2011).

Service Design provides methods and tools for orchestrating and materializing interactions between people, institutions and technological systems in innovative ways (Costa et al., 2018). Most of the methods used in service design are from the design discipline (Lee et al., 2019). The use of design methods in service design defines, creates, applies and plans the new service. The service concept incorporated with the design concept is emerging and new in the design field. Service blueprints could be adopted for a new service design and an existing service for improvement (Wang et al., 2017). Besides, the service practitioners or designers could conceptualize the design process by utilizing a service blueprint. Service blueprint enables them to explore, understand and analyze the service activities and experiences of customers. The objective of service blueprinting is to analyze service performance, controlling and improving the service quality. These are identified in the service blueprint by tracking the customer's interactions with service staff.

The service blueprinting approach originated from the service design, firstly introduced by Shostack in 1982. The service blueprint is better understood as a map or a picture that precisely depicts the service system (Fließ & Kleinaltenkamp, 2004). Service blueprinting enables accurate description and provides a map of a service system so that all the stakeholders can easily understand the operation of the business process (Wang et al., 2017). It has the advantages of precise modelling and visualization of the service processes; therefore, the

service blueprint is widely used to represent services. Researchers used the service blueprinting approach in different areas of expertise; such as hospital management, courier delivery services, room service in a hotel, restaurant management and smart parking services (Geum & Park, 2011) (Lee et al., 2019).

The service blueprint composition is structured into regions and boundaries, as shown in Figure 2.14. Physical evidence and customer actions area, the onstage interaction area, the backstage interaction area and the support processes are the regions of service blueprint composition. Line of interaction, line of visibility and line of internal interaction are the boundaries of service blueprint composition. The service process is viewed and understood in chronological order from left to right. It is shown on the horizontal axis. The arrows represent the paths of service, connecting related activities.

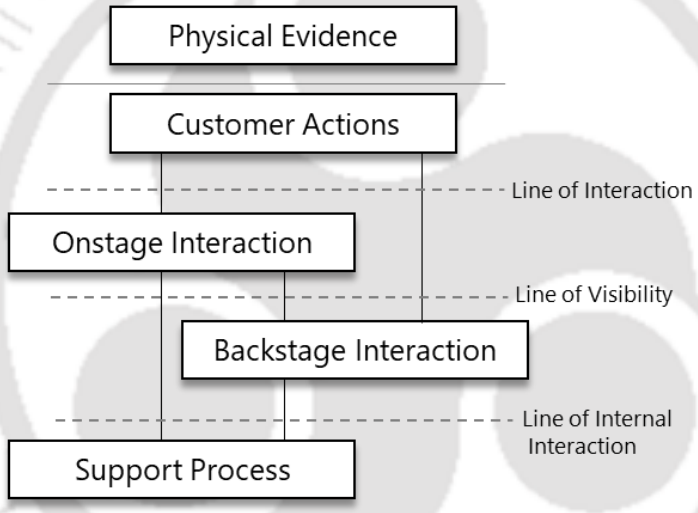


Figure 2.14: Service blueprint structure

From the customer's perspective, the service blueprint is divided by the line of visibility into the front office and back office. The front office comprises visible areas where customers can obtain observable evidence of the service company, such as facilities, equipment, service personnel and other customers. The back office consists of hidden areas that customers cannot observe, such as internal design, management staff and systems that support operating parts.

2.2.8 Data Flow Diagram

The Product Service System (PSS) is developed by combining products and services as an integrated solution to propose value proposition and fulfil customer needs. PSS development

comprises factors in identifying stakeholders, visualizing customer interactions with the system, physical resources, products and services. Once these factors are identified, the next step is modelling the business requirements of PSS (Becker et al., 2008). Business requirements of PSS define how the organization develop a value proposition and meet customers demand (Durugbo et al., 2011). Durugbo et al. (2011) inferred that PSS could be modelled based upon function-oriented design. Function-oriented design involves breaking down systems into manageable interacting parts.

Within a PSS context, modelling the functional decomposition could aid in identifying products and services (Becker et al., 2008). Meanwhile, information flow represents function-oriented design. Information flow help describes the input and output function of the system and organizations. Data Flow Diagrams (DFD) are utilized in organizations for the information flow, i.e. logical view and representing the actual flow, i.e. physical view. DFDs are a well-known technique from structured analysis and system design. DFDs are used for process modelling to represent the system under development through connections of sources, sinks, processes and data (Wang et al., 2017). A DFD represents which processes and data stores can exist in the system under development and which communications among processes, stores and external entities can exist.

There are necessarily two different types of notations or symbols representing data flow diagrams. DeMarco and Yourdon or Gane and Sarson symbols define visual representations for processes, data stores, data flow and external source/entity, as illustrated in Figure 2.15. DeMarco and Yourdon type data flow diagrams are usually used for system analysis and design, while Gane and Sarson type DFDs are more common for visualizing information systems. Visually, the most significant difference between the two ways of DFDs is how processes look. In the DeMarco and Yourdon way, processes are depicted as circles, while in the Gane and Sarson diagram, the processes are squares with rounded corners. In recent developments, the data flow diagram process utilized in widespread domains (Zhang et al., 2018) (Soegoto & Suripto, 2018). Data structure plays an essential part in designing prototypes for software applications by simplifying the data keys and their relationship to other elements (Meesang et al., 2016).

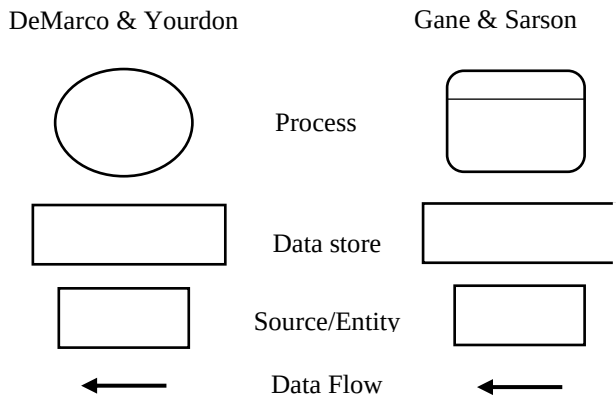


Figure 2.15: Data flow diagrams symbols and comparison

2.2.9 User Interface

User interface (UI) is a significant component of an information system (IS) with being a translator between users and the system. Researchers have adopted the development methodology of User-Centered design (Jitnupong & Jirachiefpattana, 2018) (Kikuchi et al., 2010). One particularly prominent example is the field of e-commerce. Research has shown that the good design of a UI is a valuable technique for increasing customers' trust, user satisfaction, purchase intention and decision to buy (Pfeiffer et al., 2016).

Sharma and Lijuan (2015) investigated the service quality of e-commerce websites in the online platform and their influence on e-business promotion. The study suggests that information quality and online service quality were the critical elements for user satisfaction and sustainability of e-commerce technology (Sharma & Lijuan, 2015). Moreover, Hasan and Morris (2017) evaluated the usability of seven essential international and Arab e-commerce websites and described specific types of major and minor usability problem areas that might affect users' experiences while interacting with them (Hasan & Morris, 2017). Usability problems identified on e-commerce websites are navigation, organization, content, communication, design and purchasing processes. Further, it recommended overcoming usability problems. Varela et al. (2017) proposed multi-perspective critical success factors (MPCSF) model for online shopping. Among other integrated critical success factors, usability is essential to consider for the design of websites because it is not a single, one-dimensional property of a user interface (Varela et al., 2017).

2.2.10 Benchmarking

Benchmarking is a continuous process and it is about learning how to do better. Products, services and activities could be benchmarked for competitive advantage, performance could be measured with quantitative and qualitative techniques of benchmarking (McGaughey, 2002). Since decades of benchmarking practices have evolved, Dobrzykowski et al. (2012) examined and reviewed the literature on benchmarking practices and presented a framework. Framework suggesting evolving patterns of firm benchmarking practices. Considerably, defining the scope of the benchmarking is essential for organizations as capacity and resources are limited. In literature, benchmarking can be seen within large organizations and the manufacturing industry (Dobrzykowski et al., 2012). Broderick et al. (2010) explored management attitudes towards benchmarking and its implementation in B2B architectural service firms. Their study revealed that architectural services are related more towards professional design criteria rather than productivity as in manufacturing firms (Broderick et al., 2010).

Boisvert and Caron (2006) measured and classified website functions for development through benchmarking. It suggests that the development of a website should be based on the functions that the website performs (Boisvert & Caron, 2006). A website functions corresponding to the tasks performed or the activities involved in e-commerce, such as support functions and customer value-oriented functions. Support functions comprise navigability and security. Whereas, customer value-oriented functions comprise product/service, transactions, contract, expertise, external marketing, customer service, investors and partners. Their study contributes to managers in the planning and development of relational website tasks and performances. Website design is an essential factor for business organizers because websites are the primary interface between buyers and sellers. Kim et al. (2003) proposed website evaluation criteria through literature review and evaluated different industry websites in Korea. Their study evolved a method for benchmarking different industry websites. (Kim et al., 2003).

2.2.11 SWOT

Business organizers, decision-makers or managers employ SWOT analysis at the early stages of the strategic planning process and proceed towards strategy formulation (Houben et al., 1999) (Jeyaraj et al., 2012) (Namugenyi et al., 2019). The SWOT analysis output describes firms' internal factors (strengths and weaknesses) and external factors (opportunities and threats). In literature, researchers have used SWOT as an analysis tool for e-commerce. For instance, Hosseini et al. (2020) integrated SWOT and random sampling approaches in

indicating the barriers and possibilities of e-commerce. The export of agricultural commodities in Iran for the global market was the case example (Hosseini et al., 2020). As a result, formulated strategies were to reduce operational costs, convenient exchange transactions, enforce laws, use new technology for the export process, trained labor force and support policies for exporting agricultural products. Maryati et al. (2018) have considered SWOT in developing e-commerce adoption strategies for e-library. The results indicate enhancing mobile-based services, integrating library loans with payment systems and promoting e-commerce adoption in the e-library (Maryati et al., 2018).

2.3 Inferences on Literature Review Chapter

This section provides the research gaps found and discussed in the previous sections. The following points summarizes literature review in brief:

- PSS Concept and Theory: Product Service System (PSS) is an effective integration of major entities of the system (products, services, infrastructures, networks and actors) aiming to achieve customer delight (Mont, 2002). There are successful PSS implementation applications nevertheless, there are various barriers and challenges for adopting PSS (Baines et al., 2007).
- PSS Business Models: Companies lack knowledge and experience in developing integrative perspective solutions or new business models (Mont et al., 2006). The cases or examples in developing new business models within PSS literature for business-to-consumer markets are minimal. There is a need to develop a PSS business model for business-to-consumer markets from the design management perspective.
- PSS Requirements: The requirements identification and analysis have been considered essential phases in PSS design. Existing studies lack in structuring requirements identification, prioritization and testing within PSS research (Nemato et al., 2015). The requirements engineering process includes elicitation, analysis, documentation and validation. A clear understanding of integrating the planning, developing, delivering, and using products and services is essential for PSS (Müller et al., 2010). To effectively implement PSS, requirements elicitation and prioritization must be included in the PSS design process (Vasantha et al., 2015).
- PSS Design: Knowledge assistance tools proposed in the PSS literature, have used different knowledge schema. Tran and Park (2014) pointed out that the existing PSS

design methodologies have limited industrial application. It is due to lack in structured approach of design process/design methods in PSS that may provide practical guidance to PSS designers (Tran & Park, 2014). The abundance of literature reflects the ever-increasing popularity of PSS, but at the same time it also brings to light the lack of a unified approach for understanding and developing an integrated product–service offering (Rapaccini et al., 2013) (Sakao & Lindahl, 2015). Better support frameworks must transfer information and knowledge from the PSS life cycle to PSS conceptual design. PSS design should include detailed requirements analysis and prioritization, stakeholders' definitions and involvement in the design process, creation of PSS business models, PSS evaluation, and PSS monitoring and implementations issues.

- PSS Evaluation: The PSS evaluations or assessments were from the customer perspective. PSS involves several stakeholders (product manufacturers, service providers, consumers, employees, supporting staff and delivery agents) and processes. Therefore, PSS should be evaluated from other stakeholders' perspectives. Moreover, the methodology applied in evaluating PSS studies were questionnaire, survey and multi-criteria decision-making methods.
- PSS Research in the Indian Context: Despite the surge in publications and significant recognition of the PSS concept internationally, there are very few PSS research publications in the Indian context. The majority of the articles reflected only in the manufacturing and automotive sectors for PSS research in the Indian context. There is an opportunity to revisit PSS research from design management perspective in Indian context.
- Design Methods, Design Thinking and Strategic Design Management: It is essential to build up knowledge of design-led approaches in PSS for academic and business organizers. Design thinking as a problem-solving approach has made a significant contribution in business, management, product design and practice (Liedtka, 2015). Design thinking is a well-established iterative design process that offers an approach to innovation and problem-solving (Micheli et al., 2019). Rosa et al. (2016) indicated that the design thinking approach could be helpful and support generating ideas and concepts of PSS. Significantly few researchers employed a design thinking approach in supporting the PSS development (Rosa et al., 2016).

Chapter 3

3 Research Methodology

A systematic review and analysis of scientific peer-reviewed published articles related to Product Service System (PSS) was presented in the previous chapters. Government reports and news articles related to the service sector and on-demand home services were presented. The need for design and development of a framework for a service system design from PSS perspective was identified, particularly in business-to-customer (B2C) on-demand home services in the Indian context. Based on the research need and inspiration, specific research questions were formulated, research aim and objectives were defined. Specific research methodologies, tools, techniques were applied in all the three phases of research, focussing on the research objectives.

3.1 Research Overview and Flow

The core of this thesis has three phases of research as presented in Figure 3.1. The first phase is PSS requirement identification and analysis; the second phase is PSS design and detailing; the third phase is PSS testing and implementation.

PSS requirements identification and analysis – Phase 1: This phase aims to study tools and methods for PSS requirements identification and analysis. Various tools and methods were explored and experimented viz. user behaviour study through structured questionnaire and interview, Rough Group Analytic Hierarchy Process approach for prioritizing design requirements, Scenario Planning to understand plausible futuristic situations in PSS. The experiment of the methods were conducted in PSS design of domestic plumbing in Indian context. A synthesis of combined outcome of the methods has been proposed. The findings of phase 1 was considered in defining the design brief for PSS service design.

PSS design and detailing – Phase 2: This phase maps stakeholders' power and interest in PSS and develops a service blueprint to visualize the customer journey in PSS service design. Considering the activities of the stakeholder in the PSS, process modelling was carried out though context diagrams and data flow diagrams. Wireframes were developed for basic understanding of user interface and user experience involved in the process. The entire service design process was mapped through design thinking approach viz. empathy, define, ideate, prototype and test. This exercise was carried out considering the case study of PSS service design of on-demand domestic plumbing services in Indian context.

PSS test and implementation – Phase 3: This phase aims to validate and test the outcome of service design solution derived with the input of phase 1 and phase 2. This phase also explores the synergy of business model design and PSS service design. In order to achieve this, the services and business model components of the existing business organizations, providing similar services, were benchmarked. A business model canvas was generated and SWOT analysis was conducted. A full-fledged e-commerce portal was designed and developed (www.fixplumbing.in) to test and validate the effectiveness of proposed service system design framework. Validation was conducted with feedback from potential customers and expert users. An innovative business model was proposed.

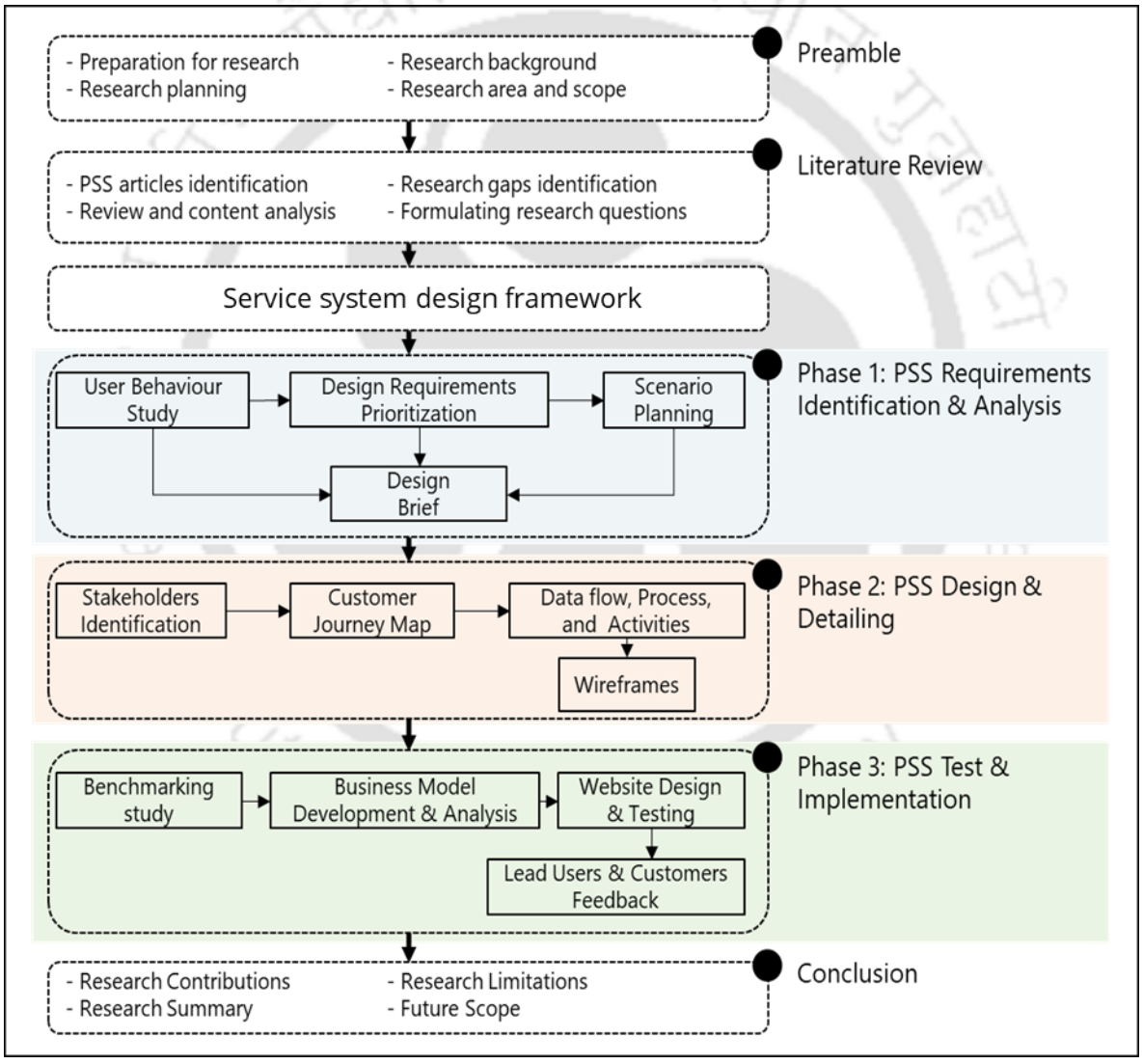


Figure 3.1: Research overview and flow

3.2 Research Stages and Methodology

In the previous section, the research overview and flow were presented. In this section, the detailed methodology, tools and techniques are tabulated in Table 3.1.

Table 3.1: Research stages and methodology

Research stages		Research Methodology/Tasks
Preamble		Research background, scope, area and objectives were identified. Reviewed scientific publications, news articles, government reports and magazines
Literature Review		Systematic literature review was conducted on research areas of PSS, design methods, design thinking and strategic design management. In addition, service sector, service design and domestic plumbing scenarios were reviewed in Indian context. The Mendeley software was employed for managing the references and for the citations of the articles.
PSS Requirements Identification and Analysis – Phase 1	User Behaviour Study	Customers' requirements were collected through the structured questionnaire-based on survey method. Statistical analysis has been conducted to observe significant relations and variations between variables. The data collected were tabulated and analyzed using SPSS 20.0 statistical software tool.
	Design Requirements Prioritization	Insights from the interview and statistical analysis were utilized in structuring the hierarchy of product service, and system-related design requirements. Five experts were chosen from three sectors viz. designer, maintenance engineer and technician. A questionnaire of pairwise comparison of product-related, service-related and system-related design requirements was developed (See appendix 2). Then, a structured interview and interactions were conducted with experts for collecting importance ratings on design requirements. The duration of the meetings and interviews were about 50-60 minutes. Pairwise comparison between design requirements was conducted in each hierarchy. The expert's judgement on the importance of each requirement was checked for consistency. We adopted the integration of the analytic hierarchy process and rough group method (Song et al., 2013) to prioritize the design requirements and product service components of domestic plumbing.
	Scenario Planning	Scenario planning started with identifying key focal issues derived from user behavior study. From the secondary data, the driving forces of change and trends were identified. Considering the current services process, communication between stakeholders, technological aspects and demographic locations, two scenarios were generated and analysed.
	Design Brief	Phase 1 findings were utilized to draw problem structure. Three design briefs were outlined as a result of phase I.
PSS Design and Detailing – Phase 2		The study reported in this phase 2 was conducted based on the design thinking approach and secondary data.
	Stakeholders Mapping	Multiple stakeholders were mapped in a matrix grid across the public and private domain to individuals working independently. The power versus interest matrix was conducted concerning each stakeholder in mapping their stake in the plumbing service system.
	Customer Journey Mapping	Two service blueprints were developed representing customer actions with the onstage contact and backstage interactions with the support process.

	Data Flow, Processes and Activities	We have used Gane and Sarson symbols of DFDs to visualize the information in the domestic plumbing service system.
	Wireframes	Wireframes are the necessary first step in formally establishing a visual design for the websites. Initially, four wireframes were developed to visualize the structure, navigation, content and information of the e-commerce website.
PSS Test and Implementations – Phase 3	Benchmark	For the benchmark study, data were collected concerning business elements accessible and available for the general public. For instance, the examined websites' operational activities for demographic presence were collected from the individual website. At the same time, website traffic data for comparison are examined through similarweb.com.
	Business Model Development and Analysis	The business model canvas proposed by Osterwalder and Pigneur approach was utilized in developing an e-commerce business model for domestic plumbing services. The SWOT analysis for the developed business model was conducted to examine the existing resources internally and externally.
	Website Design and Development	The website elements and pages were designed using the Adobe XD software (version: 39.0.12.12). The functionality, navigation and content were then coded using the PHP programming language for the website development.
	Customers and expert users feedback	The website validation was conducted through a web-based questionnaire using Google Forms. It includes a video of website demonstration (featuring website contents, navigation and information) followed by open-ended and closed-ended questions. Content analysis was conducted on open-ended questions. Closed-ended questions were formed using a five-point Likert Scale ranging from strongly agree (5) to strongly disagree (1)

Chapter 4

4 Results and Discussion

This chapter presents the analysis of design and development for existing PSS design models/frameworks. Existing PSS design models are analysed by following the conventional design process proposed by Pahl and Beitz (1988) as a reference. It proposes the service system design framework from PSS perspective. The proposed service system design framework is composed of three phases. These are viz. The first phase is PSS requirement identification and analysis; the second phase is PSS design and detailing; the third phase is PSS testing and implementation.

4.1 Analysis of PSS Design Models/Frameworks

The existing PSS design models/frameworks were analysed through the conventional design process by Pahl and Beitz (1988). This conventional design process consists of the following phases: ideation and task analysis, conceptual design, embodiment design, and validation and release. We identified and tabulated the existing PSS models/framework, which falls under the above design processes. Table 4.1 summarize the analysis of existing PSS models/frameworks.

Table 4.1: Analysis of PSS design models/frameworks

Author(s) & Year	Ideation & Task analysis	Conceptual design	Embodiment design	Validation & Release
(Morelli, 2006)	X	X	X	
(Sakao et al., 2009)	X		X	X
(Kindström & Kowalkowski, 2009)	X			
(Maussang et al., 2009)	X	X	X	
(Geum et al., 2011)	X	X		
(J. Lee & AbuAli, 2011)	X	X		
(C. H. Lim et al., 2012)	X			
(Berkovich et al., 2014)	X			
(Hussain et al., 2012)	X			
(Y. S. Kim et al., 2013)	X		X	
(Ana Paula Bezerra Barquet et al., 2013a)	X			
(Rapaccini et al., 2013)	X			
(Marques et al., 2013)	X	X		X
(Bertoni et al., 2013)	X			
(Tran & Park, 2014)	X		X	X
(Zine et al., 2016a)	X		X	
(Pezzotta et al., 2015)	X		X	
(Muto et al., 2015)	X			
(Joore & Brezet, 2015)	X	X	X	
(Trevisan & Brissaud, 2016)	X	X	X	

'X' denotes the topics discussed in PSS ideation, conceptual design, embodiment design and validation

Analysis of PSS design models/frameworks indicates that most of the models proposed mainly focus on a specific phase of the design process. There is a need to combine PSS approaches into design activities, defining an organized procedure to guide designers throughout the various activities that characterize the whole PSS service development process. The PSS development models are primarily discussed in the literature for the manufacturing, automobile industries, tourism and service sectors. There is a lack of a service process in PSS for e-commerce business models.

4.1.1 Service system design framework - Proposal

The methods or tools considered in the proposed service system design framework are not new. They are well established and often used in design management, design, information system, service design and system design disciplines. The prime contribution of the study is the structured and systematic selection, flow and application of the methods in Product Service System context inspired by design. Significant research contribution also lies in application of these methods in generating a service process for e-commerce of domestic plumbing services. The consideration of the domestic plumbing services case example guides the pathway to the development of the service process in PSS.

Morelli (2006) suggested application of design tools/methods in developing a PSS. Moreover, tools like scenarios and use cases in the narrative form should be considered in the definition phases. In contrast, techniques like service blueprint and system analysis, which are in the technical form, must be preferred in defining a PSS structure. Services are an essential part of the developing phases and product development (Marques et al., 2013). Product development involves various activities, from the product-centric in fulfilling customer needs to finish the production, delivery and selling of a product in the market. Nevertheless, service entities also play an essential role in adding value to the product and retaining customers. Although several methodologies in this context have been proposed in the PSS literature, none have been detailed in the entire lifecycle of PSS from design management perspective.

Service development methodologies are few compared to product development methodologies. Besides, in PSS, development methodologies provide little attention to service and are complex (Marques et al., 2013). Tran and Park (2014) suggest employing the design sequence of product and service components while designing PSS. According to Maussang et al. (2009), PSS comprises service units and physical objects. As a whole system, physical objects are functional entities and service units are mainly technical. These play a role in elementary functions and

the smooth functioning of the whole system. In addition, these elements have relationships and interactions. Therefore, developing a PSS into a whole system has various influencing elements and must be considered in the early design phases. Influencing elements are viz. partners and organization of the enterprise, benefits for customer/provider (economic assessments), physical objects with service units, environmental aspects, social aspects and encouraging PSS (use instead of owning a product). Engineers focus on the design of tangible products and their interactions with other objects. However, the associated technical services part is neglected (Maussang et al., 2009).

The capabilities required for service development depend on communication and empathy with customers and combining various types of knowledge (Beltagui, 2018). Customer centric design and focus on service processes are also essential for service development (Rapaccini et al., 2013). The design process has to consider broader information about designing an effective PSS model (Kim et al., 2013). Therefore, the proposed PSS service development process model involves integrated strategic management and engineering perspectives, design thinking, service design and information system design. The proposed service development process model includes three phases: requirements identification & analysis, design & detailing, and test and implementation. The proposed framework/model is named "service system design framework" because it focuses on identifying service needs, visualization and mapping, and experimenting with the service part of the PSS. Figure 4.1 illustrates the proposed PSS service development process.

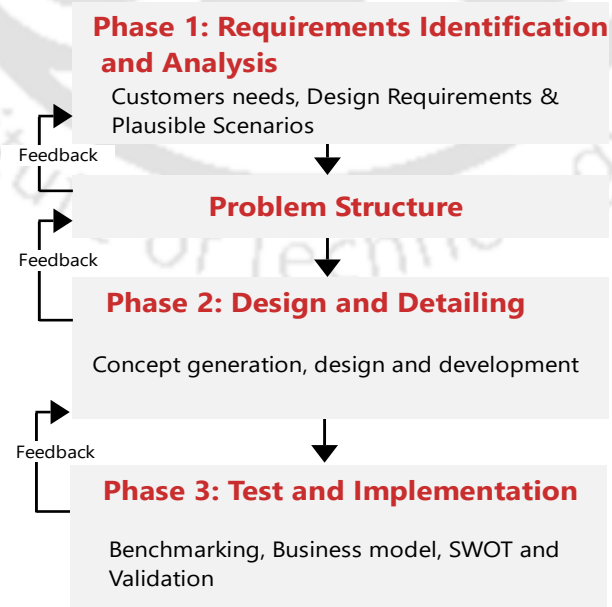


Figure 4.1: Proposed service system design framework from PSS perspective

The proposed model provides a continuing mechanism so that each phase's output provides input to the following phase. Nevertheless, the phases are non-linear and iterative; therefore as depicted in figure 4.1 there is a feedback loop in each phase. Table 4.2 depicts reasons for considering the methods/tools/techniques in the proposed service system design framework. The description of each phase is presented below,

Requirement Identification & Analysis phase 1: Design principles and customer needs typically cast the requirements in the early stages of development. We generate customer requirements with a structured questionnaire to understand the customer's lifecycle using the product or service. Ranking and prioritizing would help manage resources better and result in higher customer satisfaction levels, increased competitiveness, decreased environmental impact and material savings. The Rough Group Analytic Hierarchy Process method (Song et al., 2013) was utilized to prioritize and rank the design requirements. Lastly, plausible scenarios to adapt and anticipate future events. Scenario planning accounts for the effect of multiple drivers of change, trends and delivers significant possibilities, risks and opportunities.

Problem Structure: In phase 1, customer's requirements, design requirements and plausible futuristic scenarios are identified and created. Findings from phase 1 are utilized as insights for the design brief. The Design brief provides a structured statement that outlines problem definition, goals, constraints, budgets and timeline.

Design and Detailing phase 2: This phase primarily concentrate on the Design Thinking approach by mapping stakeholders, visualizing the service process, data flow and wireframe. All the stakeholders are initially identified through primary data that could directly or indirectly influence the e-commerce business model's success to serve this purpose. The mapping of all stakeholders in the power vs. interest matrix shows stakeholders' future strategic management. Furthermore, the service blueprint approach illustrates multiple stakeholders' touchpoints, customer journey and interaction between technology with supporting staff, tangible products, and intangible services. The Data Flow Diagram (DFD) is carried out for the decomposition of a process into sub-processes through connections of sources, sinks, processes and data stores. Data flow diagrams clarify activities from the service provider's perspective and depict data flow between various actors for smooth operations. Lastly, wireframes guide designers to establish a visual design for the new system.

Test and Implementation phase 3: For the market launch, this phase accounts for benchmarking, business model, SWOT and validation. The goal of benchmarking is to learn

from the best practice of others. It is an incremental improvement tool. The business model explains how a business creates and delivers value to customers. The deliverables in developing a business model help companies to capture, understand, design, analyze and change their business logic. Value perception and customer habits are among the most dominant hindrances to PSS implementation. Thus, customer feedback is essential for continuous improvement & growth on a long-term basis.

The proposed service system design framework from PSS perspective model's effectiveness was employed in a practical case of domestic plumbing services in the Indian context. This framework utility for designing and developing the service process from PSS perspective is shown and discussed in the next three subsequent sections. Section 4.2 covers phase 1 of this proposed model, i.e., PSS requirements identification and analysis with the design brief. The Phase 2 comprises PSS design and detailing as presented in section 4.3. The section 4.4 presents the PSS test and implementation, which is phase 3 of this proposed service system design from PSS perspective.

Table 4.2: Reasons for considering the methods/tools/techniques in the proposed service system framework

Research Phases	Methods/Tools/Techniques	Rationale
Requirements Identification & Analysis	User Behavior Study	User behavior data is required to enhance the design activities, such as target customer identification, idea generation, and information content generation (M.-J. Kim et al., 2018)
	Rough Group Analytic Hierarch Process	The Rough AHP has the strengths in prioritizing the fuzzy, subjective, and uncertain PSS requirements (Song, 2017)
	Scenario Planning	It is a strategic planning tool for improving decision making against a background of possible future environments (Derbyshire & Giovannetti, 2017)
Problem Structure	Design Brief	Design brief is recognized to achieve greater clarity and more predictability (Blyth and Worthington, 2001). Defining a design brief has become an integral part of the design process (Dewulf et al., 2012).
Design & Detailing	Stakeholder Mapping	Stakeholder mapping or analysis aid in the design of specific knowledge of who has a stake and why (Ginige et al., 2018)
	Service Blueprint	Service blueprinting enables accurate description and provides a map of a service system so that all the stakeholders can easily understand the business process's operation (Wang et al., 2017)
	Data Flow Diagram	DFDs are used for process modelling to represent the system under development through connections of sources, sinks, processes and data stores (Wang et al., 2017)
	Wireframes	UI is a valuable technique for increasing customers' trust, user satisfaction, purchase intention, and decision to buy

Test & Implementation	Benchmarking	Benchmarking is a continuous process; products, services, activities, and processes could be benchmarked; for competitive advantage, performance could be measured quantitative and qualitative; and it is about learning how to do better (McGaughey, 2002)
	Business Model Canvas	The deliverables in developing a business model provide companies to capture, understand, design, analyze and change their business logic (Ana Paula Bezerra Barquet et al., 2013b) (Adrodegari et al., 2017).
	SWOT	Business organizers, decision-makers or managers employ SWOT analysis at the early stages of the strategic planning process and proceed towards strategy formulation (Houben et al., 1999) (Jeyaraj et al., 2012) (Namugenyi et al., 2019)

4.2 PSS Requirement Identification and Analysis of Domestic Plumbing Services – Phase 1

This section aims to study tools and methods for PSS requirements identification and analysis. It describes exploration and experimentation of various tools and methods viz. user behaviour study through structured questionnaire and interview, Rough Group Analytic Hierarchy Process approach for prioritizing design requirements, Scenario Planning to understand plausible futuristic situations in PSS. The experiment was conducted in PSS design of domestic plumbing services in Indian context.

4.2.1 User Behavior Study

Data concerning the customer's opinions about the service aspects in domestic plumbing is collected through a questionnaire. A total of 160 respondents' opinions are collected through structured questionnaires. Opinions related to plumbing service aspects were collected from the respondents of Guwahati city, India with the help of a structured questionnaire. Guwahati is the capital city of state of Assam, India. Guwahati city is a cosmopolitan and habitat of all class and breed of India. It is one of the fastest-growing cities in the country and has a population of 0.9 million as of the 2011 census. The city consists of old traditional areas of residence and as well as newly developed residential areas with modern plan and amenities. The Guwahati city was broadly divided into three categories of locations viz. Very old, Old, and New. In each category of locations eight-nine residential areas were selected. Altogether, ten to fifteen responses were collected from each residential areas of Guwahati city. Total number of respondents covering all the residential areas in all the three categories were 160. Respondents were approached to participate in the survey, then briefed on the purpose of the survey and interview duration. The survey was conducted during January 2017 to June 2017.

The duration spent with each respondent was around 25 - 30 minutes. Among the respondents, 128 are males and 32 are females. The data for this study was collected through the survey, which was a paper-based questionnaire. The rationale for using a survey is primarily because these data did not currently exist. This survey provided a better source for insights into plumbing service aspects from users. The data collected is tabulated and analyzed using SPSS 20.0 statistical software tool.

Plumbing service aspects were categorized into the groups viz. corrective maintenance, preventive maintenance, the time required to fix plumbing issues, servicemen responsiveness, and contact mode. The other essential variables considered were the frequency of domestic plumbing issues occurring more often and users expectations/needs towards plumbing services. Demographic data of domestic plumbing services under the survey were categorized into residential typology, locality, occupation, age group and gender (Appendix 1). Figure 4.2 illustrates the demographic data of domestic plumbing services. Residential typology of detached houses (37.5%) comprised single-family houses within a plot with the surrounding land. The attached houses (25%) relates to single-family houses sharing walls with another. The apartment (25%) involves families staying at multi-storey buildings. The last residential typology of residential buildings (12.5%) pertains to families within a community. Data about the respondents' place or area of living is termed as locality and classified as very old (38%), old (12%) and new (50%).

During the survey, respondents having various occupations were considered. Occupation of 38% respondents were business, 35% were self-employed, 19% were housewife and 8% were retired persons. The respondents' age ranged from 25 to 64 years, with the maximum age group being 35 – 44 years, which constituted 42% of the respondents. Respondents within 45 – 54 age group were 30% and 25 – 34 were approximately 18%. Altogether 10% of respondents were from the age group of 54 – 64. Among the respondents, 128 were male (78%) and 32 were female (22%). In the Indian context, men's behavior is more significant in the case of domestic plumbing services, in particular for identification, search, contact and tracing of a plumber including procurement of spare parts.

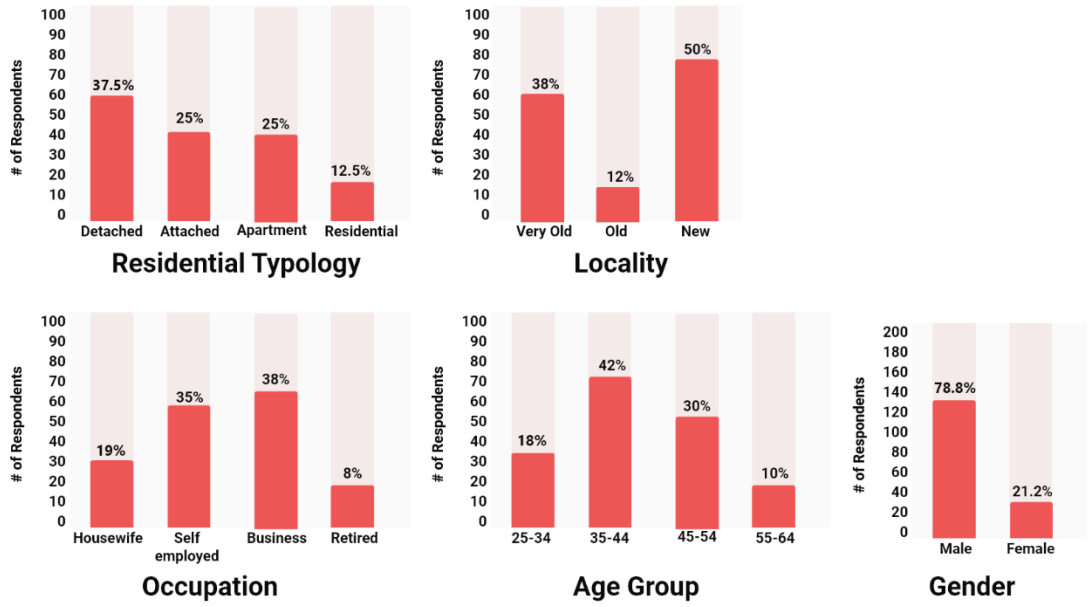


Figure 4.2: Demographic data of domestic plumbing

4.2.1.1 Statistical Analysis of Domestic Plumbing Services with Demographic Profile

Non-parametric and parametric statistical analysis of domestic plumbing services were conducted in relation to demographic profile of the respondents. The following are the non-parametric and parametric tests conducted as follows,

Chi-square tests were conducted for a significance level of 0.05 to observe the variance between the frequency of corrective maintenance, preventive maintenance, the time required to fix plumbing issues, the responsiveness of servicemen and the mode of contact made with variables viz. residential typology, locality, occupation, age-group and gender. Table 4.3 shows the significance (sig.) of the Pearson chi-square test. The study shows that there is a significant difference in the frequency of preventive maintenance with residential typology (sig.= 0.001); servicemen responsiveness with residential typology (sig = 0.019); time required to fix plumbing issues with occupation (sig.= 0.044) and age-group (sig.= 0.003).

Table 4.3: Significance of Pearson chi-square test

Variables	Residential Typology	Locality	Occupation	Age Group	Gender
Corrective Maintenance	0.461	0.245	0.589	0.634	0.681
Preventive Maintenance	0.001	0.297	0.924	0.073	0.358
Time required to fix plumbing issues	0.514	0.086	0.044	0.003	0.190
Servicemen Responsiveness	0.019	0.101	0.637	0.741	0.395
Mode of contact	0.120	0.079	0.659	0.642	0.514

The descriptive statistics and output of tests results are presented in appendix 2. Cross tabulation for the frequency of preventive maintenance and residential typology indicates that 47.3% of respondents with the detached house have never called for preventive maintenance. In comparison to detached houses, we observed low percentage of preventive maintenance for attached houses (26.4%), apartment blocks (20.0%) and residential buildings (6.4%). Altogether, 36.0% of respondents with apartment blocks have called 1 or 2 times for preventive maintenance in a year. 32.0% of respondents with residential buildings have called more than three times for preventive maintenance in a year. Cross tabulation for servicemen's frequency responding to customer plumbing issues and residential typology shows that 37.5% of respondents with the attached house disagree with servicemen responding to customer plumbing issues, followed by for detached house 21.9%, for apartment blocks 28.1% and for residential buildings 12.5%.

Cross tabulation for the frequency of time required to fix plumbing issue and occupation shows that 48.1% of respondents with business occupation opined that the time taken to fix plumbing issues takes 4 to 8 hrs. Altogether, 38.8% of respondents with self-employed occupation opined that the time taken to fix plumbing issues takes more than 24 hrs. Cross tabulation for the frequency of time required to fix plumbing issues were conducted. It has been observed that 59.2% of respondents with 35-44 age group opined that the time taken to fix plumbing issues takes more than 24 hrs. Altogether, 54.5% of respondents in the 45-54 age group have opined that the time to fix plumbing issues takes 4 to 8 hrs.

One-Way-ANOVA test was conducted for a significance level of 0.05 to observe the variance of service frequency of dripping faucets issue, water pressure issue, running toilet issue, slow/ clogged drain and leaky pipe issue with corrective maintenance, preventive maintenance, the time required to fix plumbing issues, servicemen responsiveness, mode of contact, residential typology, locality, occupation, age group and gender.

The ratings of the service frequency were measured in a 7-point semantic differential scale where 1 = never and 7 = very frequently. Statistical analyses helped us to identify and describe complex relationships between the variables of domestic plumbing services. Table 4.4 shows the ANOVA means, standard deviation and significance of descriptive statistics. The analysis of variance showed that,

- The effect of occupation on dripping faucet issue was significant, $F(3,156) = 4.375$, $p = 0.005$.

- The effect of resident typology on dripping faucet issue was significant, F (3,156) = 2.859, p = 0.039.
- The effect of locality on running toilet issue was significant, F (2,157) = 3.402, p = 0.036.
- The effect of resident typology on leaky pipes issue was significant, F (3,156) = 4.160, p = 0.004.

Table 4.4: Descriptive statistics of one-way ANOVA

Dependent Variable	Independent Variable	Mean	SD	Sig.
Dripping faucet issue	Occupation	4.14	1.635	0.005
Dripping faucet issue	Residential typology	4.14	1.635	0.039
Running Toilets issue	Locality	3.26	1.771	0.036
Leaked pipes issue	Residential typology	2.83	1.855	0.004

Further, multiple comparisons of Post Hoc tests were conducted to observe the significant differences within the groups of respondents (Appendix 2, One-Way ANOVA test results). The Tukey HSD test reflects that,

- There is a significant difference in dripping faucet issues between the groups of occupation, i.e., the housewife and the retired (p = 0.003), the self-employed and the retired (p = 0.013), and the business and the retired (p = 0.013). The mean value of dripping faucets issues was significantly different between occupation viz. housewife and retired (p = .003, 95% C.I. = [.51, 3.24]), between occupation viz. self-employed and retired (p = .013, 95% C.I. = [.24, 2.77]) and between occupation viz. business and retired (p = .023, 95% C.I. = [.23, 2.75]). The mean difference (I-J) of dripping faucets issues between occupation viz. housewife and retired is 1.874, between occupation viz. self-employed and retired is 1.504 and between occupation viz. business and retired is 1.488. There was no statistically significant difference in the mean dripping faucets issues between occupation viz. housewife and self-employed (p = .731), between occupation viz. housewife and business (p = .694) or between occupation viz. self-employed and business (p = 1.000).
- There is a significant difference in dripping faucet issues between the groups of residential typologies, i.e., The detached house and the apartment blocks (p = 0.021). However, there were no differences of dripping faucet issues between the residential buildings and the detached house (p = 0.709), residential buildings and the attached house (p = 0.998), residential buildings and the apartment blocks (p = 0.645). The

mean value of dripping faucets issues was significantly different between residential typologies viz. detached houses and apartment blocks (p = .021, 95% C.I. = [-1.81, -.11]). The mean difference (I-J) of dripping faucets issues between detached house and apartment blocks is -.960.

- There is a significant difference in running toilet issues between the localities groups, i.e., the very old and the new (p = 0.028). However, there were no differences of running toilet issues between old and very old (p = 0.657) and old and the new (p = 0.452). The mean value of running toilet issues was significantly different between localities viz. very old and new (p = .028, 95% C.I. = [-1.53, -.07]). The mean difference (I-J) of running toilet issues between localities viz. very old and new is 0.800.
- There is a significant difference in leaky pipe issues between the groups of residential typologies, i.e., the residential buildings and the detached house (p = 0.002), residential buildings and the attached house (p = 0.014). However, there were no differences of leaky pipe issues between the apartment blocks and the detached house (p = 0.646), apartment blocks and the attached house (p = 0.922), apartment blocks and the residential buildings (p = 0.058). The mean value of leaky pipe issues was significantly different between residential typologies viz. residential buildings and detached house (p = .002, 95% C.I. = [.48, 2.88]), between residential typologies viz. residential buildings and attached house (p = .014. 95% C.I. = [.23, 2.79]). The mean difference(I-J) of leaky pipe issues between residential typologies viz. residential buildings and detached house is 1.682 and between residential typologies viz. residential buildings and attached house is 1.509.

4.2.2 Rough Group Analytic Hierarchy Process

In this section, a study on elicitation and prioritization of design requirements using Analytic Hierarchy Process (AHP) and Rough Group (Song et al., 2013) is demonstrated for domestic plumbing services. Analytic Hierarchy Process (AHP) is a fundamental theory of subjective measurement and is a popular tool for assigning weights to compare specific criteria or alternatives (Ghimire & Kim, 2018). The AHP method provides a valuable aid in organizing, assessing requirements, ranking and incorporating multiple experts' judgements. Comparison values may be taken from surveys or measurements from the respondents using fundamental scales, as shown in Table 4.5 (Saaty, 1977).

Table 4.5: Satty's pairwise comparison scale and explanations

Importance Scale	Definition of Importance Scale
1	Equally Important Preferred
3	Moderately Important Preferred
5	Strongly Important Preferred
7	Very Strongly Important Preferred
9	Extremely Important Preferred
2,4,6,8	Intermediate value between two judgements

The Rough Group originated from the rough set theory (Yang et al., 2017). Pawlak proposed the rough set theory. This tool is used in handling vagueness and imprecision of information from decision-makers. It deals with imprecise and subjective concepts (Lee et al., 2012). Lee et al. (2012) mentioned that the advantage of rough set theory in contrast with other methods lies in handling subjective information without any adjustments or assumptions. Moreover, vague concepts or information could be presented as precise through lower and upper approximations. Figure 4.3 illustrates the flow of AHP and Rough Group method applied for prioritizing design requirements of domestic plumbing.

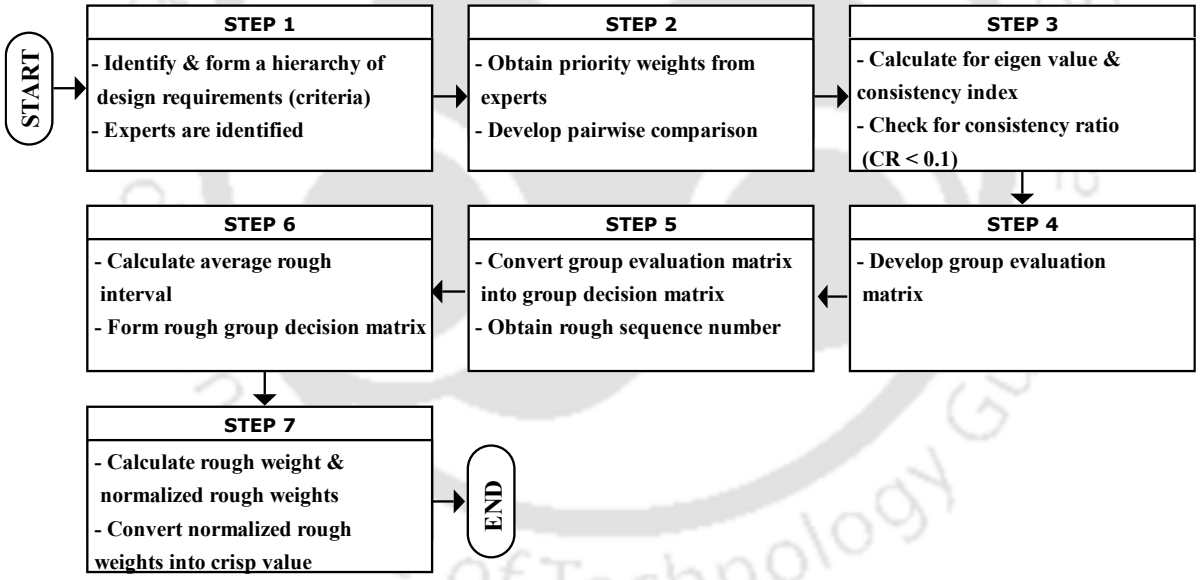


Figure 4.3: Flow of AHP and Rough Group method applied for prioritizing design requirements of domestic plumbing

STEP 1: Identify and form a hierarchy of design requirements (criteria) related to product, service and system. Develop a group of pairwise comparison matrices for product, service and system separately. A group of '*k*' experts is formed to rate importance. Where $k = 1,2,3\ldots$.

STEP 2: For the pairwise comparison, each expert from group 'k' are invited. Then obtain priority weights of a data matrix. The 'k' experts' pairwise comparison matrix A^k is as follows

$$A^k = \begin{bmatrix} 1 & r_{12}^k & \cdots & r_{1n}^k \\ r_{21}^k & 1 & \cdots & r_{2n}^k \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1}^k & r_{n2}^k & \cdots & 1 \end{bmatrix}_{nxn}$$

Where r_{ij}^k is the k^{th} expert's judgement for the i^{th} design requirement importance compared with j^{th} design requirement and n is the number of design requirements.

STEP 3: Check for consistency of the pairwise comparison matrix. The consistency test is conducted by the following equation (1) and equation (2).

$$CI = \frac{\lambda_{\max} - n}{n-1} \quad \textbf{(1)}$$

$$CR = \left(\frac{CI}{RI(n)}\right) \quad \textbf{(2)}$$

Where CI is consistency index, λ_{max} is the largest eigenvalue of matrix A^k. n is the dimension of the matrix A^k. CR is the consistency ratio. RI is the random index which depends on the dimension of matrix as shown in Table 4.6 (Saaty, 1977)

Table 4.6: Random Index

Order	1	2	3	4	5	6	7	8	9	10
RI(n)	0	0	0.52	0.89	1.11	1.25	1.35	1.40	1.45	1.49

Consistency test pairwise comparison matrix is acceptable when CR is less than 0.1. If CR is greater than 0.1, experts need to adjust a pairwise comparison until it clears the consistency test.

STEP 4: After combining all pairwise matrixes from expert's opinions, develop group evaluation matrix B of design requirements and sub-requirements.

$$B = \begin{bmatrix} 1 & r_{12} & \cdots & r_{1n} \\ r_{21} & 1 & \cdots & r_{2n} \\ \vdots & \vdots & \ddots & \vdots \\ r_{n1} & r_{n2} & \cdots & 1 \end{bmatrix}_{nxn}$$

Where $r_{ij} = [r_{ij}^1, r_{ij}^2, r_{ij}^3, \ldots . r_{ij}^k]$

Rough Group: Assume that there is a set of m classes of human judgements. $J = \{r_{ij}^1, r_{ij}^2 \ldots r_{ij}^k \ldots r_{ij}^m\}$ ordered in the manner of $r_{ij}^1 \prec r_{ij}^2 \prec \ldots \prec r_{ij}^k \ldots \prec r_{ij}^m$. U is the universe, including all the objects and Y is an arbitrary object of U.

Then lower and upper approximation of r_{ij}^k can be defined as (Yang et al. 2017)

Lower approximation: $\underline{Apr}\left(r_{ij}^k\right) = \cup\left\{Y \in U/J(Y) \leq r_{ij}^k\right\}$

Upper approximation: $\overline{Apr}\left(r_{ij}^k\right) = \cup\left\{Y \in U/J(Y) \geq r_{ij}^k\right\}$

STEP 5: Convert the element r_{ij} in group decision matrix B into $RN\left(r_{ij}^k\right)$ of r_{ij} as:

$$RN\left(r_{ij}^k\right) = \left[r_{ij}^{kL}, r_{ij}^{kU}\right] \quad (3)$$

Where r_{ij}^{kL} is the lower limit and r_{ij}^{kU} is the upper limit of rough number $RN\left(r_{ij}^k\right)$ in k^{th} pairwise comparison matrix respectively

$$r_{ij}^k = \underline{Lim}\left(r_{ij}^k\right) = \left(\prod_{m=1}^{N_L} x_{ij}\right)^{1/N_L} \qquad r_{ij}^k = \overline{Lim}\left(r_{ij}^k\right) = \left(\prod_{m=1}^{N_U} y_{ij}\right)^{1/N_U}$$

Where x_{ij} and y_{ij} are the elements of lower and upper approximation for r_{ij}^k.

N_L and N_U are the number of objects included in the lower and upper approximation of r_{ij}^k respectively.

STEP 6: Then we obtain rough sequence number as,

$$RN\left(r_{ij}\right) = \left\{\left[r_{ij}^{1L}, r_{ij}^{1U}\right], \left[r_{ij}^{2L}, r_{ij}^{2U}\right], \ldots\ldots \left[r_{ij}^{kL}, r_{ij}^{kU}\right]\right\}$$

The average rough interval $\overline{RN(r_{ij})}$ is obtained by using an equation,

$$\overline{RN(r_{ij})} = \left[r_{ij}^L, r_{ij}^U\right] \quad (4)$$

Where $r_{ij}^L = \sqrt[k]{r_{ij}^{1L} \times r_{ij}^{2L} \times \ldots\ldots r_{ij}^{kL}}$ and $r_{ij}^U = \sqrt[k]{r_{ij}^{1U} \times r_{ij}^{2U} \times \ldots\ldots r_{ij}^{kU}}$

Then rough group decision matrix M is formed as,

$$M = \begin{pmatrix} [1,1] & \left[r_{12}^L, r_{12}^U\right] & \cdots & \left[r_{1n}^L, r_{1n}^U\right] \\ \left[r_{21}^L, r_{21}^U\right] & [1,1] & \cdots & \left[r_{2n}^L, r_{2n}^U\right] \\ \vdots & \vdots & \ddots & \vdots \\ \left[r_{n1}^L, r_{n1}^U\right] & \left[r_{n2}^L, r_{n2}^U\right] & \cdots & [1,1] \end{pmatrix}$$

STEP 7: Calculate rough based weight and its normalized counterparts as follows,

$$W_i = (W_i^L, W_i^U) = \left[\left(\prod_{i=1}^{n} r_{ij}^L\right)^{1/n}, \left(\prod_{i=1}^{n} r_{ij}^U\right)^{1/n}\right] \quad (5)$$

$$NW_i = (NW_i^L, NW_i^U) = \left[\frac{W_i^L}{max(W_i^U)}, \frac{W_i^U}{max(W_i^U)}\right] where: i = 1,2,3.. \quad (6)$$

4.2.2.1 Prioritization of Design Requirements for Domestic Plumbing using Analytic Hierarchy Process and Rough Group

Initially we conducted in-depth interviews, including exploratory surveys. The survey's prime focus was to study the 'plumbing tools' and service aspects' in domestic plumbing. A structured interview with various stakeholders (plumbers, technicians, plumbing retailers) revealed plumbing tools viz. adjustable wrenches, pliers, metal files, hacksaw, lubricants and replacement parts. Various aspects of customer service requirements were identified viz. corrective maintenance, preventive maintenance, operation time, service frequency, replacement of spare parts, consumables and fittings.

Further, insights from the interview were utilized in structuring the hierarchy of product, service and system-related design requirements. We applied the AHP and Rough Group method to prioritize the plumbing design requirements and product service components. Thirty-four design requirements were identified from and interactions with stakeholders for domestic plumbing (Berkovich et al., 2014). These design requirements are categorized into a hierarchical structure of product, service and system. Product-related design requirements comprise technical function, economic and quality. Service-related design requirements comprise process, interaction, timing and reliability. System-related design requirements comprise human resources, facility, material, information and capital.

Five experts were chosen from three sectors viz. designer, maintenance engineer and technician. A questionnaire of pairwise comparison of product-related, service-related and system-related design requirements was developed (Appendix 3). Then structured interview and interactions were conducted with experts for collecting importance ratings on design requirements. The meetings and interviews were about 50-60 minutes. Pairwise comparison between design requirements is conducted in each hierarchy. The expert's judgement on the

importance of each requirement was checked for consistency (Appendix 4). AHP and Rough Group method for prioritizing design requirements of domestic plumbing are as follows,

STEP 1 and 2: A hierarchy of design criteria related to product/service/system was formed. A separate pairwise comparison matrix was developed for product, service and system as shown in Figure 4.4, Figure 4.5 and Figure 4.6.

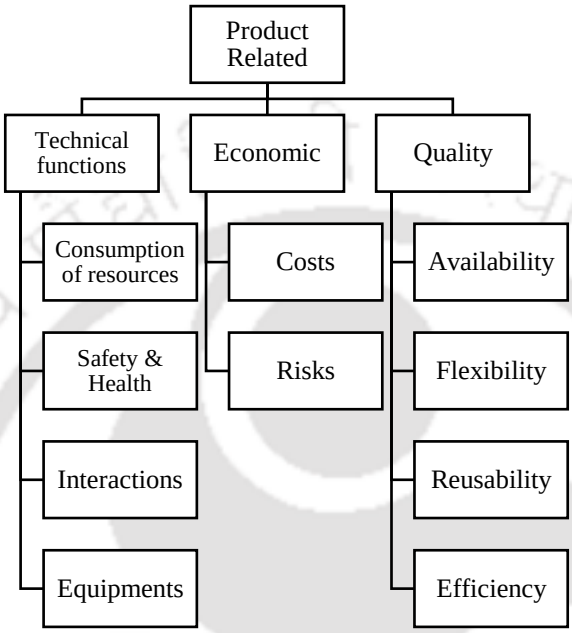


Figure 4.4: Hierarchical structure for product-related design requirements of domestic plumbing

Abbreviation	**Explanation**
Technical functions	Tasks performed by technical products (such as a toolkit, spare parts)
Economic	Costs and risks aspects that occur in the process of provision or usage of the technical product
Quality	Data that represents the quality of the technical product, i.e. availability, efficiency, and flexibility of the product deployment or reusability
Consumption of resources	Usage of materials
Safety & Health	Plumber protection equipment's (such as gloves, protective eyewear, masks)
Interaction	Interaction between plumber and tools
Equipment's	Number of tools required for the job
Costs	Amount of money has to be paid for technical products
Risks	The situation involved with technical products
Availability	Technical products to be used or obtained
Flexibility	Provision of alternate products
Reusability	Products capable of being used again
Efficiency	Use of products efficiently to perform a job

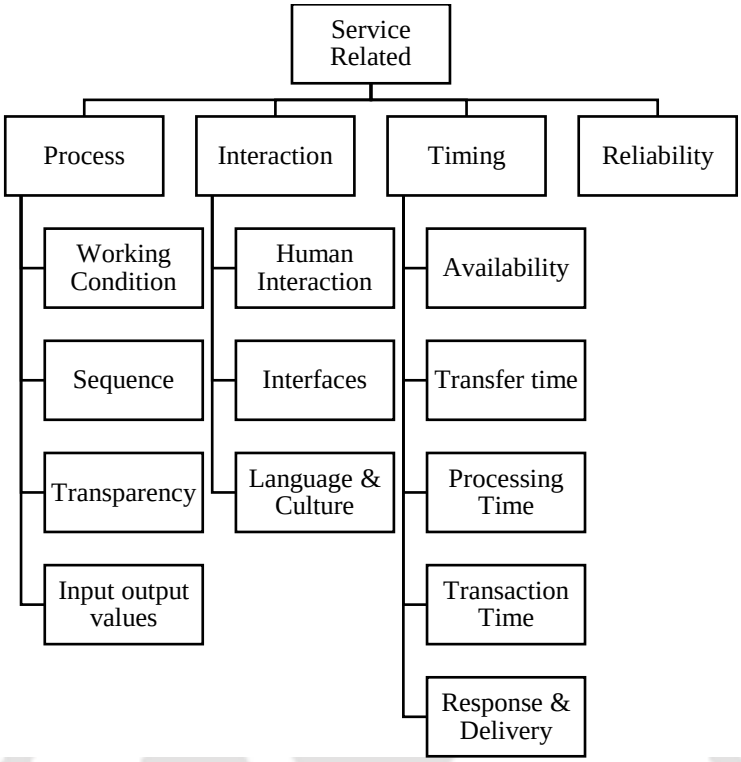


Figure 4.5: Hierarchical structure for service-related design requirements of domestic plumbing

Abbreviation	**Explanation**
Process	"The activities involved in plumbing services, such as steps, information flow, tools used, procurement of spare parts."
Interaction	"Customer meets & interact with a service provider, plumber, during plumbing service."
Timing	Guarantee of plumbing repair service.
Reliability	Trust & consistent performance between customer and service provider.
Working conditions	"Working environment where plumber does job (hours of work, rest period, work schedules, and physical conditions)."
Sequence	Follow up standard instruction for resolving plumbing issues
Transparency	Easy understanding and interpretation
Input & output values	"Information about plumbing issues from customer to service provider. results were delivered to the customer. "
Human interaction	Interaction between customer and plumber/service provider
Interfaces	A point where two people meet
Language & culture	Communication and conducts between customer and plumber/service provider
Availability	Available of plumber
Transfer time	Areal distance to the service location
Processing time	Necessary activities to the provision of plumbing service
Transaction time	Time to actual service provision
Response & delivery	Time to the service provision

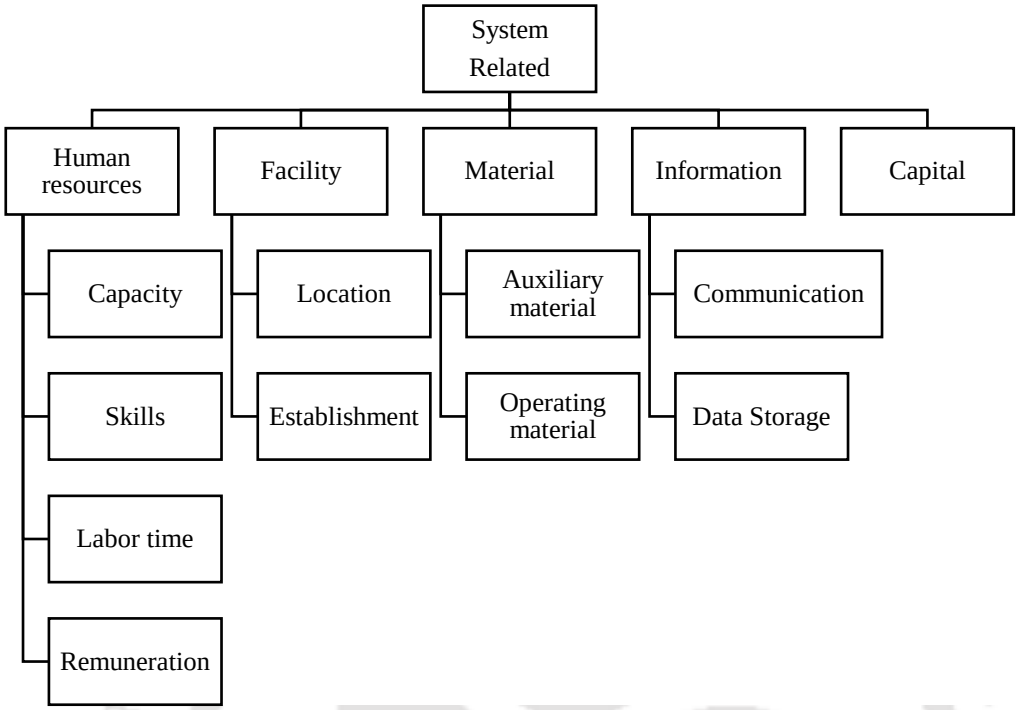


Figure 4.6: Hierarchical structure for system-related design requirements of domestic plumbing

Abbreviation	**Explanation**
Human resources	Staff consisting number of plumbers, trainer, helper, admin to fulfil plumbing service
Facility	Place where plumbing service is offered and maintained
Material	Raw material, tools
Information	Communication between stakeholders (reports, data, method and tools used)
Capital	Available amount and costs associated plumbing service
Capacity	Staff consisting number of plumbers, trainer, helper, admin to fulfil plumbing service
Skills	Plumbing knowledge, experience, handling tools and maintenance
Labor time	Time required to reach service area and finish specific plumbing issues
Remuneration	Money paid for inspection and repair for a service
Location	Place where service provider/plumber available
Establishment	The unit that operates and provide services to plumbing issues
Auxiliary material	Supplementary help and support of materials
Operating material	Consumable materials for plumbing service
Communication	"Exchange of information between customer, plumber, and service provider. (through = mobile App/ phone/ mail/ walk-in/recommendation)"
Data storage	Information stored and maintained for future assessments, case studies

STEP 3 and 4: Pairwise comparison between design requirements is conducted in each hierarchy until each comparison matrix gets through a consistency test.

Table 4.7 depicts judgments (expert 1) pairwise comparison matrix of product-related design requirements. To illustrate the computation process, matrix A^1 shows expert judgements on the

first level of product-related design requirements of domestic plumbing viz. technical functions, economic and quality.

Table 4.7: Pairwise comparison matrix with importance scale of product-related design requirements

Product-related (level 1)	Technical functions	Economic	Quality
Technical functions	1	5	1/3
Economic	1/5	1	1/7
Quality	3	7	1

$$A^1 = \begin{bmatrix} 1 & 5 & 1/3 \\ 1/5 & 1 & 1/7 \\ 3 & 7 & 1 \end{bmatrix}$$

$$Columnn\ sums = [4.2 \quad 13 \quad 1.48]$$

$$Normalized\ column\ sums = \begin{bmatrix} 0.238 & 0.385 & 0.225 \\ 0.048 & 0.077 & 0.097 \\ 0.714 & 0.538 & 0.676 \end{bmatrix}$$

$$Row\ average, X = \begin{bmatrix} 0.283 \\ 0.074 \\ 0.643 \end{bmatrix}$$

According to equations (1) and (2) consistency test and consistency ratio are calculated as follows,

$$AX = \lambda_{max} X$$

$$\begin{bmatrix} 1 & 5 & 1/3 \\ 1/5 & 1 & 1/7 \\ 3 & 7 & 1 \end{bmatrix} \begin{bmatrix} 0.283 \\ 0.074 \\ 0.643 \end{bmatrix} = \lambda_{max} \begin{bmatrix} 0.283 \\ 0.074 \\ 0.643 \end{bmatrix}$$

$$(1 * 0.283) + (5 * 0.074) + (1/3 * 0.643) = 0.867$$

$$\begin{bmatrix} 0.867 \\ 0.223 \\ 2.010 \end{bmatrix} = \lambda_{max} \begin{bmatrix} 0.283 \\ 0.074 \\ 0.643 \end{bmatrix}$$

$$\lambda_{max} = \left[\frac{0.867}{0.283} + \frac{0.223}{0.074} + \frac{2.01}{0.643}\right] = 9.203$$

$$\lambda_{max} = \left[\frac{9.203}{3}\right] = 3.067$$

$$Consistency\ Index, CI = \left(\frac{\lambda_{max} - n}{n-1}\right) = \left(\frac{3.067-3}{3-1}\right) = \frac{0.067}{2} = 0.0335$$

$$Consistency\ Ratio, CR = \left(\frac{CI}{RI}\right) = \left(\frac{0.0335}{0.52}\right) = 0.063$$

$$A^1 = \begin{bmatrix} 1 & 5 & 1/3 \\ 1/5 & 1 & 1/7 \\ 3 & 7 & 1 \end{bmatrix} \qquad A^2 = \begin{bmatrix} 1 & 2 & 1 \\ 1/2 & 1 & 1/2 \\ 1 & 2 & 1 \end{bmatrix} \qquad A^3 = \begin{bmatrix} 1 & 1 & 1/7 \\ 1 & 1 & 1/3 \\ 7 & 3 & 1 \end{bmatrix}$$

$\lambda = 3.066, CR = .063 < 0.1$ $\lambda = 3., CR = .00 < 0.1$ $\lambda = 3.082, CR = .078 < 0.1$

$$A^4 = \begin{bmatrix} 1 & 1 & 1/5 \\ 1 & 1 & 1/6 \\ 5 & 6 & 1 \end{bmatrix} \qquad A^5 = \begin{bmatrix} 1 & 4 & 1/3 \\ 1/4 & 1 & 1/6 \\ 3 & 6 & 1 \end{bmatrix}$$

$\lambda = 3.004, CR = .004 < 0.1$ $\lambda = 3.054, CR = .052 < 0.1$

Similarly, matrix A^2, A^3, A^4 and A^5 show experts' judgements on the first level of product-related design requirements of domestic plumbing viz. technical functions, economic and quality. The consistency test and consistency ratio are depicted in the above matrices.

The rough group evaluation matrix B of first-level product-related design requirements can be obtained by combining the above five pairwise matrices.

$$B = \begin{bmatrix} 1,1,1,1,1 & 5,2,1,1,4 & 1/3,1,1/7,1/5,1/3 \\ 1/5,1/2,1,1,1/4 & 1,1,1,1,1 & 1/7,1/2,1/3,1/6,1/6 \\ 3,1,7,5,3 & 7,2,3,6,6 & 1,1,1,1,1 \end{bmatrix}$$

The same procedure can be conducted to other levels of hierarchical structure to get their comparison matrices.

STEP 5 and 6: To get the rough form of the group comparison matrix, the B matrix elements are transformed into rough number form, according to equation (3).

Now, to find lower and upper approximations B matrix element $C_{12} = (5,2,1,1,4)$ is considered. The rough number conversion process is as follows and shown in Table 4.8.

$\underline{Lim}(5) = (5 \times 4 \times 2 \times 1 \times 1)^{1/5} = 2.091$ $\overline{Lim}(5) = 5$

$\underline{Lim}(2) = (2 \times 1 \times 1)^{1/3} = 1.259$ $\overline{Lim}(2) = (2 \times 4 \times 5)^{1/3} = 3.419$

$\underline{Lim}(1) = 1$ $\overline{Lim}(1) = (1 \times 1 \times 2 \times 4 \times 5)^{1/5} = 2.091$

$\underline{Lim}(4) = (4 \times 2 \times 1 \times 1)^{1/4} = 1.681$ $\overline{Lim}(4) = (4 \times 5)^{1/2} = 4.472$

Table 4.8: Rough number conversion for matrix B

Experts	C_{11}	*Lower limit*	*Upper limit*	C_{12}	*Lower limit*	*Upper limit*	C_{13}	*Lower limit*	*Upper limit*
1	1	1	1	5	2.09	5	1/3	0.23	0.48
2	1	1	1	2	1.25	3.41	1	0.31	1
3	1	1	1	1	1	2.09	1/7	0.14	0.31
4	1	1	1	1	1	2.09	1/5	0.16	0.38
5	1	1	1	4	1.68	4.47	1/3	0.23	0.48
Experts	C_{21}	*Lower limit*	*Upper limit*	C_{22}	*Lower limit*	*Upper limit*	C_{23}	*Lower limit*	*Upper limit*
1	1/2	0.2	0.47	1	1	1	1/7	0.23	0.23
2	1/2	0.29	0.79	1	1	1	1/2	0.23	0.5
3	1	0.47	1	1	1	1	1/3	0.19	0.19
4	1	0.47	1	1	1	1	1/6	0.15	0.26
5	1/4	0.22	0.59	1	1	1	1/6	0.15	0.26
Experts	C_{31}	*Lower limit*	*Upper limit*	C_{32}	*Lower limit*	*Upper limit*	C_{33}	*Lower limit*	*Upper limit*
1	3	2.08	4.21	7	4.32	7	1	1	1
2	1	1	3.15	2	2	4.32	1	1	1
3	7	3.15	7	3	2.44	5.24	1	1	1
4	5	2.59	5.916	6	3.83	6.31	1	1	1
5	3	2.08	4.21	6	3.83	6.31	1	1	1

The average rough interval $\overline{RN(r_{12})}$ is obtained by using equation (4).

$$r_{12}^{L} = \sqrt[5]{2.09 \times 1.25 \times 1 \times 1 \times 1.68} = 1.34$$

$$r_{12}^{U} = \sqrt[5]{5 \times 3.41 \times 2.09 \times 2.09 \times 4.47} = 3.19$$

$$\overline{RN(r_{12})} = (1.34,3.19)$$

Similarly, other elements of the rough sequence table are obtained. Then rough group decision matrix *M* is formed as,

$$M = \begin{bmatrix} (1.00,1.00) & (\mathbf{1.34,3.19}) & (0.21,0.48) \\ (0.31,0.74) & (1.00,1.00) & (0.19,0.27) \\ (2.04,4.71) & (3.15,5.75) & (1.00,1.00) \end{bmatrix}$$

STEP 7: The rough based weight is calculated using equation (5) as,

$$W_1 = (W_1^L, W_1^U) \; : \; W_1^L = (1 \times 1.34 \times 0.21)^{1/3} = 0.65 \; , \; W_1^U = (1 \times 3.19 \times 0.48)^{1/3} = 1.16$$

$$W_2 = (W_2^L, W_2^U) \; : \; W_2^L = (0.31 \times 1 \times 0.19)^{1/3} = 0.39 \; , \; W_2^U = (0.74 \times 1 \times 0.27)^{1/3} = 0.58$$

$$W_3 = (W_3^L, W_3^U) \; : \; W_3^L = (2.04 \times 3.15 \times 1)^{1/3} = 1.85 \; , \; W_3^U = (4.71 \times 5.75 \times 1)^{1/3} = 3.00$$

$$W = \begin{bmatrix} (0.65,1.16) \\ (0.39,0.58) \\ (1.85,3.00) \end{bmatrix}$$

The above matrix *W* gives the rough weight of the first level hierarchical structure for product related design requirements of domestic plumbing, i.e., technical functions, economic and quality. Similarly, the rough weights are calculated for other hierarchical structure levels and shown in Table 4.9. Table 4.10 shows overall weights & normalized rough weights for service-related design requirements.

The first level for service-related design requirements i.e., the rough weights of process is [0.30, 0.58], interaction is [0.64, 1.20], timing is [0.86, 2.12] and reliability is [1.50, 2.73]. The second level rough weights for service-related design requirements under process are viz. working conditions [0.53, 0.98], sequence [0.85, 1.73], transparency [0.59, 0.89], and input and output values [1.12, 2.24]. Similarly, the rough weights under interaction are viz. human interaction [1.24, 2.60], interfaces [0.44, 1.24], and language and culture [0.49, 1.16]. The rough weights under timing are viz. availability [1.12, 2.19], transfer time [0.27, 0.48], processing time [0.86, 2.13], and response and delivery [0.89, 2.42]. There are no second level service-related design requirements under reliability. The final overall weights are calculated using the multiplication synthesis method from top-level to bottom level. For instance, the rough weights of process [0.30, 0.58] is multiplied with second level requirements i.e., working conditions [0.53, 0.98]. Then, the overall weights for working conditions will be [(0.30*0.53, 0.58*0.98] = [0.16, 0.57]. Normalized rough weights are calculated using equation (6) as follows,

$$NW_i = \left(NW_i^L, NW_i^U\right) = \left[\frac{W_i^L}{max\left(W_i^U\right)}, \frac{W_i^U}{max\left(W_i^U\right)}\right] where: i = 1,2,3..$$

Here, $NW_i = normalized\ rough\ weight\ for\ working\ conditions = NW_1$

$$W_1^L = lower\ limit\ of\ overall\ weight\ for\ working\ conditions = 0.16$$

$$and\ W_1^U = upper\ limit\ of\ overall\ weight\ for\ working\ conditions = 0.57$$

$\max\left(W_i^U\right)$

$= maximum\ number\ of\ upper\ limit\ under\ column\ overal\ weights from\ table\ 4.10$

$= 5.12$

$$NW_1 = \left[\frac{0.16}{5.12}, \frac{0.57}{5.12}\right] = [0.03\ 0.11]$$

Table 4.11 shows overall weights & normalized rough weights for system-related design requirements.

Table 4.9: Overall weights & normalized rough weights for product-related design requirements

First level requirements			*Second level requirements*			*Overall weights*		*Normalized rough weights*	
	Lower Lim	*Upper Lim*		*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*
Technical functions	0.66	1.16	Consumption of resources	1.19	2.26	0.79	2.63	0.10	0.32
			Safety & Health	1.71	3.40	1.13	3.95	0.14	0.48
			Interaction	0.36	0.72	0.24	0.84	0.03	0.10
			Equipment's	0.35	0.70	0.23	0.82	0.03	0.10
Economic	0.39	0.59	Costs	0.58	1.68	0.23	0.99	0.03	0.12
			Risks	0.59	1.73	0.23	1.02	0.03	0.12
Quality	1.86	3.00	Availability	0.39	1.25	0.73	3.76	0.09	0.46
			Flexibility	0.54	1.59	1.00	4.78	0.12	0.59
			Reusability	0.42	1.45	0.79	4.36	0.10	0.53
			Efficiency	1.42	2.72	2.65	8.17	0.32	1.00

The first level for product-related design requirements i.e., the rough weights of technical functions is [0.66, 1.16], economic is [0.39, 0.59] and quality is [1.86, 3.00]. The second level rough weights for product related design requirements under technical functions are viz. consumption of resources [1.19, 2.26], safety and health [1.71, 3.40], interactions [0.36, 0.72] and equipment's [0.35, .70]. similarly, the rough weights under economic are viz. costs [0.58, 1.68] and risks [0.59, 1.73]. The rough weights under quality are viz. availability [0.39, 1.25], flexibility [0.54, 1.59], reusability [0.42, 1.45] and efficiency [1.442, 2.72]. The final overall weights are calculated using the multiplication synthesis method from top-level to bottom level. For instance, the rough weights of technical functions [0.66, 1.16] is multiplied with second level requirements i.e., consumption of resources [1.19 2.26]. Then, the overall weights for consumption of resources will be [(0.66*1.19, 1.16*2.260] = [0.79, 2.63]. Normalized rough weights are calculated using equation (6) as follows,

$$NW_i = \left(NW_i^L, NW_i^U\right) = \left[\frac{W_i^L}{max\left(W_i^U\right)}, \frac{W_i^U}{max\left(W_i^U\right)}\right] where: i = 1,2,3..$$

Here, $NW_i = normalized\ rough\ weight\ for\ consumption\ of\ resources = NW_1$

$$W_1^L = lower\ limit\ of\ overall\ weight\ for\ consumption\ of\ resources = 0.79$$

$$and\ W_1^U = upper\ limit\ of\ overall\ weight\ for\ consumption\ of\ resources = 2.63$$

$\max(W_i^U)$

$= maximum\ number\ of\ upper\ limit\ under\ column\ overal\ weights from\ table\ 4.9$

$= 8.17$

$$NW_1 = \left[\frac{0.79}{8.17}, \frac{2.63}{8.17}\right] = [0.10\ 0.32]$$

Table 4.10: Overall weights & normalized rough weights for service-related design requirements

First level requirements			*Second level requirements*			*Overall weights*		*Normalized rough weights*	
	Lower Lim	*Upper Lim*		*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*
Process	0.30	0.58	Working conditions	0.53	0.98	0.16	0.57	0.03	0.11
			Sequence	0.85	1.73	0.25	1.01	0.05	0.20
			Transparency	0.59	0.89	0.18	0.52	0.03	0.10
			Input & output values	1.12	2.24	0.34	1.30	0.07	0.25
Interaction	0.64	1.20	Human interaction	1.24	2.60	0.80	3.11	0.16	0.61
			Interfaces	0.44	1.24	0.28	1.49	0.05	0.29
			Language & culture	0.49	1.16	0.32	1.39	0.06	0.27
Timing	0.86	2.12	Availability	1.12	2.19	0.96	4.63	0.19	0.90
			Transfer time	0.27	0.48	0.23	1.02	0.05	0.20
			Processing time	0.86	2.13	0.74	4.51	0.14	0.88
			Transaction time	0.55	1.43	0.48	3.03	0.09	0.59
			Response & delivery	0.89	2.42	0.76	5.12	0.15	1.00
Reliability	1.50	2.73				1.50	2.73	0.29	0.53

The first level for service-related design requirements i.e., the rough weights of process is [0.30, 0.58], interaction is [0.64, 1.20], timing is [0.86, 2.12] and reliability is [1.50, 2.73]. The second level rough weights for service-related design requirements under process are viz. working conditions [0.53, 0.98], sequence [0.85, 1.73], transparency [0.59, 0.89], and input and output values [1.12, 2.24]. Similarly, the rough weights under interaction are viz. human interaction [1.24, 2.60], interfaces [0.44, 1.24], and language and culture [0.49, 1.16]. The rough weights under timing are viz. availability [1.12, 2.19], transfer time [0.27, 0.48], processing time [0.86, 2.13], and response and delivery [0.89, 2.42]. There are no second level service-related design requirements under reliability. The final overall weights are calculated using the multiplication synthesis method from top-level to bottom level. For instance, the rough weights of process [0.30, 0.58] is multiplied with second level requirements i.e., working conditions [0.53, 0.98]. Then, the overall weights for working conditions will be [(0.30*0.53, 0.58*0.98] = [0.16, 0.57]. Normalized rough weights are calculated using equation (6) as follows,

$$NW_i = \left(NW_i^L, NW_i^U\right) = \left[\frac{W_i^L}{max\left(W_i^U\right)}, \frac{W_i^U}{max\left(W_i^U\right)}\right] where: i = 1,2,3..$$

Here, $NW_i = normalized\ rough\ weight\ for\ working\ conditions = NW_1$

$$W_1^L = lower\ limit\ of\ overall\ weight\ for\ working\ conditions = 0.16$$

$$and\ W_1^U = upper\ limit\ of\ overall\ weight\ for\ working\ conditions = 0.57$$

$\max\left(W_i^U\right)$

$= maximum\ number\ of\ upper\ limit\ under\ column\ overal\ weights from\ table\ 4.10$

$= 5.12$

$$NW_1 = \left[\frac{0.16}{5.12}, \frac{0.57}{5.12}\right] = [0.03\ 0.11]$$

Table 4.11: Overall weights & normalized rough weights for system-related design requirements

First level requirements			*Second level requirements*			*Overall weights*		*Normalized rough weights*	
	Lower Lim	*Upper Lim*		*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*	*Lower Lim*	*Upper Lim*
Human resources	0.53	1.32	Capacity	0.31	0.48	0.17	0.63	0.03	0.13
			Skills	2.22	3.82	1.18	5.04	0.23	1.00
			Labour time	0.66	1.15	0.35	1.51	0.07	0.30
			Remuneration	0.75	1.40	0.40	1.85	0.08	0.37
Facility	0.77	1.59	Location	0.86	1.59	0.66	2.53	0.13	0.50
			Establishment	0.63	1.16	0.48	1.85	0.10	0.37
Material	0.57	1.01	Auxiliary material	0.53	0.81	0.30	0.82	0.06	0.16
			Operating material	1.23	1.89	0.71	1.91	0.14	0.38
Information	0.80	1.73	Communication	0.86	1.87	0.69	3.24	0.14	0.64
			Data storage	0.53	1.16	0.43	2.01	0.09	0.40
Capital	0.91	1.55				0.91	1.55	0.18	0.31

The first level of system-related design requirements i.e., the rough weights of human resources is [0.53, 1.32], facility is [0.77, 1.59], material is [0.57, 1.01], information is [0.80, 1.73] and capita is [0.91, 1.55]. The second level rough weights for system-related design requirements under human resources are viz. capacity [0.31, 0.48], skills [2.22, 3.82], labour time [0.66, 1.15], and remuneration [0.75, 1.40]. Similarly, the rough weights under facility are viz. location [0.86, 1.59] and establishment [0.63, 1.16]. the rough weights under material are viz. auxiliary material [0.53, 0.81] and operating material [1.23, 1.89]. the rough weights under information are viz. communication [0.86, 1.87] and data storage [0.53, 1.16]. There are no

second level system-related design requirements under capital. The final overall weights are calculated using the multiplication synthesis method from top-level to bottom level. For instance, the rough weights of human resources [0.53, 1.32] is multiplied with second level requirements i.e., capacity [0.31, 0.48]. Then, the overall weights for capacity will be [(0.53*0.31, 1.32*0.48] = [0.17, 0.63]. Normalized rough weights are calculated using equation (6) as follows,

$$NW_i = \left(NW_i^L, NW_i^U\right) = \left[\frac{W_i^L}{max\left(W_i^U\right)}, \frac{W_i^U}{max\left(W_i^U\right)}\right] where: i = 1,2,3..$$

Here, $NW_i = normalized\ rough\ weight\ for\ capacity = NW_1$

$$W_1^L = lower\ limit\ of\ overall\ weight\ for\ capacity = 0.17$$

$$and\ W_1^U = upper\ limit\ of\ overall\ weight\ for\ capacity = 0.63$$

$\max\left(W_i^U\right)$

$= maximum\ number\ of\ upper\ limit\ under\ column\ overal\ weights from\ table\ 4.11$

$= 5.04$

$$NW_1 = \left[\frac{0.17}{5.04}, \frac{0.63}{5.04}\right] = [0.03\ 0.13]$$

The normalized rough weights prioritization and ranking is given to crisp value. To convert normalized rough weights into crisp value, authors W. Song et al. (Song et al., 2013) has introduced the optimistic indicator $\lambda(0 \leq \lambda \leq 1)$. If decision-makers are more optimistic about their judgements, then λ can be selected greater than 0.5. If decision-makers are more pessimistic about their judgements, then λ can be selected as lesser than 0.5. If decision-makers are more moderate about their judgements, then λ can be selected 0.5. The crisp weight and ranking for product, service and system-related priority of design requirements are shown, when $\lambda = 0.5$ using equation $= (1 - \lambda)NW_i^L + \lambda NW_i^U$ in below Table 4.12.

Table 4.12: Crisp weight & ranking for product service and system-related design requirements

Product			*Service*			*System*		
Criteria	***Crisp weight***	***Rank***	***Criteria***	***Crisp weight***	***Rank***	***Criteria***	***Crisp weight***	***Rank***
Consumption of resources	0.209	6	Working conditions	0.071	12	Capacity	0.079	11
Safety & Health	0.311	4	Sequence	0.123	11	Skills	0.616	1
Interaction	0.066	9	Transparency	0.067	13	Labour time	0.184	9
Equipment's	0.064	10	Input & output values	0.159	9	Remuneration	0.223	8
Costs	0.074	8	Human interaction	0.381	5	Location	0.316	3
Risks	0.077	7	Interfaces	0.172	7	Establishment	0.231	7
Availability	0.275	5	Language & culture	0.166	8	Auxiliary material	0.111	10
Flexibility	0.354	2	Availability	0.545	2	Operating material	0.259	4
Reusability	0.315	3	Transfer time	0.122	10	Communication	0.389	2
Efficiency	0.662	1	Processing time	0.512	3	Data storage	0.241	6
			Transaction time	0.342	6	Capital	0.244	5
			Response & delivery	0.574	1			
			Reliability	0.413	4			

Table 4.12 represents crisp weight and ranking for product, service and system-related design requirements. The prioritization or ranking through Rough Group AHP study results show that the most important product-related design requirements are efficiency, flexibility and reusability. Service-related design requirements are response/delivery, availability and processing time. System-related design requirements are skills, communication of plumber and location.

4.2.3 Scenario Planning for Domestic Plumbing Services

The scenario planning started with a key focal issue of services toward domestic plumbing. Likely issues of preventive maintenance, corrective maintenance, plumber's responsiveness to the customer and strategic management to the service provider. Plausible scenarios were created for a time frame of 5-10 years. Scenario planning accounts for the effect of multiple drivers of change, trends and delivers significant possibilities, risks and opportunities. This study identified the driving forces of change and trends for domestic plumbing from four perspectives: political, economic, social and technological.

The political drivers of change are Skill India, Digital India, Pradhan Mantri Kaushal Vikas Yojana and National Skill Development Mission. The economic drivers of change are the gig economy, family income, demand and supply. The social drivers of change are buying habits,

lifestyle, education and online platforms. The technological drivers of change are video in real-time, mixed reality and drone delivery. The aforementioned driving forces of change and trends were collected from government reports, research articles and market surveys. The impact vs. uncertainty matrix was conducted for each identified driving force of change. Figure 4.7 depicts the impact vs. uncertainty mapping for the domestic plumbing in Indian context. A brief discussion on driving forces of change and trends are as follows,

Political: The Government of India has implemented various programs for skill development, skill upgradation and certification under schemes viz. Pradhan Mantri Kaushal Vikas Yojana, National Skill Development Mission. The prime objective of such skill development/certification program is to provide livelihood and employment for Indian youths. The Government of India has organized several training programs for skill development and upgradation in plumbing sector.

Economic: The Government of India has initiated 'Start-up India' to nurture innovations and start-ups to drive sustainable economic growth through entrepreneurship development and employment generation. In India, gig workers have enormous opportunities to work for online platform-based businesses. Gig workers are those who work on-demand and provide services mainly through online platforms.

Social: Nowadays, social media are emerging and new ways of marketing and increasing online business. The impact of customer reviews and feedback directly affects the way of doing online business. Consumers have a much wider choice of products/services available in the cyber market. Consumers can compare products, features, prices and even look up reviews before selecting what they want. Consumers enjoy more extensive access to assistance and advice from experts and peers. Consumers also avail options of fast services and fast delivery of products/services.

Technological: Technology may transform jobs of the future and lean more towards tech-enabled. Digital services from e-learning to online payments, e-health to broadcasting preventive measures, news, online video streaming is all seeing a boom. There could be a rise in technological advancement and consumers' adoption of technologies as they embrace technology while working from home. The aid of drones was beneficial during the Covid-19 crisis. For example, medical deliveries, spraying disinfectants, surveillance and monitoring public places. Therefore, technology will greatly influence the domestic plumbing sector.

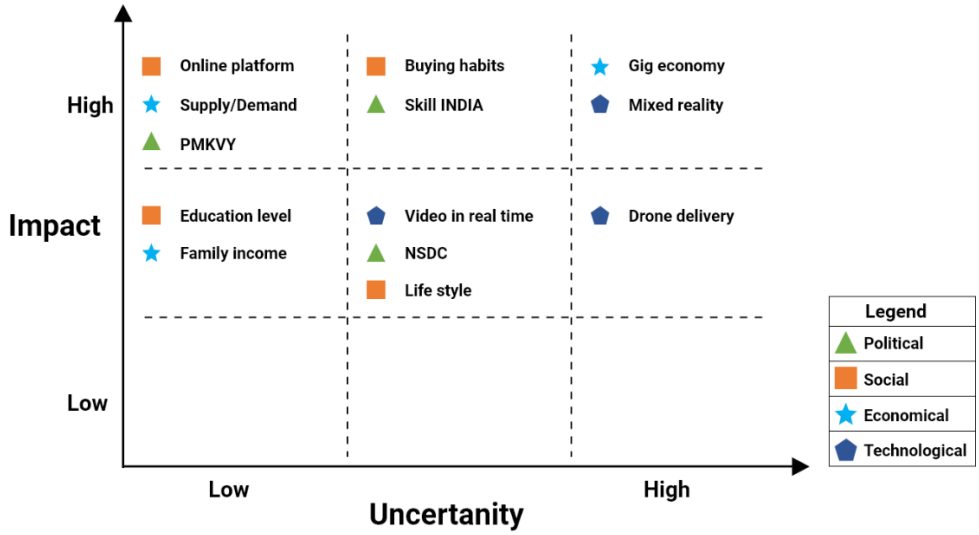


Figure 4.7: Impact vs Uncertainty mapping of domestic plumbing services

Two scenarios were created for the plumbing service system as follows,

Scenario 1: With Indian cities witnessing significant growth, plumbing services online will expand sufficiently to tier II and tier III cities. Figure 4.8 illustrates the first scenario on existing online plumbing services in urban areas and why to choose on-demand home services. In this scenario, the extent to which online ordering for plumber service is limited to urban cities. The number of plumber service requests could be high, but most consumers request plumber service through a phone call, neighbours' recommendation and walk-in. The Indian Plumbing Association (IPA) has taken several initiatives for professionalization of plumbing. However, generally plumbing apprentices work as helpers in urban cities with a practising plumber (Ranganathan, 2013). These apprentices learn plumbing skills as they worked on practical jobs. Plumbers concentrate more on conventional learning and there is lack of professional training including plumbing codes and certification programs. Therefore, the service provided by the plumbers are subjective and challenging to regulate. The strategic implications for service providers and consumers in this scenario are challenging, particularly in identifying certified plumbers. The strategic actions for on-demand home services are identified as follows,

- To encourage the apprentices to take up certification programs to improve labour status and income through professionalization.
- To have uniform guidelines on health and safety measures. Policies on monetary benefits, job security for plumbers.
- To refocus on business models and areas of potential growth in the future.

- To have the advantage of delivering first its kind in services to attract more customers.
- To invest or capitalize in research and development for new products and services.
- Design Thinking in development of online platforms for better user navigation, user interactions, secure payment methods and transparency in pricing details.

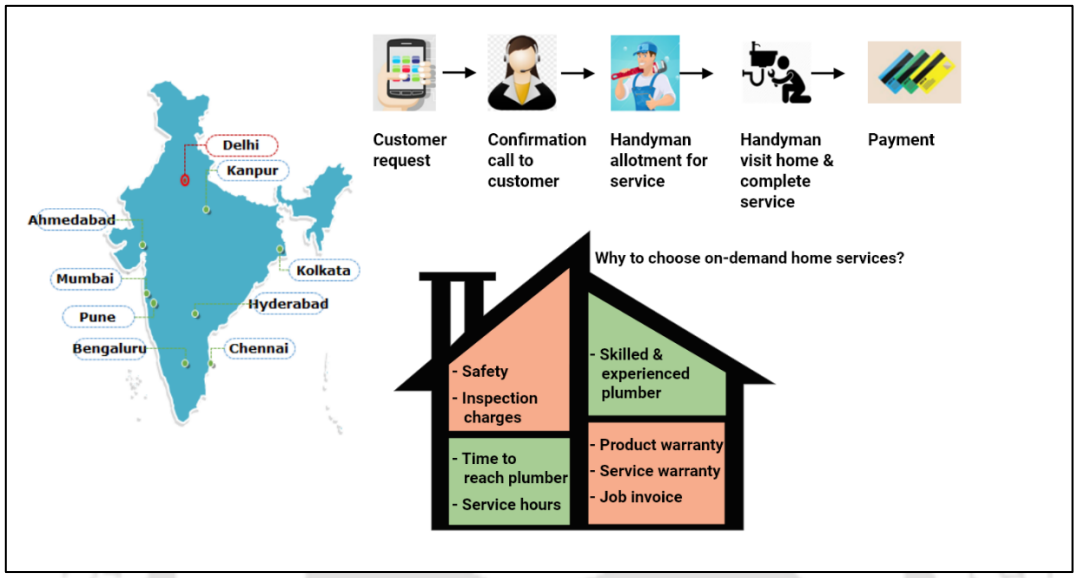


Figure 4.8: Scenario-1 of the plumbing service system

Scenario 2: Potential customers are likely to solve minor plumbing issues with specific instructions through online streaming. Figure 4.9 depicts the second scenario of the domestic plumbing in Indian context. In this scenario, the stakeholders involved are viz. customers, service providers, delivery agents and plumbers. Customers can access the website for resolving minor plumbing issues with proper instruction and specific images of particular plumbing issues. This design solves the problem of long waiting times for the arrival of plumbers. From the survey data, minor plumbing issues were identified as dripping faucets/taps, low water pressure, clogged drain/toilets and leaked pipes. Customers can compare and purchase the tools/spare parts for a particular plumbing issue through the information obtained from the website. This design solves the problem of transparency in the cost of tools/spare parts. Further, customers can make direct contact with the plumbers through the internet for significant issues of on-demand services. This design solves the search and availability of plumbers in the market. The support process such as easy access to the website, inventory of products, availability of plumbers must be added to the solution so that the quality of the whole operational process, including onstage and backstage process, can be enhanced.

Service providers could have opportunities to attract new customer segments with specific content that delivers value. The strategic implication for business organizers in this scenario would,

- To consider factors such as mobility, privacy risk and assessment of the service provider, which may affect the adoption of home services.
- To consider systematic management in trade-offs and balances between customers and plumbers in need of urgency.
- Design management strategies in service quality, easy access, availability and customization in service processes.
- To develop a new business model with an emphasis on design thinking approaches.

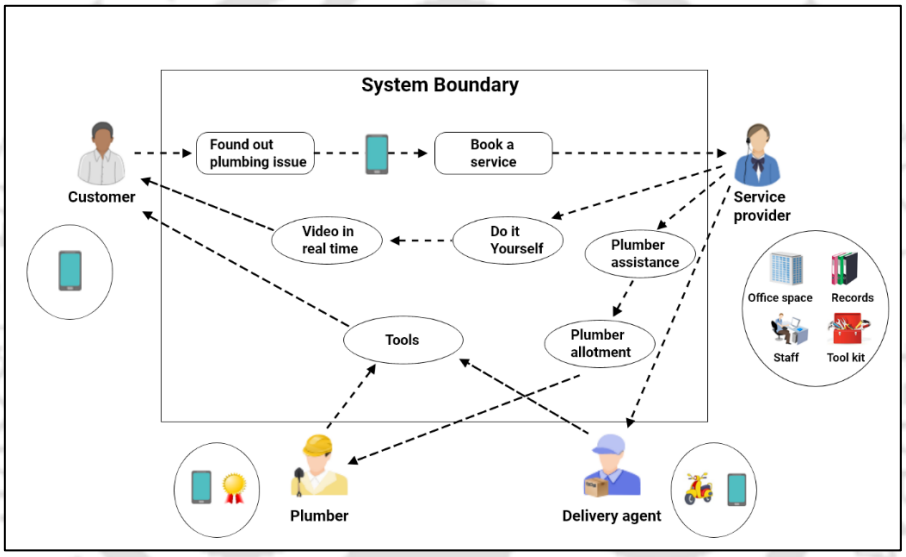


Figure 4.9: Scenario-2 of the plumbing service system

4.2.4 Design Brief

In this section, findings of phase 1 (Requirements Identification & Analysis) were utilized to define the design brief. Three design briefs were outlined. Design Brief-1 is shown in Table 4.13 for designing a plumbing toolkit. Design Brief-2 for designing a mobile-based app for plumbing services is shown in Table 4.14. Design Brief-3 for designing and developing an e-commerce website for domestic plumbing services is shown in Table 4.15

Table 4.13: Design brief-1

Design brief title: Plumbing Toolkit	
We are designing:	A toolkit that can be easily carried & enough space to fit plumbing tools
That:	It can be used to resolve dripping faucet, running toilet and leaky pipes problems
For:	• Occupation with housewife, self-employed, and business • Respondents with detached and attached house • Residence with very old locality • 25-34 and 35-44 age group
So that:	• A consumer can rent/buy a toolkit online for the minor plumbing problem • A consumer can enhance the skill set of "DO IT Yourself."

Table 4.14: Design brief-2

Design brief title: App-based skill sharing	
We are designing:	Mobile-based app for plumbing services
That:	Provide guidelines to preventive maintenance for minor plumbing problems
For:	• Residential typology of detached houses • Respondents with Attached house to avoid the delay of servicemen response towards resolving issues • 35-44 age group
So that:	• The consumer no need to go through a process of searching plumber online for the minor plumbing problem • A consumer can enhance the skill set of "DO IT Yourself."

Table 4.15: Design brief-3

Design brief title: E-Commerce Website	
We are designing:	E-Commerce website for domestic plumbing services
That:	Provide guidelines (images + Videos) to resolve minor plumbing issues or Purchase tools/spare parts, or Hire a nearby plumber
For:	• Residential typology of detached houses • 25-34; 35-44 age group • Respondents with Attached house to avoid the delay of servicemen response towards resolving issues
So that:	• The consumer no need to go through the process of searching plumber online for a minor plumbing problem • The consumer gets online professional support • The consumer can enhance the skill set of do-it-yourself

All the three Design Briefs were shared with a small focus group of designers. Design Briefs were explained and their probable design outcome was envisaged. On the basis of the general feedbacks received, Design Brief – 3 was selected for phase 2, which is designing and detailing phase of the proposed service system design from PSS perspective. Design and detailing (phase 2) on the basis of Design Brief-3 with design thinking approach is discussed in section 4.3.

4.3 PSS Design and Development of Domestic Plumbing Services – Phase 2

The phase 2 illustrates the application of design thinking through stakeholder mapping, service blueprint, data flow and wireframe techniques in developing e-commerce with the practical case of domestic plumbing services. Figure 4.10 shows the mapping of the design thinking approach with the proposed PSS service design. It has been observed that in each specific phase of PSS service design, two steps of design thinking were merging. In the overlapping of empathize and define stages of design thinking framework we observed 'stakeholder mapping'. Similarly, in the overlapping of define and ideate stages of design thinking framework we observed 'service blueprint'. In the overlapping of ideate and prototype stages of design thinking framework we observed 'data flow diagram'. In the overlapping of prototype and test stages of design thinking framework we observed 'wireframes'.

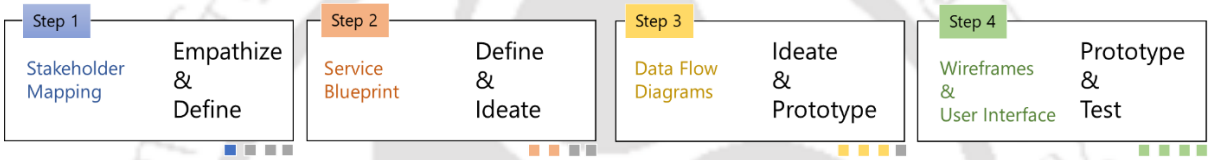


Figure 4.10: Mapping of the Design Thinking approach with PSS service design

4.3.1 Empathize and Define: Stakeholder Mapping

Multiple stakeholders were mapped in a matrix grid across the public and private domain to individuals working independently. Accordingly, the power vs. interest matrix was conducted concerning each identified stakeholder in mapping their stake in domestic plumbing in the Indian context. Figure 4.11 depicts the stakeholders mapping for the plumbing service system in the power-interest matrix. The key stakeholders that are considered to be influential in this study are Government, Investors, Service provider, Vendors, Plumbers and Customers. The Government is a stakeholder that influences the adoption process of e-commerce by its role as a regulator. Investor is an individual or a corporation who allocates capital to build and boost e-commerce with the agenda of financial return. Service provider is a company or organization handling the overall process between all the stakeholders. Vendor is an organization who owns independent outlets and provides/sales the tools/spare parts. It also maintains and manages the inventory of products. Plumber is a qualified individual with vocational skills and specialized in fix/repair domestic plumbing issues. Customer/end-user is an individual or organization who accesses portal for on-demand plumber services, online ordering of tools/spare parts, vendors contact information and DIY tutorial on minor plumbing issues.

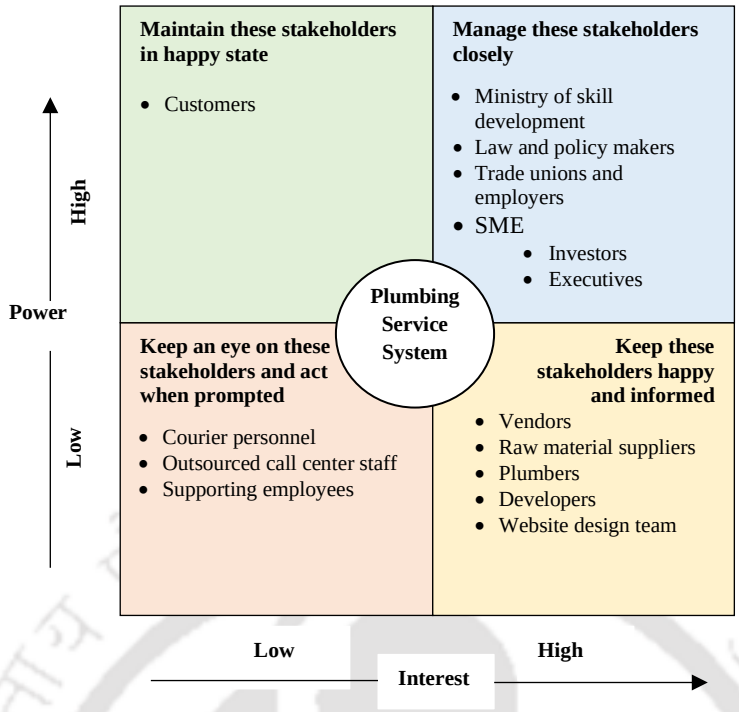


Figure 4.11: Stakeholders mapping in Power-Interest matrix

4.3.2 Define and Ideate: Service Blueprint

Two service blueprints were developed representing customer actions with the onstage contact and backstage interactions with the support process. First, customers access Do-It-Yourself (DIY) tutorials for resolving minor plumbing issues, as depicted in Figure 4.12. Minor plumbing issues identified in the user behaviour study (section 4.2.1) are considered for DIY tutorials. Second, customers access the e-commerce website for on-demand plumber service or order online for plumbing tools and spares, as depicted in Figure 4.13. The developed service blueprints help visualize customer interactions and experiences. In addition, it enhances the service quality of the onstage and backstage process. The schematic representation of service blueprint of domestic plumbing is described as follows,

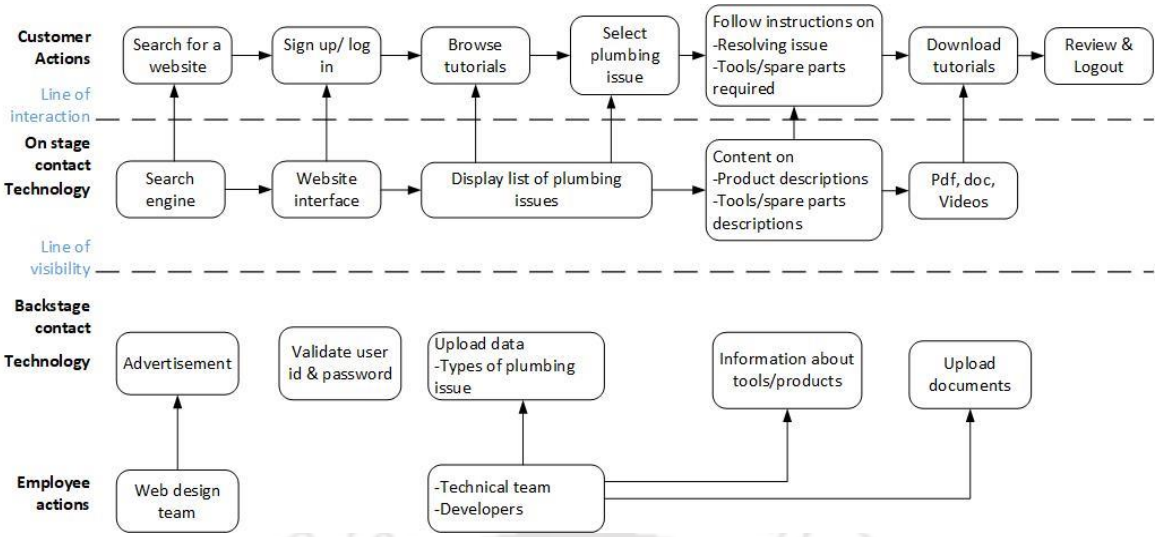


Figure 4.12: Service blueprint of domestic plumbing

From the service blueprint, as illustrated in Figure 4.12, we can see that customers can access the website for resolving minor plumbing issues with proper instruction and specific images to particular plumbing issues. This design solves the problem of long waiting times for the arrival of plumbers. New customers can sign up to register and existing customers can log in with the account credentials. Then, customers can browse the required minor plumbing issues displayed on the website. Customers can read and follow instructions on resolving issues and the required plumbing tools for selected minor plumbing issue. Customers have the option of downloading the tutorials. Lastly, customers can rate and review the DIY tutorials based on their experience. On backstage, the website design team functions in designing the website interface for easy understanding and navigation. The technical team upload data and documents of minor plumbing issues. This data is about plumbing solution procedure in detail and instructions of handling tools. This data is in the form of high-quality images with specifications/instructions and instructional videos.

From the service blueprint, as illustrated in Figure 4.13, we can see that customers can browse the required plumbing service and purchase the tools/spares parts for a particular plumbing issue. This design solves the problem of transparency in the cost of tools/spare parts. We can see the customers can make direct contact with the plumbers for significant issues for on-demand services. This design solves the search and availability of plumbers in the market. The support process, such as easy access to the website, inventory of products and plumber's

availability, must be added to the solution so that the quality of the whole operational process, including the onstage and backstage process, can be enhanced.

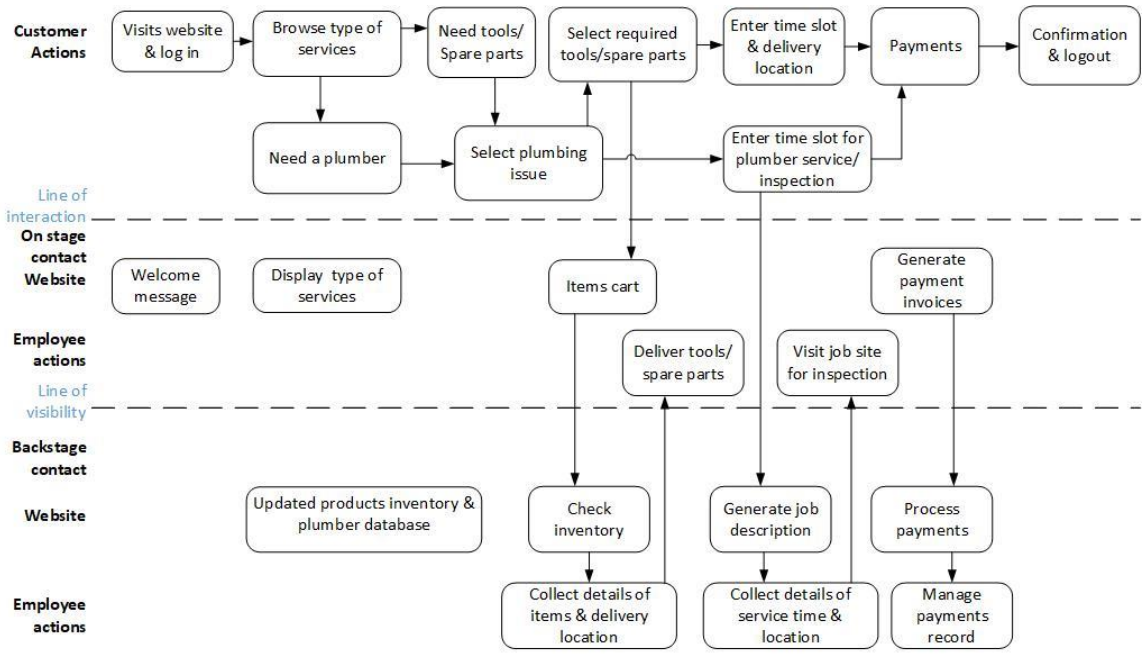


Figure 4.13: Service blueprint of domestic plumbing

4.3.3 Ideate and Prototype: Data Flow Diagrams (DFDs)

We have used Gane and Sarson symbols of DFDs to visualize the information system of domestic plumbing system. Figure 4.14 is the context diagram of the system. The process in the context diagram is named as a plumbing service system. The four sources/sinks of the plumbing service system are customer, plumber, vendor and admin. Customer provides input to plumbing service system to access DIY tutorials, purchase tools/spares, hire plumbers and make payments. Then, customer receives about e-learning, tools on rent, spare parts, plumber service and payment receipt. Plumbing service system provides input to plumber for job order request and payment details. Plumbing service system receives information from plumber about job accept/decline and inspection/repair service. Plumbing service system provides input to vendors for order request and payment details. Plumbing service system receives information from vendor about supply of spare parts and payment receipts. Admin provides input to plumbing service system about add/tutorials, product descriptions and databases of user/vendor/plumber.

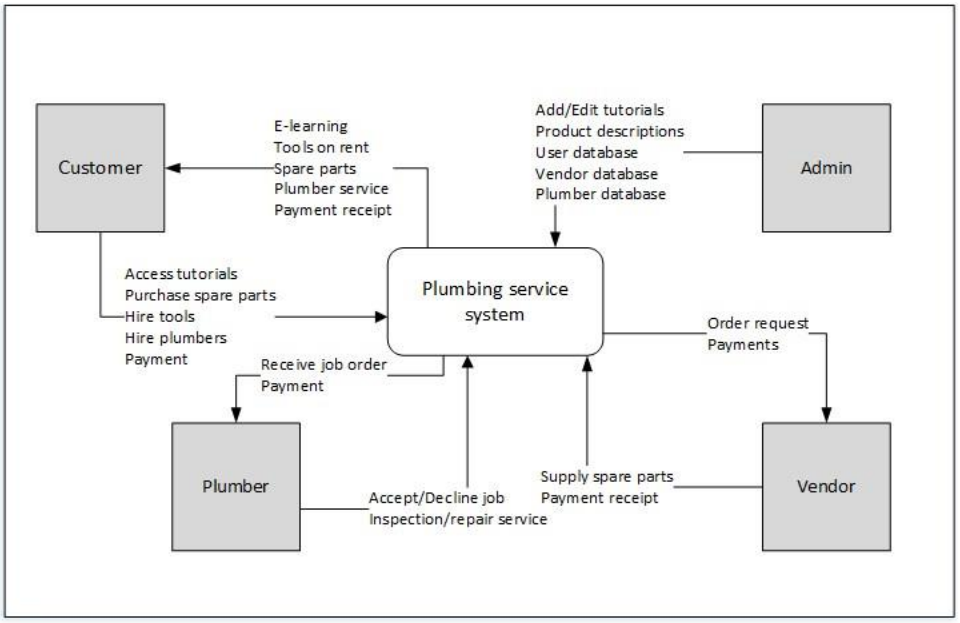


Figure 4.14: Context diagram of plumbing service system

On the basis of the context diagram, level-0 data flow diagram has been developed, as illustrated in Figure 4.15. Level-O DFD of plumbing service system has four processes viz. (1.0) Request and approve login to an account, (2.0) Receive and transform tutorial request, (3.0) Receive and transform tools/spare parts request, and (4.0) Receive and transform plumber service request. Data stores in this DFD are (D1) Customer database, (D2) Plumber database, (D3) Vendor database and (D4) Tutorials store.

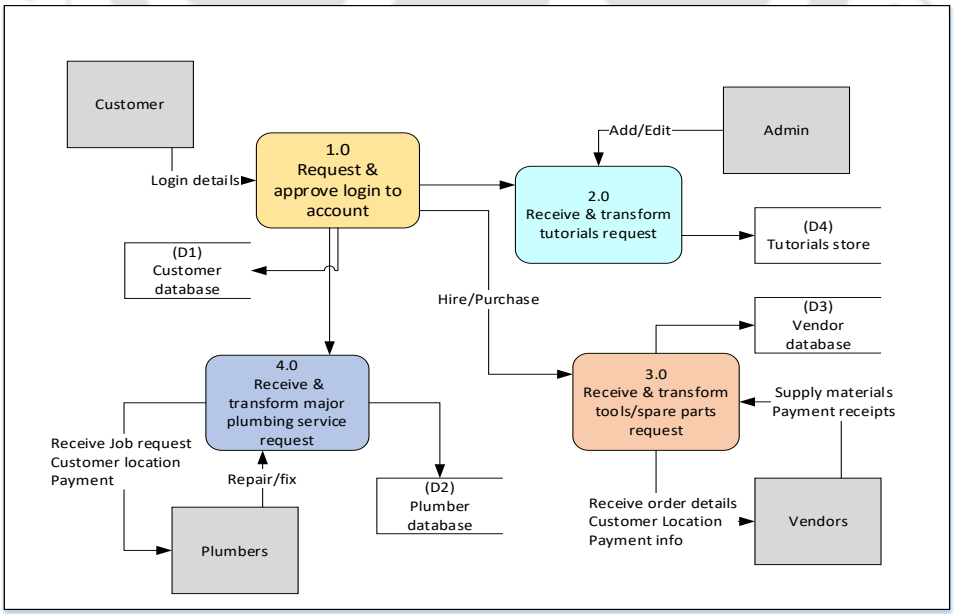


Figure 4.15: Level-0 DFD of plumbing service system

All the processes of level-0 DFD has been decomposed to the next level for better understanding of data flow. Following is the detail of decomposition.

Decomposition of process 1.0 Request and approve login to account:

The decomposition of process 1.0 is illustrated in Figure 4.16. It consists of three processes viz. (1.1) Signup, (1.2) Login and (1.3) Manage customer database. The data stores of this level-1 DFD has two data stores viz. New customer database and Registered customer database. Further, the process 1.1 has been decomposed to level-2. This level-2 decomposition of process 1.1 consists of three-process viz. (1.1.1) Provide valid e-mail id, (1.1.2) Password and (1.1.3) Create account. It has three data stores viz. Customer e-mail id, New customer database and Customer password. The process 1.2 has been decomposed to level-2. This level-2 decomposition of process 1.2 consists of five process viz. (1.2.1) E-mail, (1.2.2) Password, (1.2.3) Forgot password, (1.2.4) Generate new password and (1.2.5) Registered mail id. It has only one data store i.e., Registered customer data store.

Customer provides inputs such as email id and password to create or access account to plumbing service system. Admin manages customer data into registered customer databases and new customer databases. In level-2 decomposed of process 1.2 Log in, customer provides input to plumbing service system through process 1.2.1 Email and 1.2.2 Password. Then, plumbing service system confirms access to portal through datastore of registered customer database. If customer chooses process of 1.2.3 Forgot password, plumbing service system generates new password through process 1.2.4 and sends email through process 1.2.5 Registered mail-id. Customer receives e-mail through process 1.2.5 Registered mail id from plumbing services system.

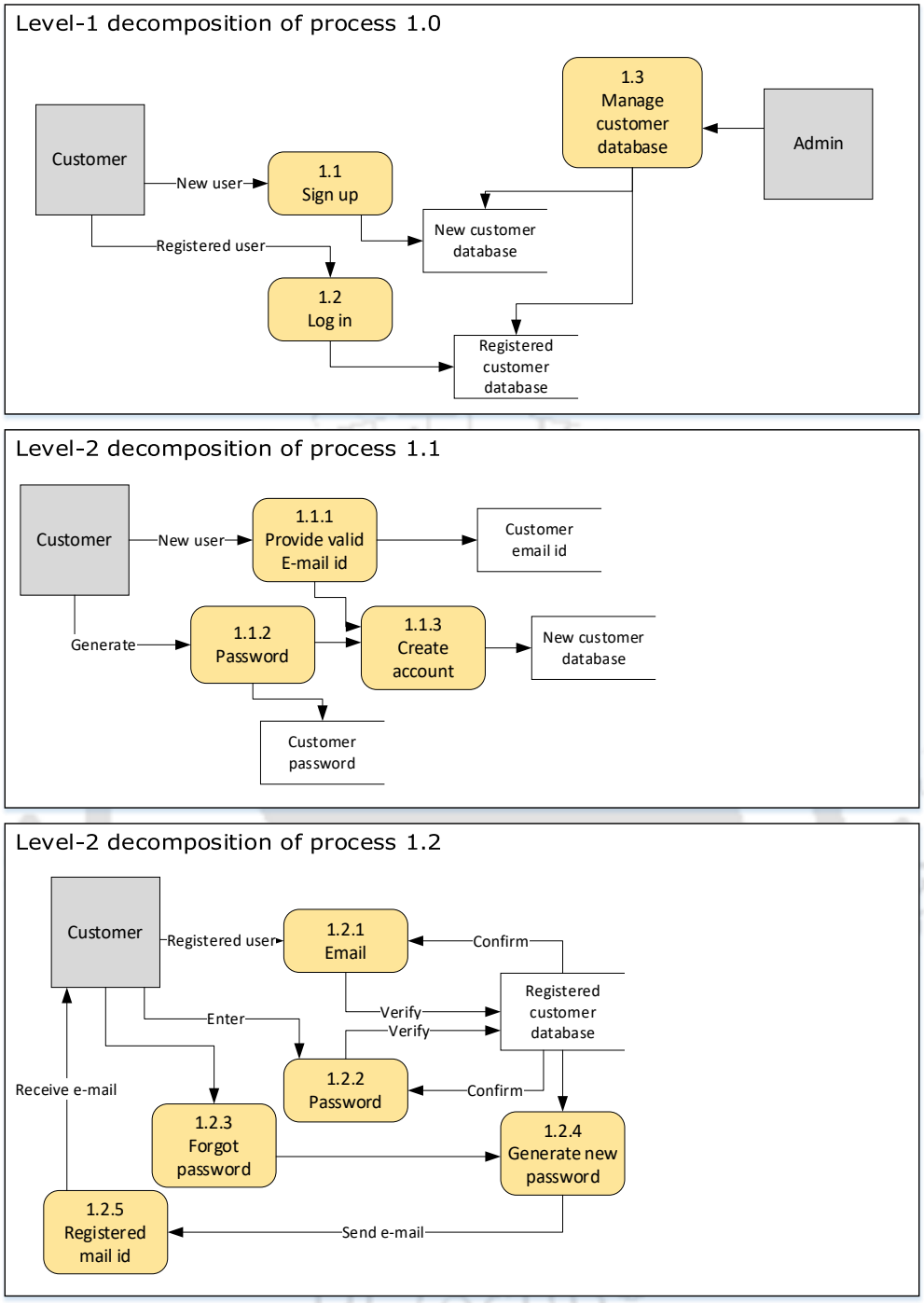


Figure 4.16: Level-1 and level-2 decomposition of process 1.0

Decomposition of process 2.0 Receive and transform tutorial requests:

The decomposition of process 2.0 is illustrated in Figure 4.17. It consists of two process viz. (2.1) Repair or fix minor plumbing issues and (2.2) Download tutorials. The data stores of this level-1 DFD has two data stores viz. Plumbing solutions and Study tutorials. Further, the process 2.1 has been decomposed to level-2. This level-2 decomposition of process 2.1 consists of five processes viz. (2.1.1) Display list of minor plumbing issues, (2.1.2) Dripping faucet

issue/low water pressure/Clogged drains/Running toilets/Leaky pipes, (2.1.3), Specific images with instructions to fix issue, (2.14) Practical demo with instructions to fix issue and (2.1.5) Organize plumbing solution categories and documents. It has two data stores viz. Plumbing issue list and Plumbing solutions.

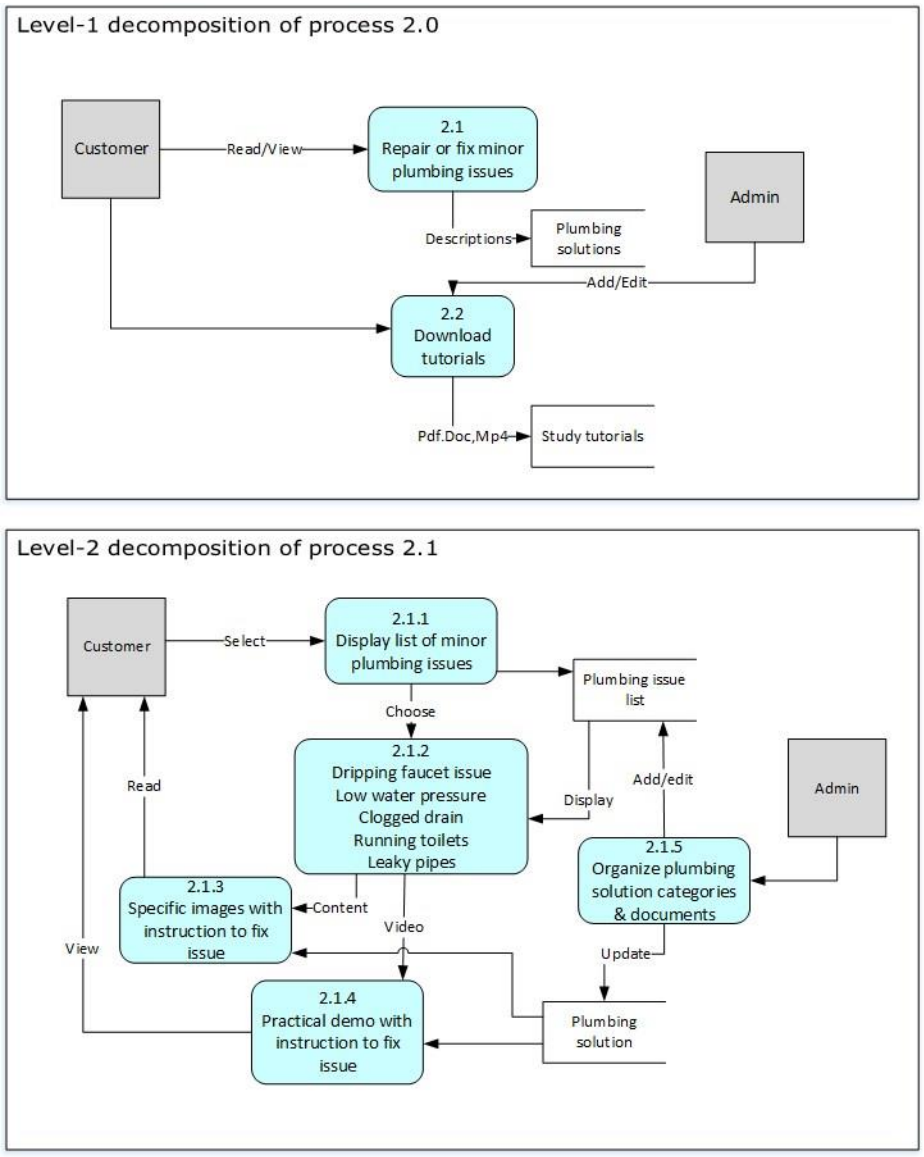


Figure 4.17: Level-1 and level-2 decomposition of process 2.0

In level-2 decomposed process of 2.1 Repair of fix minor plumbing issue, customer selects list of minor plumbing issues through process 2.1.1. Plumbing service system displays list of minor plumbing issues through process 2.1.2, which is organised by admin for the process (2.1.5) plumbing solution categories and documents. Customer can read specific images with instruction to fix plumbing issue through process 2.1.3 or view practical demo with instruction to fix plumbing issue through process 2.1.4.

Decomposition of process 3.0 Receive and transform tools/spare parts request:

The decomposition of process 3.0 is depicted in Figure 4.18. It consists of six processes viz. (3.1) Dispatch specific tools or spare parts, (3.2) Display list of plumbing issue, (3.3) Show tools and spare parts required, (3.4) Checklist of items, (3.5) Shipping details and payments and (3.6) Generate order request. The data stores of this level-1 DFD has four data stores viz. Plumbing issue, Inventory, Items cart and Shipment details.

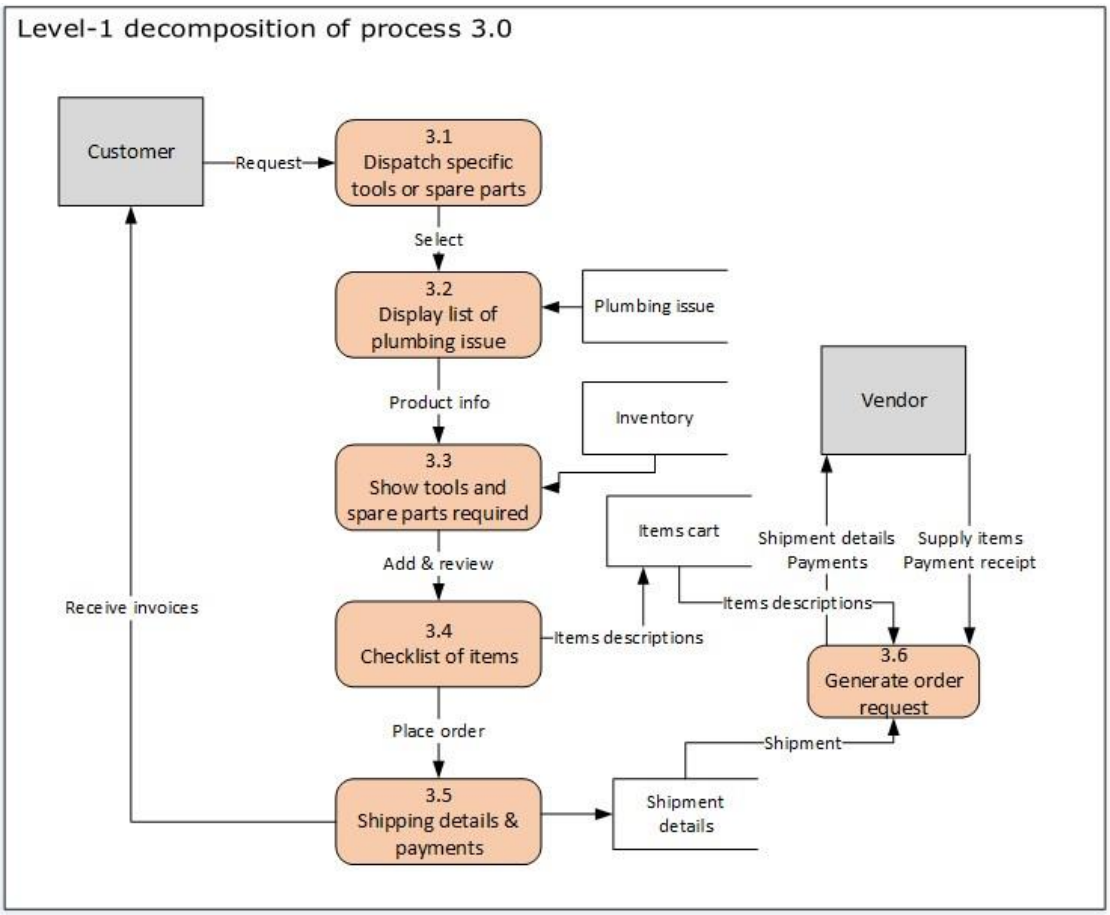


Figure 4.18: Level-1 decomposition of process 3.0

Further, the processes 3.5 and 3.6 has been decomposed to level-2, as shown in Figure 4.19. The level-2 decomposition of process 3.5 consists of two processes viz. (3.5.1) Items delivery address and contact details and (3.5.2) Select payment methods. The level-2 decomposition of process 3.6 consists of five processes viz. (3.6.1) Receive items order request, (3.6.2) Check inventory, (3.6.3) Transform items order requests, (3.6.4) Generate Payments and (3.6.5) Update inventory. It has two data stores viz. Product inventory and Items log.

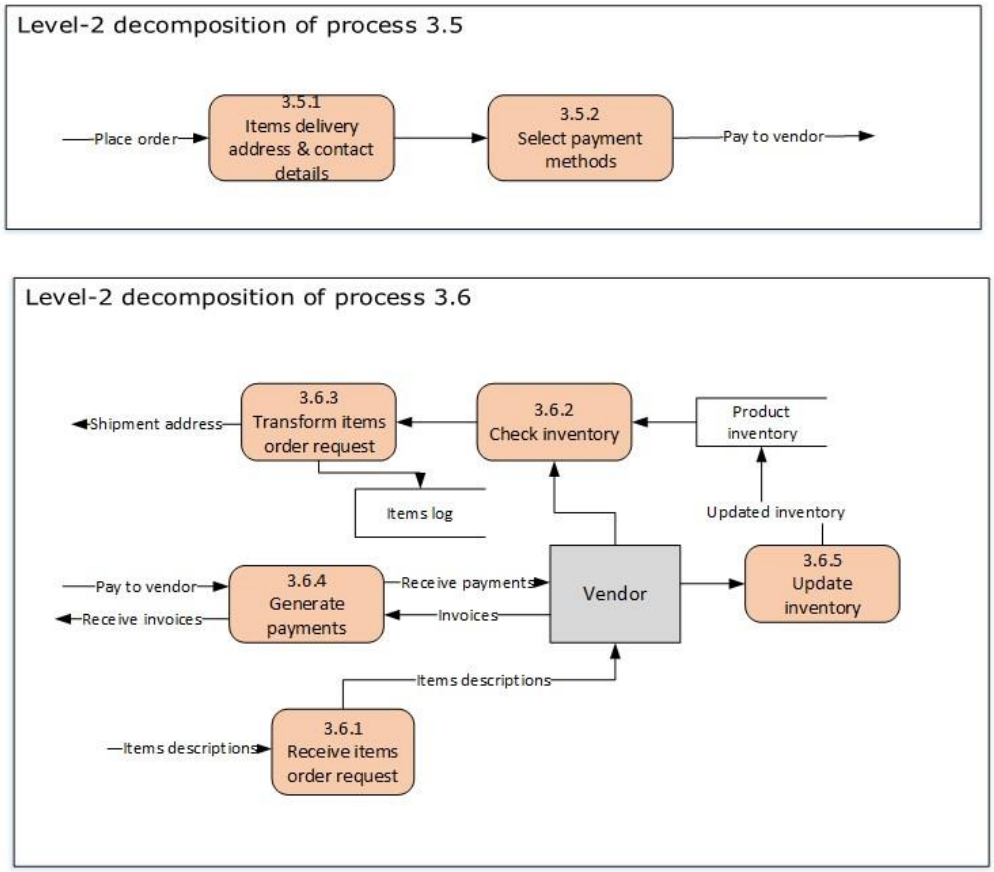


Figure 4.19: Level-2 decomposition of processes 3.5 and 3.6

In level-2 of decomposed of process 3.6 Generate order requests, vendor receives items description from plumbing service system through process 3.6.1. Vendor checks inventory of process 3.6.2 and transforms items order request through process 3.6.3 to shipment address received from plumbing service system. Vendor generates invoices through process 3.6.4 to plumbing service system and receives payments. Then, vendor updates inventory through process 3.6.5, which is logged in data store product inventory.

Decomposition of process 4.0 Receive and transform major plumbing service requests:

The decomposition of process 4.0 is depicted in Figure 4.20. It consists of four processes viz. (4.1) Request plumber for repair/fix issue, (4.2) Inclusions and exclusions service details, (4.3) Add address and contact details and (4.4) Confirmation message. The data stores of this level-1 DFD has three data stores viz. Service categories, Service cart and Service log. Further, processes 4.2, 4.3 and 4.4 has been decomposed to level-2, as shown in Figure 4.21. Level-2 decomposition of process 4.2 consists of three processes viz. (4.2.1) includes labour charges, (4.2.2) includes fitting and installations and (4.2.3) Excludes materials/spare parts cost. Level-

2 decomposition of process 4.3 consists of three processes viz. (4.3.1) Provide name/email id, (4.3.2) Residence details and (4.3.3) Mobile number. It has only one data store i.e., Service log. Level-2 decomposition of process 4.4 comprises five processes viz. (4.4.1) Receive job site details, (4.4.2) Assign service request for plumber, (4.4.3) Decision to accept, (4.4.4) Decision not to accept and (4.4.5) Assign alternate plumber. It has two data stores viz. Service log and Plumber database.

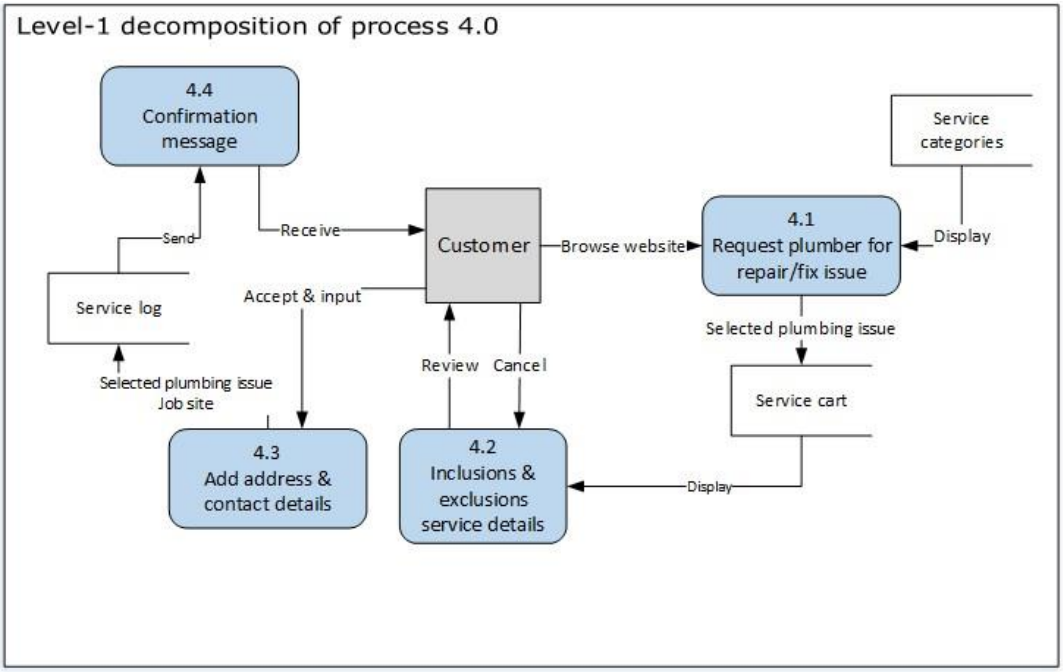


Figure 4.20: Level-1 decomposition of process 4.0

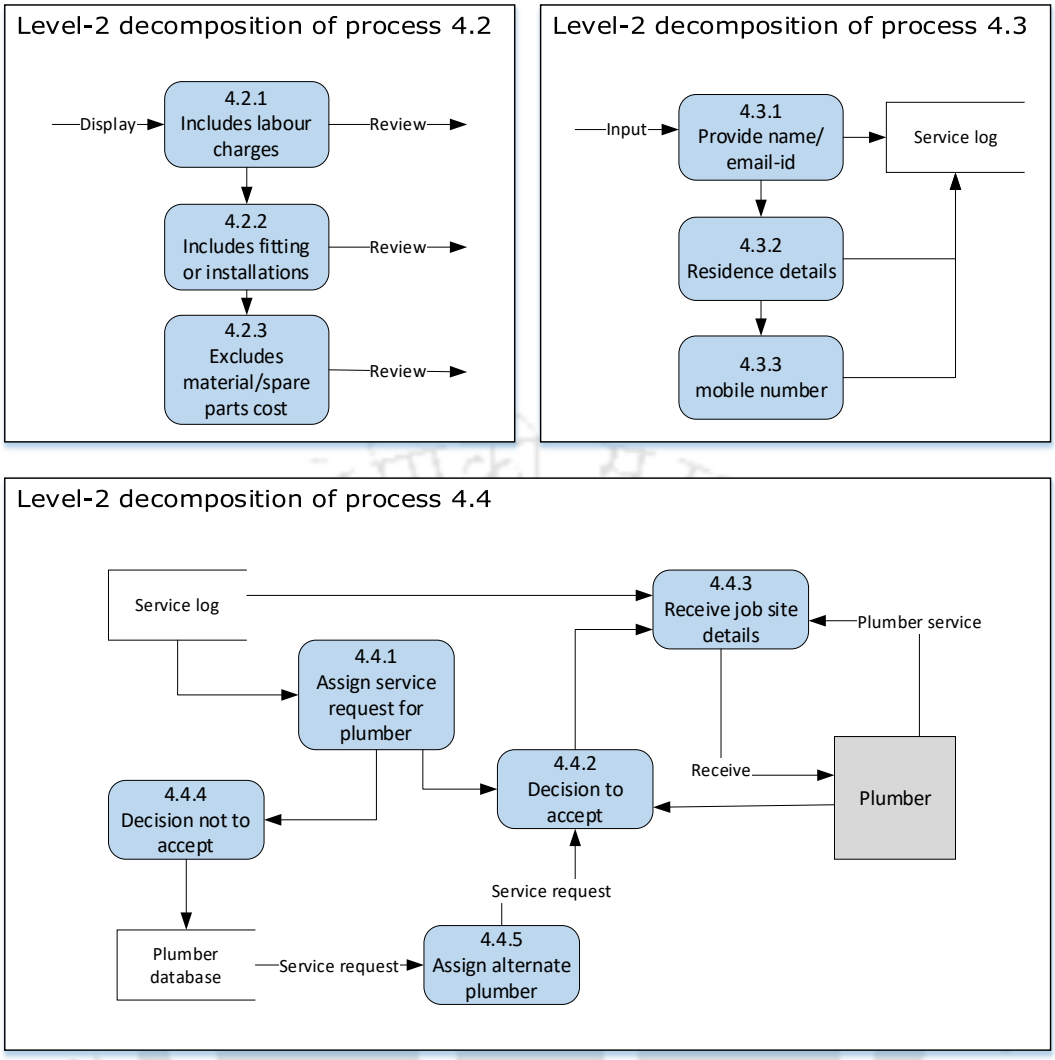


Figure 4.21: Level-2 decomposition of processes 4.2, 4.3 and 4.4

In level-2 decomposed of process 4.2 Inclusions and exclusions service details, customers review process through 4.2.1 includes labour charges, 4.2.2 includes fitting and installations and 4.2.3 excludes material/spare costs. In level-2 decomposed of process 4.3 Add address and contact details, customer provides input to pluming service system about process 4.3.1 Provide name/email-id, 4.3.2 Residence details and 4.3.3 Mobile number. In level-2 decomposed of process 4.4 Confirmation message, data store service log assigns service request for plumber. Plumber receives job site details through process 4.4.3 from plumbing service system. Assigned plumber has option of process 4.4.2 Decision to accept or 4.4.4 Decision not to accept. If plumber chooses through process 4.4.4 Decision not to accept, plumbing service system assigns service request through process 4.4.5 Assign alternate plumber. Then, customer receives confirmation message of plumber service request from plumbing service system.

4.3.4 Prototype and Test: Wireframes

Wireframes for four interfaces were developed to visualize the structure, navigation, content and information of the e-commerce website. The four wireframes depict the e-commerce homepage, DIY tutorials page, plumbing tools/spares page and plumber service page. Figure 4.22 depicts a structural layout for the home page of the plumbing service system. This layout includes viz. website URL, company logo, product/service search, plumbing tutorials, a brief introduction about plumbing, icons to select the type of service, contact information and terms of service. Figure 4.23 illustrates the DIY tutorials page of the plumbing service system. Customers can navigate to the tutorial for accessing the information on resolving minor plumbing issues. Here customers can select plumbing issues from the drop-down menu. Then for the selected plumbing issue, tools and spares (if necessary) will be displayed with images and descriptions. In addition, there is an option to download materials on how to resolve minor plumbing issues.

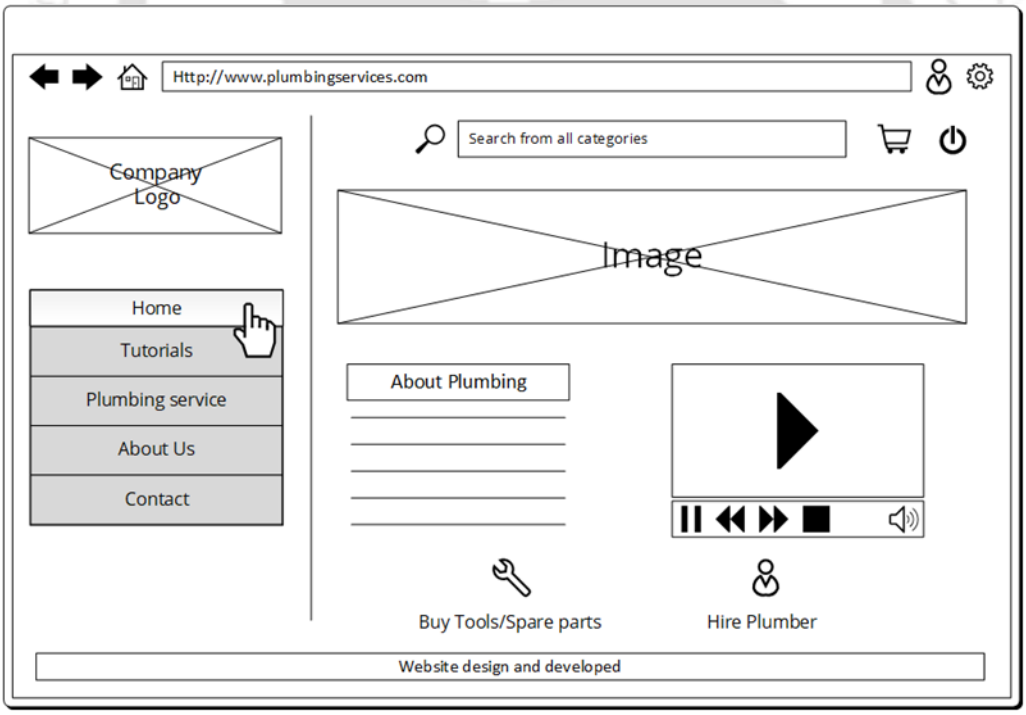


Figure 4.22: Homepage of plumbing service system

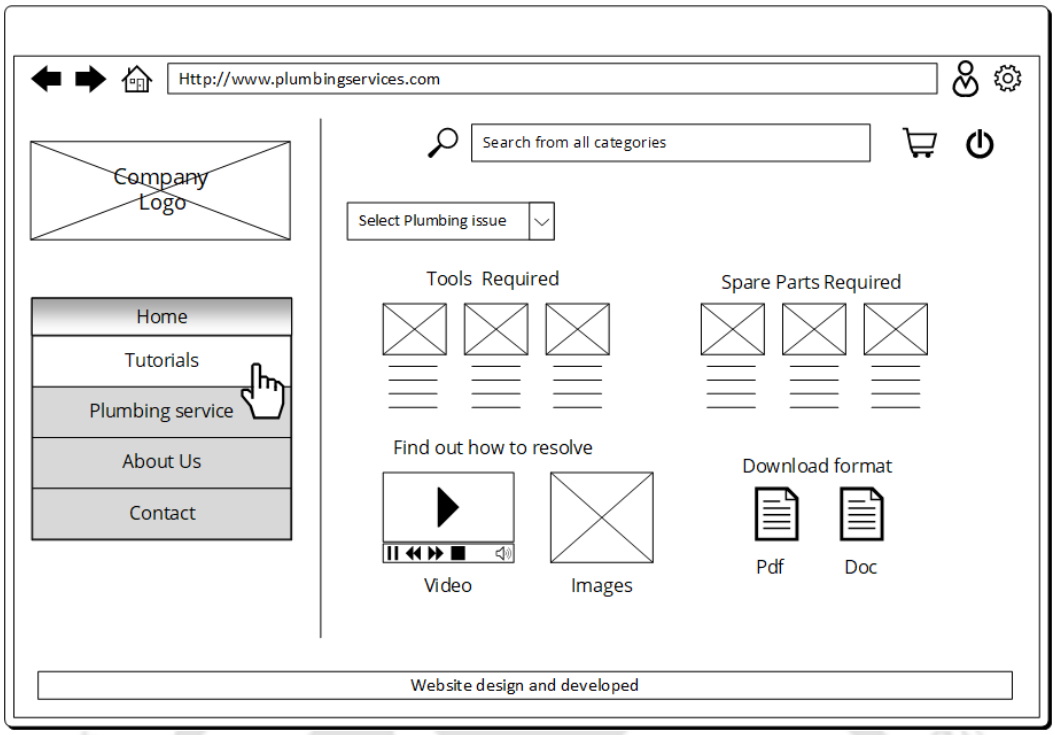


Figure 4.23: Tutorials page of plumbing service system

The customer can place an online order for plumbing tools and spares from the menu plumbing service, as depicted in Figure 4.24. The wireframe depicts three steps to complete the process of ordering plumbing tools or spares:

Step 1: Customer selects the plumbing issue, inputs date, time and location.

Step 2: For the selected plumbing issue, tools and spares are displayed.

Step 3: Customer selects the tools or spares required, reviews selected items and confirms to place an online order.

Similarly, customers can request plumber service from the menu plumbing service, as depicted in Figure 4.25. Here, the customer selects the plumbing issue, inputs the date, time and location for the plumber service. Customer can review the particulars of the plumbing issue inspection, service charges. After the review customer confirms the plumber service request.

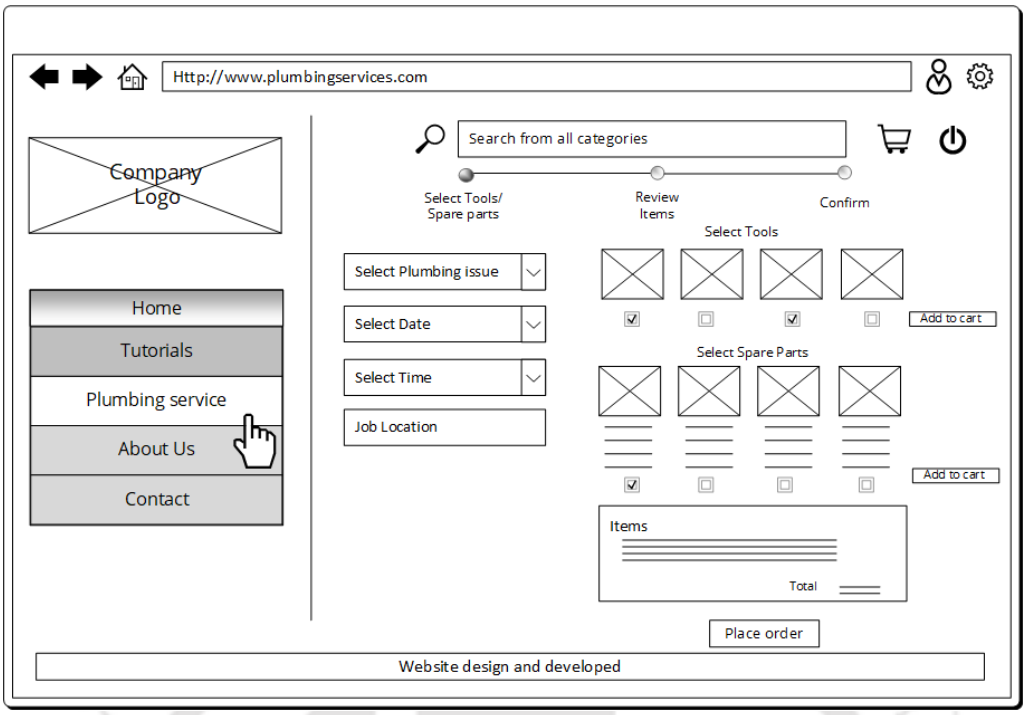


Figure 4.24: Plumbing tools/spares page of plumbing service system

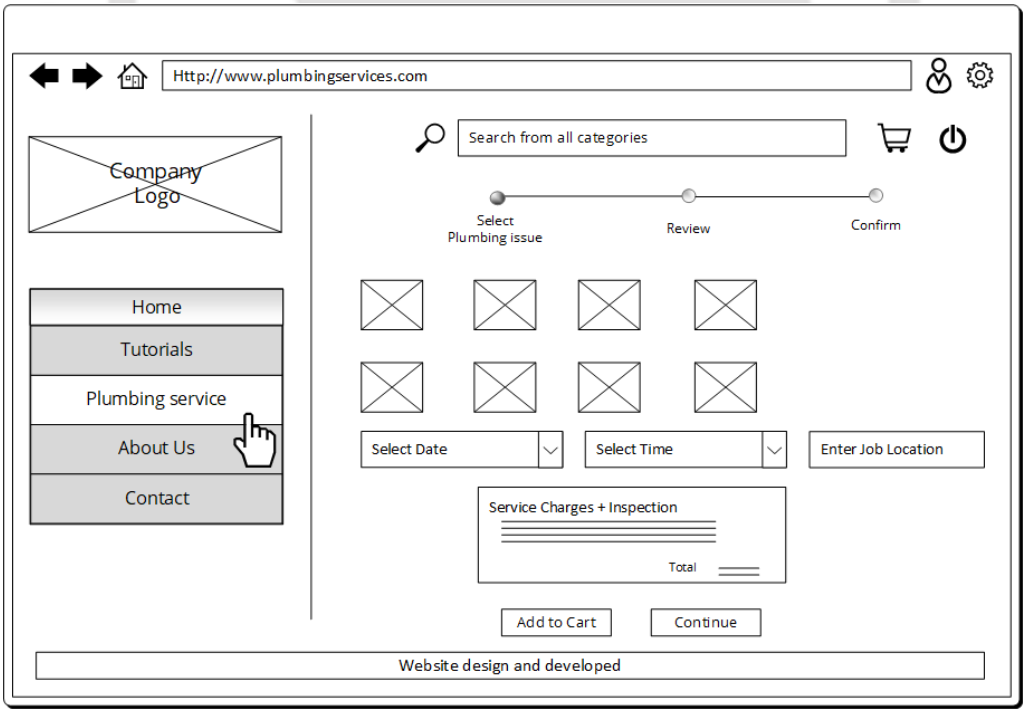


Figure 4.25: Plumber service request page of plumbing service system

4.4 PSS Test and Implementation for Domestic Plumbing Services – Phase 3

In the previous section 4.3, the design thinking application has been employed to design and detail domestic plumbing services. In continuation for market launch, this phase aims to benchmark the business model's components of leading on-demand home services provider in India. The phase 3 also aims to develop and analyze the B2C e-commerce business model in this context. Besides, a web application is developed as a PSS solution for domestic plumbing services. Validation of PSS solution for domestic plumbing services is presented with qualitative and quantitative measure of effectiveness based on responses from customers and expert users.

4.4.1 Benchmark Study in E-Commerce of Home Services in Indian Context

The benchmarking study aims to understand how the home service providers' approach towards business elements differs by considering the (i) organization size, (ii) value proposition, (iii) revenue streams, (iv) geographical presence and website traffic, (v) website design and (vi) competitive advantages.

UrbanCompany & Housejoy has been considered for the benchmarking study. Business model components of leading on-demand home services provider in India is tabulated in Table 4.16. UrbanCompany has been chosen as one of the benchmarking home services providers due to the following reasons. First, UrbanCompany is one of the leading service providers within the e-commerce platform industry. Second, UrbanCompany covers niche service segments like salon at home, plumber, carpentry and many more. Third, the company is a large organization, and therefore the UrbanCompany is suitable for benchmarking analysis. The other home services provider, Housejoy, is also a large-sized company that acts as a facilitator for providing home services through an e-commerce platform. Although the Housejoy and the UrbanCompany launched in the same year, i.e., 2014, Housejoy lacks in demographic presence, funding and covering many niche services. For these reasons, Housejoy has been chosen as the other benchmarking company.

Table 4.16: Business model components of leading on-demand home services provider in India

Components		**UrbanCompany**	**Housejoy**
Company Overview	Establish year	2014	2014
	Headquarter	Gurgaon, Delhi	Bangalore
	Business model	Marketplace model	Marketplace model
	Company Size	501 – 1000 employees	201 – 500 employees

	Products and Services	Cleaning & disinfection, Salon at home, electricians, carpenter, plumbers, painters, AC service & repairs, pest control, massage therapy and yoga fitness	Beauty, interior design, construction, and renovation services home cleaning, repairs, painting, installing appliances, pest control, plumbing, electrician, and carpentry services
	Online Platforms	Website and App	Website and App
	Customers served	5+ millions	2+ millions
	Total funding	$ 190.9 million	$ 30.2 million
	No. of acquisitions	3 (Handyhome.in; in 2016) (Goodservice.in; in 2016) (Glamazon.com; in 2020)	2 (Mywash.in; in 2016) (Orobind fitness technologies Pvt Ltd; in 2016)
	Investors	Steadview Capital, VY Capital, SAIF Partners, ACCEL Partners + 5	Matrix Partners, Amazon, and Vertex Ventures + 6
	Type of E-commerce	B2C	B2C, and B2B
Value Proposition	For Customers	Ease of browse and booking an essential service. Visit the service provider profile and his qualities. Multiple payment options. Rate and review the services on their platform. Avail of free service by invite and referring services to friends. Insurance up to INR 10,000. Service acceptance notifications to confirm the booking. In-app chat with service professionals.	Verified professional for service requests, Insured work, Rework assurance, Professional support, Rate and review the services on their platform.
	For Service Provider	Expand service business, Flexible working hours, Partner support to solve queries.	Become a tech-friendly professional, Confirmed bookings and business growth, Incentives & conveyances
Revenue	Streams	Commissions, Reverse-Auction. Advertisement.	Commissions. Subscriptions. Lead generation.
Geographical Presence	Location	Ahmedabad, Bangalore, Chennai, Delhi NCR, Chandigarh, Jaipur, Hyderabad, Kolkata, Mumbai, Pune, Nagpur, Ludhiana, Vishakhapatnam, Lucknow, Bhubaneswar, Surat, and Indore. Abu Dhabi, Dubai, Australia, and Singapore.	Bangalore, Chennai, Delhi, Hyderabad, Mumbai, and Pune
Website Traffic	Total visit in last six months (as of Sept 2020)	756.19K	54.84K
	Average time spent	1.13 minutes	3.16 minutes
	Bounce rate	61.72%	62.10%
	Traffic source	Search (66.78%), Direct (30.54%), Social (1.75%), Referrals (0.92%)	Search (67.98%), Direct (27.47%), Social (0.04%), Display (3.48%), Referrals (1.03%)

Website Design	Website homepage	Company logo and call to action (CTA) link for blogs, service provider registration, and user signup/login. Wide range of services depicted with vector images Cashback offers, bank discounts, service warranty, and minimum consultation charges are displayed. User testimonials are shown for the safety standards from social media Twitter. Refer and get free service, download links for mobile apps. Operational activities were serving in India and International cities. Social media links for Twitter, Instagram, Facebook, YouTube, LinkedIn, and Pinterest	Company logo, a search query for services, service provider registration, user login, and cart icon The website navigation represents the drop-down menu for the services. CTA for a salon at home and home cleaning offers are displayed. Line diagram representation of several services is depicted to select the required services. The image and short description for an instant discount, cashback offer for new users. Subscription offers monthly, annual basis, and the number of services. Operational activities were serving in Indian cities. Download links for mobile app. Social media links for Twitter, Instagram, Facebook, YouTube, and LinkedIn
Business Strategy	Competitive Advantage	Cost leadership, product and service differentiation, demographic presence, niche market acquisitions, and overseas operations Young and aspirational management team. Use of real-time data and AI techniques. Customization and ease in online booking services 30,000+ service professionals across India.	End-to-End responsibility on every service. Aggregator in a niche market of construction and renovation services, Development in brand awareness, new technology, and business expansion in new cities for interiors, renovation and construction business. New and experienced leadership team hired with a focus on innovation and digital transformation. 65,000+ service professionals across India.

(i) Organization size: It has been observed that, the Urbancompany has more number of employees (501 – 1000) compared to Housejoy (201 - 500). The benchmarked organizations in this study has market place business model. The number of customers served by Urbancompany is more than five million, whereas, Housejoy has served two million customers, as a status of September 2020. The number of acquisitions by Urbancompany is three and Housejoy is two. Urbancompany has raised $190 million of total funding and Housejoy has raised $ 30.2 million.

(ii) Value proposition: As observed under this study, on-demand services provide different value propositions to their customers like the ease of booking an essential service, in-app chat with the service professional, insurance for damage during service, verified professional, service guarantee, refer and earn free service. These value propositions can be benchmarked during the development phase of on-demand service.

(iii) Revenue streams: It has been observed in this study, on-demand service aggregators have a commission model through the listing of plumbers, carpentry and electrician services. With

advent growth due to funding and capturing niche services, aggregators have subscription fees, reverse-auction and advertisement fees.

(iv) Geographical presence & website traffic: It is observed that on-demand services are operational in India's urban cities. There is an opportunity to extend these services to tier 2 cities. Website traffic or the total number of visits to websites is a popular measure for online business success. Consumers find on-demand services through search in contrast with direct web addresses. To reach the maximum audience, social media, referrals and advertisements are employed.

(v) Website design: Website design is an essential factor that converts visitors to customers. Content and information overload could cause customers to leave before making any purchase. The website's landing page design examined in this study has a clear layout, minimal content, and more Call-to-Action (CTA) for easy navigation. These factors could be benchmarked for consumers' willingness to book on-demand services.

(vi) Competitive advantage: In the last few years, many start-ups have evolved to provide on-demand services in India. However, only a few have sustained competitive advantages, such as cost leadership, product and service differentiation, customization and global presence. Significant differentiating factors may evolve from effective utilization of funding resources, brand awareness, adaptation of new technology, management of leadership team, business acquisitions and expansions.

4.4.2 PSS Business Model for Domestic Plumbing Services

The business model developed for domestic plumbing is a marketplace business that acts as an aggregator for domestic plumbing issues. Figure 4.26 illustrates the business model representation of B2C e-commerce. It is an e-commerce business-to-consumer (B2C) offering on-demand plumber services, order plumbing tools and spares, DIY tutorials for minor plumbing issues and nearby retailers' information. It acts as a facilitator that receives a commission on each service or order request. Customers visit the website at their comfort, where they register as a user to request plumber service. Plumber services are categorized into the kitchen, toilet, bathroom and others to ease required service selection. Customers select the required service, review service description and service charges, provide service location details and confirm the plumber service request. To diagnose plumbing issues quickly, customers can upload their current plumbing issue images through the website platform.

The support staff receives service requests from the customer through the website portal and forward the request to the available plumber. The acceptance of the job from the plumber is then forwarded to customers through the support staff. The support staff will also acknowledge the service confirmation according to the scheduled date, time and location. The plumber visits the allocated service location and completes the job. If spares are necessary during the plumber service, the customer can avail the ordering plumbing spares through the registered account. Else, the allocated plumber can procure plumbing spares through the registered plumbing retailer. The customer bears for procuring the plumbing spares either online payment or by the cash. Once the service is completed, the support staff will send a service invoice to the registered mail id and a text message to the registered contact number. Customers could resolve minor plumbing issues by following DIY projects on the website platform.

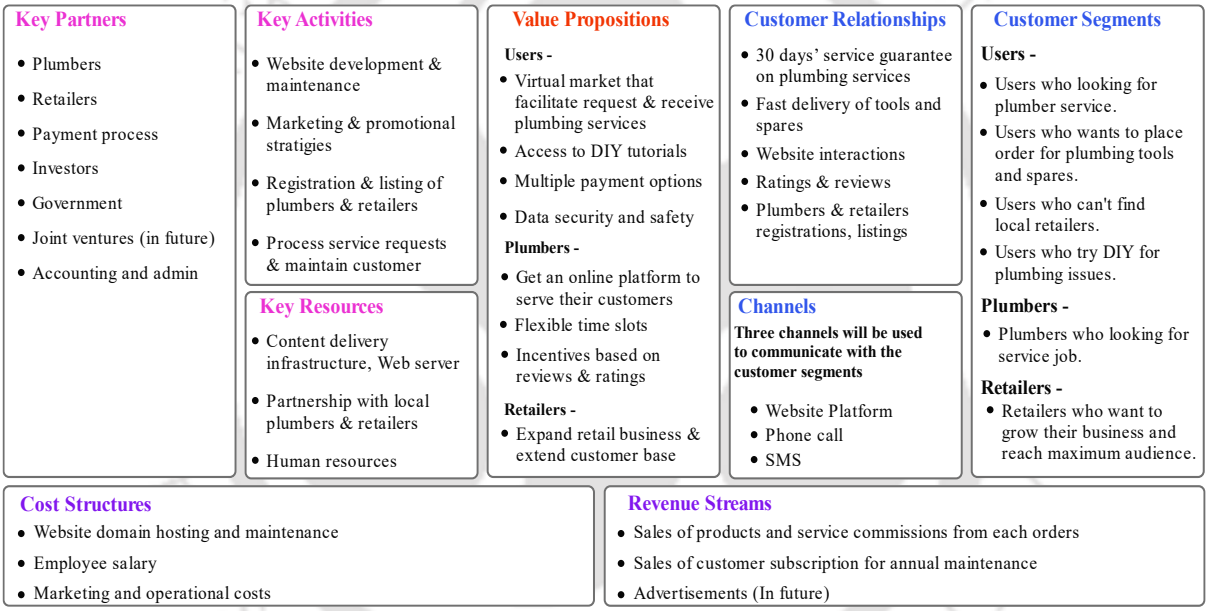


Figure 4.26: Business model representation of B2C E-commerce for domestic plumbing services

Following is the description of business model canvas developed using nine-building blocks viz. value proposition, customer segments, channel, customer relationships, key activities, key resources, key partners, cost structure and revenue streams (Osterwalder and Pigneur, 2004)

Value proposition: The e-commerce business model delivers value proposition as a moderator through a website platform that offers plumbing solutions. Plumbing solutions include not only the on-demand plumber service but also delivery and procurement of plumbing tools/spares, DIY tutorials on minor plumbing issues and nearby retailers' information. The other similar website platform in India only facilitates on-demand plumber services. In contrast with the existing sites offering plumbing services, this innovative platform provides customers the

advantage of online orders of spares, retailers' contact information and DIY tutorials. The value proposition for plumbers will be, listing as a plumbing service provider, options for acceptance or cancellation of plumbing services, more service opportunities, incentives and wages based on customer ratings and reviews.

Customer segments: The customer segment served by the developed business model are viz. users who avail plumber service, users who order online for plumbing tools and spares, users who try DIY for minor plumbing issues, plumbers who seek work with the flexible timings, and retailers who reach target audience to sell plumbing tools and spares.

Channel: Since the developed business model is a B2C e-commerce business base, three channels are used to communicate with the stakeholders as follows,

- Website platform: Customers request on-demand plumber services, order tools and spares. Retailers receive orders for tools and spares. Admin receives customer request for plumber service.
- Phone call: Admin confirms service details, location, and scheduled service date and time with the customer. Admin confirms acceptance of a job with the available plumber.
- Text messages: Customers receive service confirmation, service delivery, payment confirmation. Plumbers receive service details, service location, service scheduled date and time.

Customer relationships: The developed business model must establish and maintain three customer segments viz. users, plumbers and retailers. In relationship with the users are viz. thirty days service guarantee on plumbing services; fast delivery of tools and spares; review and ratings on plumbing services, delivery of tools/spares; customer website interactions; provide data security and secured payment system; In relationship with the plumbers are viz. online registration and listing as a plumbing service provider. In relationship with the retailers are viz. online registration and listing as plumbing products supplier.

Key activities: The business model's first and foremost activity is development and maintenance of a website platform, marketing activity and the planning of promotional strategies of the website. The second is to reach out to local plumbers and retailers for registration and listing as partners. The third activity is to maintain customer database and

process service requests to available plumbers. Fourth activity is to process online order of tools and spares and linking the same with the retailers.

Key resources: The business model's essential resources are the capabilities of plumbers and retailers to deliver services. The other major key resources are such as viz. the capabilities of admin and supporting staff for processing service requests, the capabilities of managers and designers for executive decisions on website development, website maintenance, marketing and promotional strategies. Resources include updated DIY tutorials and physical assets of office equipment.

Key partners: the proposed business model has primary key partners such as viz. plumbers, retailers, admin and supporting staff. The secondary key partners of the proposed business model include viz. investors, payment process partners, Government for initiatives and schemes, joint ventures for co-owning and investments.

Cost structure: The major cost incurred by the business model are viz. website domain hosting and maintenance charges, salaries of admin and supporting staff, marketing, promotional and operational costs.

Revenue streams: In the proposed business model, there are two major revenue streams viz. (i) sales of domestic plumbing services, (ii) sales of plumbing tools/spares through vendors/retailers. Revenue stream also includes customer subscriptions for annual maintenance services through Annual Manual Contracts (AMC) and advertisements.

4.4.3 SWOT Analysis for the Developed PSS Business Model

The SWOT analysis for the developed business model was conducted to examine the existing resources internally and externally. A small focus group discussion was conducted. The business model canvas was shown to them and their views and comments were sought in SWOT matrix. Table 4.17 depicts the mapping of the SWOT matrix to design the strategies. The developed business model's SWOT analysis indicates that the on-demand plumber services are not operational in India's tier-II cities. With the internet penetration and use of smartphones by customers, it will be easy to capture market share and reach maximum customers. As the current home service is plumbing, we can devote our resources to fulfil customers' needs and satisfaction. The developed business model requires investors, a leadership team, employees, support staff and capital funding. Many cities are still not covered by the on-demand service sector in India. The developed business model can target them and

gain a first-mover advantage. Existing on-demand service providers could reach or expand their operations to tier-II cities of India. However, there are threats of new entrants providing similar services.

Table 4.17: SWOT matrix of the developed B2C e-commerce business model

		Strength	**Weakness**
		• Unique selling proposition (on-demand service + online store + DIY) • Preferred location (Guwahati) • We could provide good customer care and support. The website is simple and easy to navigate. Operational and overhead costs are minimum. • Inclusion of nearby retailers of hardware and plumbing.	• Lack of registered plumbers and partnership with local retailers • Business through app • Investors, capital funding, and leadership team
Opportunity	• A niche market for on-demand services • First mover advantage • Government schemes and initiatives for start-ups	**Strength-Opportunity Strategy** To capture market share and reach maximum customers. As the current home service is plumbing, we can devote our resources to fulfil customers' needs and satisfaction. Continuous improvement and development of website design for easy navigation.	**Weakness-Opportunity Strategy** Establish and build a partnership with plumbers and vendors. Design and development of a mobile-based app to capture the market. Business proposals for capital funding and seed fund.
Threat	• Existing players • New entrants of a similar service provider • Data security and privacy	**Strength-Threat Strategy** Promote stakeholders for e-commerce. Hire dedicated support staff and verified plumbers. Standardized procedure and policies on customer data protection, collection and usage.	**Weakness-Threat Strategy** To promote the domestic plumbing service to sustain in e-commerce business environment.

4.4.4 E-Commerce Website Design

In this section, the website interface for the customers, plumbers and retailers is presented. A software product (web application) is developed utilizing PHP programming language as the front end and SQL Server as back end. It assists the customers in requesting on-demand plumber services, online orders of plumbing tools and spares, access to DIY tutorials on minor plumbing issues and plumbing retailers information. The website landing page is depicted in Figure 4.27. The website landing page is composed of three sections viz. 'Header', 'Main Body' and 'Footer'. The header section is the top content of the website landing page. It includes static information like company logo, search box, customers login and signup, cart, and navigation menu for different product and service categories. The main body includes sliding animation of plumber service, online store and tutorials with call-to-action links. Besides, a title for plumber service and plumber service request form is provided. For customers' trust and ease of identification, icons with a short description of value propositions

and images depicting plumbing tools, spares and retailers, distinct content for do-it-yourself of minor plumbing issues are provided. The bottom (footer) content of the website landing page contains static information. It includes social media links, quick links, our services, about us, plumbers and retailers registration, contact information, frequently asked question, and terms and conditions.

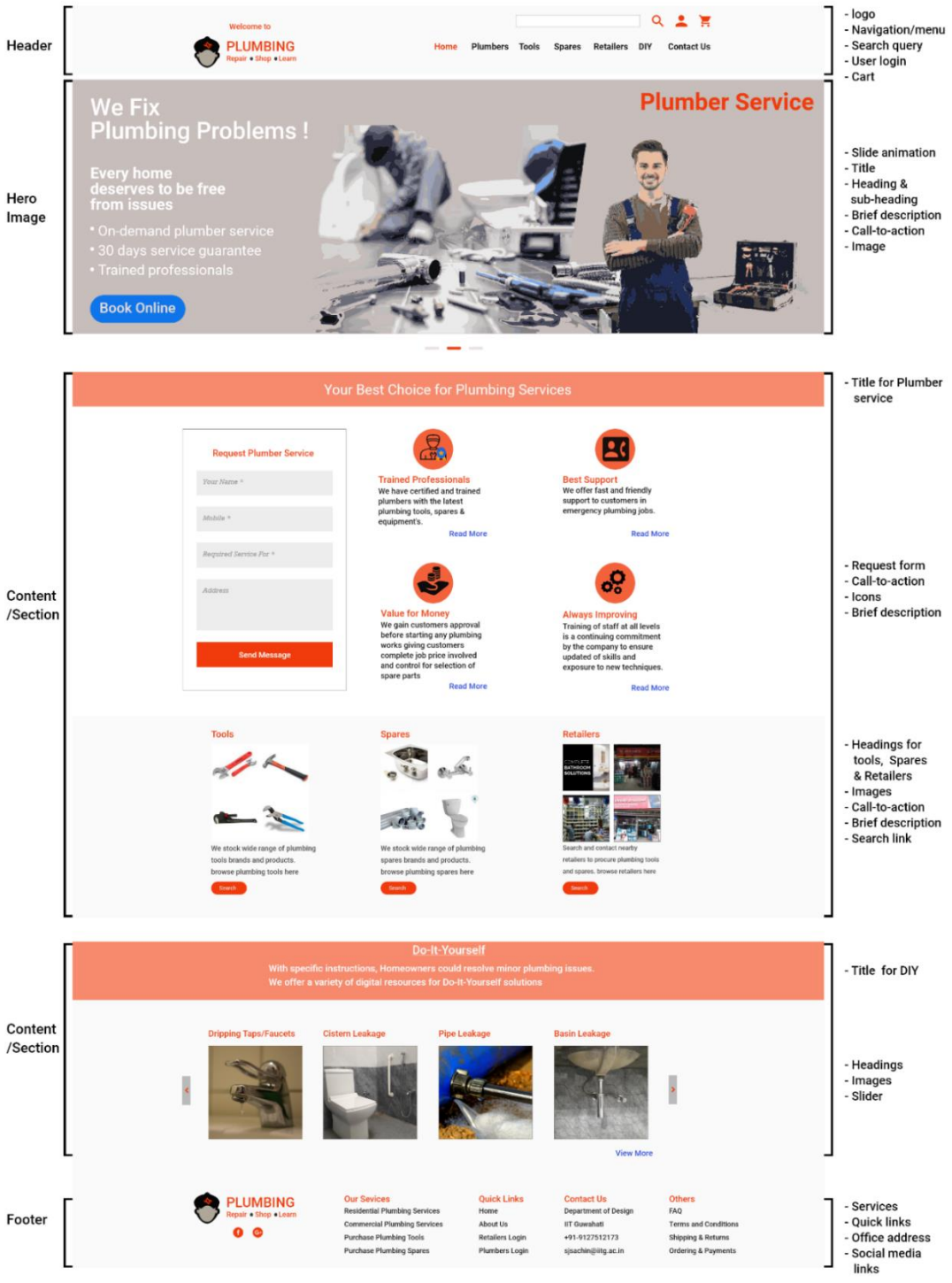


Figure 4.27: Website homepage of domestic plumbing service system

Plumber service page: Customers arrive on this page by clicking the ‘plumbers’ from the menu. Here, customers can view and request a plumber service request. On this page, the plumber service process is shown with the heading ‘how it works’. The plumber service process consists of four steps: book online, confirmation, work status and payment. All plumber services are differentiated based on categories and further, each category is divided into different subcategories, as shown in Figure 4.28.

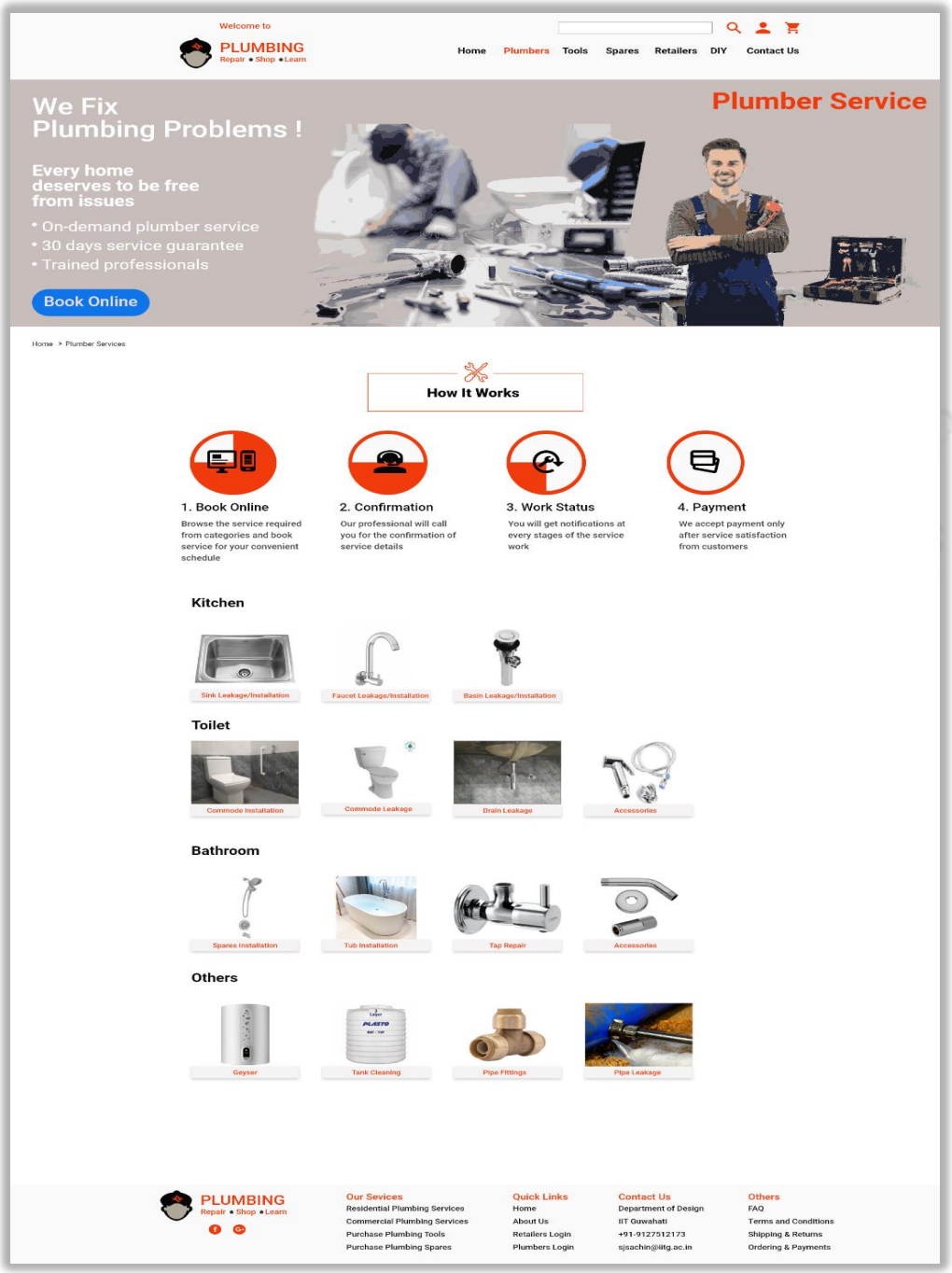


Figure 4.28: Plumbers service request page of domestic plumbing service system

Service detail page: On this page, customers review service detail before confirmation on plumber service requests. Here, services under the kitchen category are shown. For example, as shown in Figure 4.29, customers can review the service inclusion and exclusion for kitchen sink/tap installation. Customers can upload plumbing issue images through the link 'upload images' on this page to diagnose the issue quickly. The summary of service charges is also shown with a price breakdown.

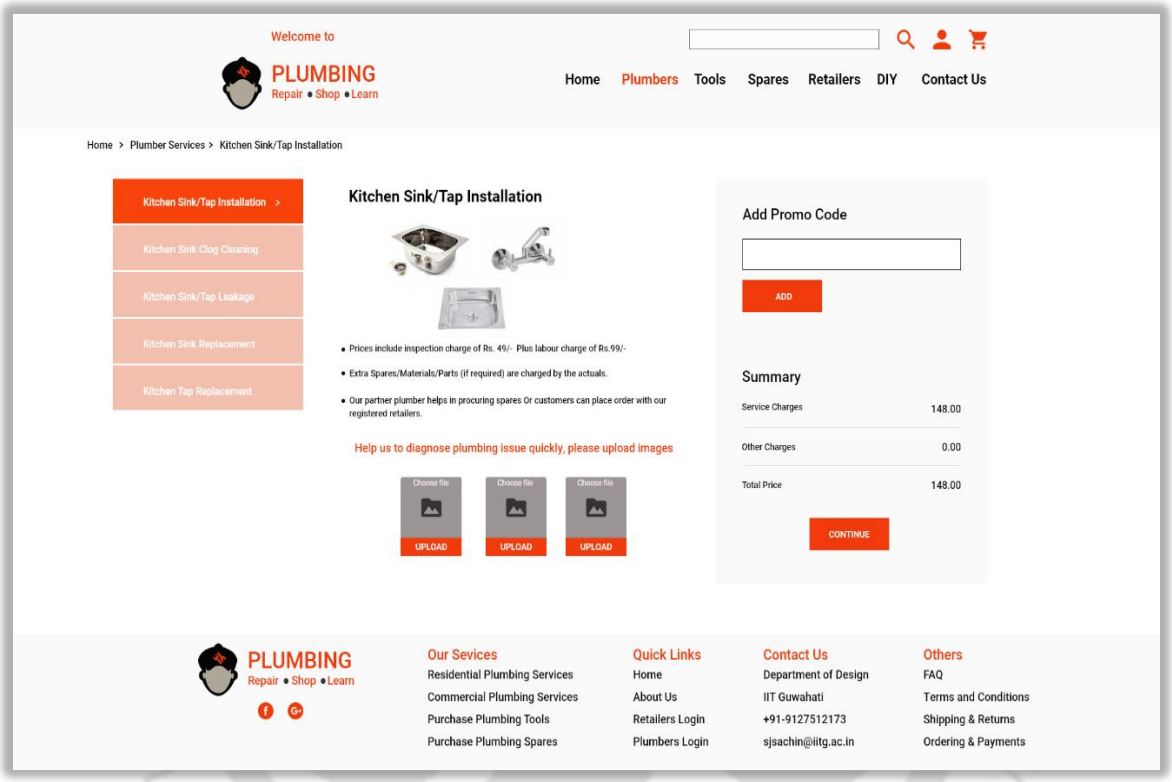


Figure 4.29: Service detail page of domestic plumbing service system

Address details page: The customers can give details on the service location and select the required date of service and time, as shown in the Figure 4.30. After selecting 'submit', the customer will receive the service confirmation to the registered mail id and contact number as shown in Figure 4.30 and Figure 4.31.

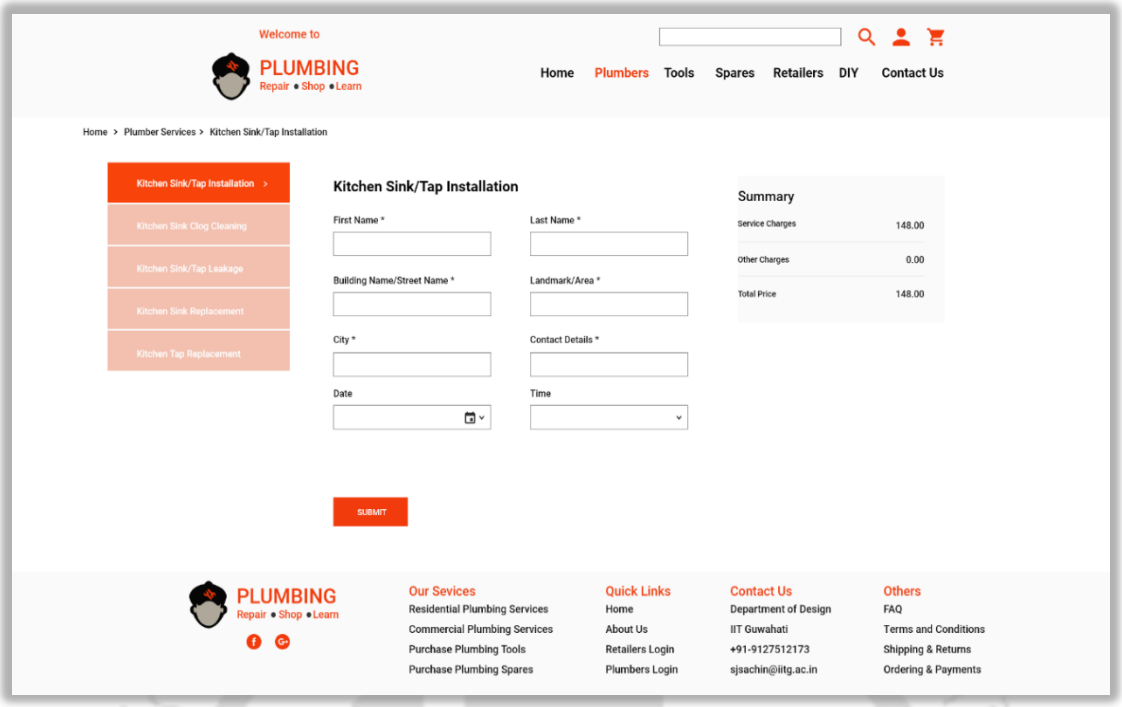


Figure 4.30: Address details page of domestic plumbing service system

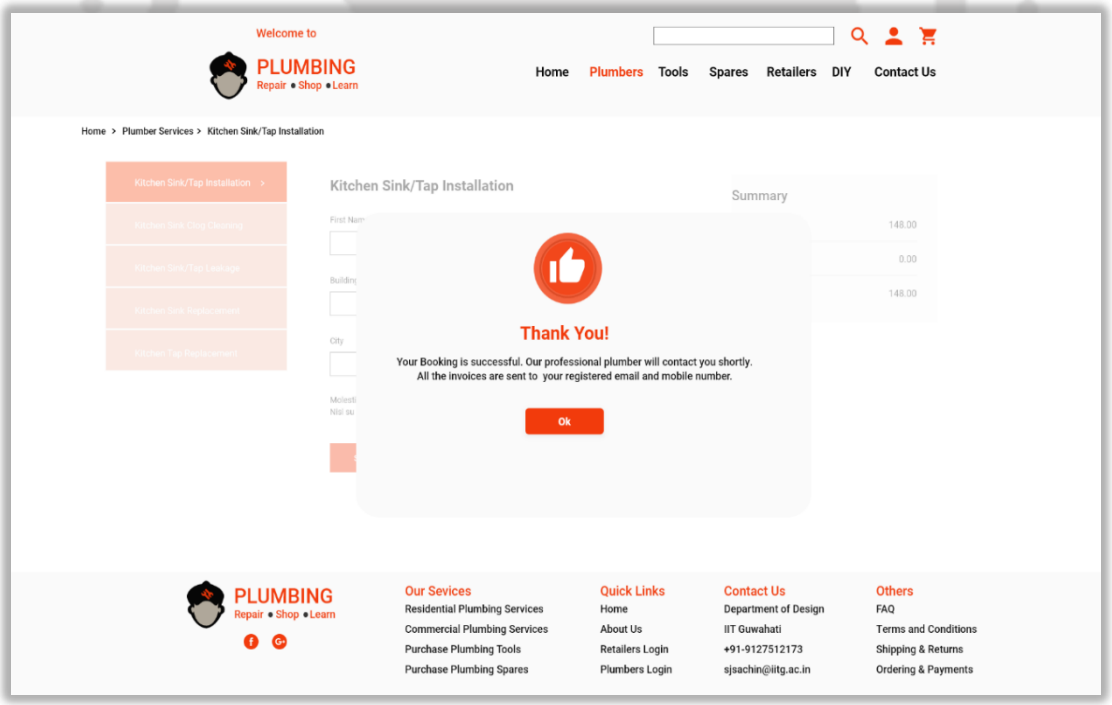


Figure 4.31: Service confirmation page domestic plumbing service system

Tools Page: Customers arrive on this page by clicking the ‘tools’ from the menu. Here, the customer can view and order plumbing tools. For ease of browsing, customers can select filter

options for plumbing tools. Plumbing tools filter options include tools based on price ‘low to high’ or ‘high to low’. Further, tools can be filtered by customer reviews, brands and categories, as shown in Figure 4.32

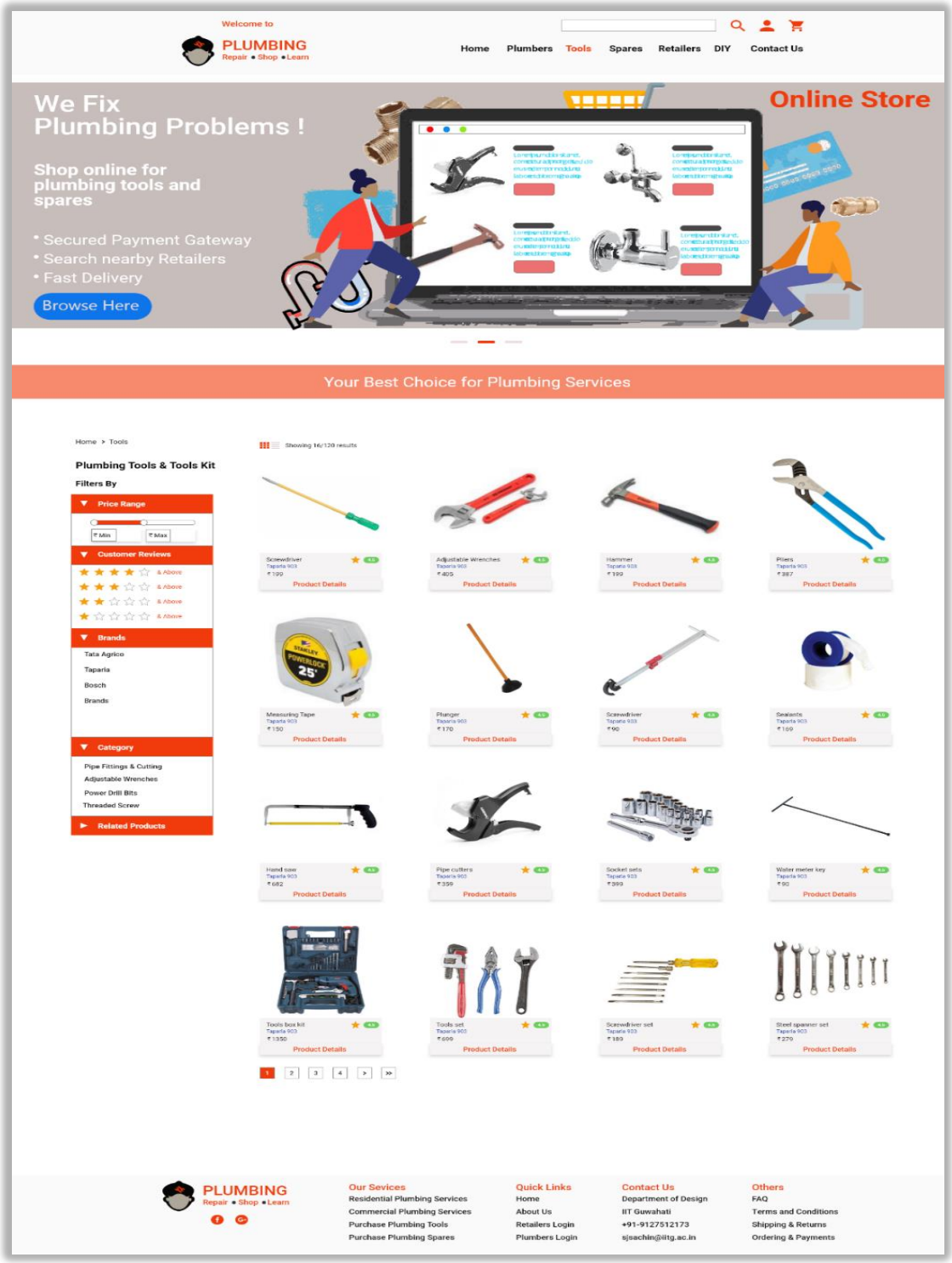


Figure 4.32: Tools page of domestic plumbing service system

Spares Page: Customers arrive on this page by clicking the ‘spares’ from the menu. Here, the customer can view and order plumbing spares. For ease of browsing, customers can select filter options for plumbing spares. Plumbing spares filter options include spares based on price ‘low to high’ or ‘high to low’. Further, plumbing spares can be filtered by customer reviews, brands and categories, as shown in Figure 4.33

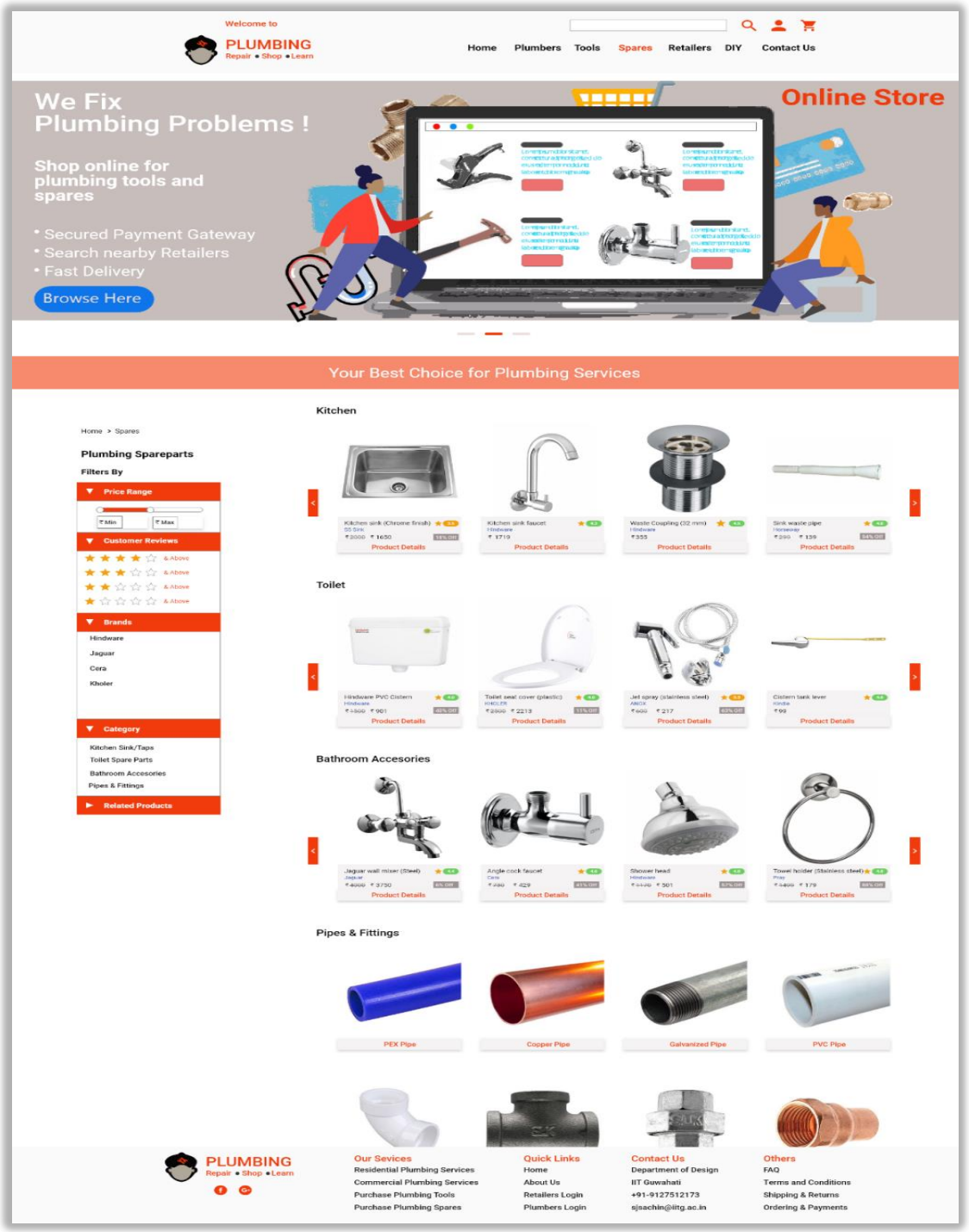


Figure 4.33: Spares page of domestic plumbing service system

Tools or Spares detailed page: After clicking on the ‘tool’ or ‘spares’ on the product listing page, the selected product details are displayed on the product detailed page, as shown in Figure 4.34. The product details include its image (with two more images), ratings and reviews, different parameters, quantity required, product price, product details, specifications and features. Customers can add the selected product to the shopping cart by clicking on “Add to cart”. This feature will allow the user to add the product to the shopping cart and buy that product. The Shopping cart function present at the header will be updated with the number of items present in the shopping cart. A similar type of product, i.e. the products with the same parameters or same price range, are recommended on this page. Customers can also view the previously browsed products on this page.

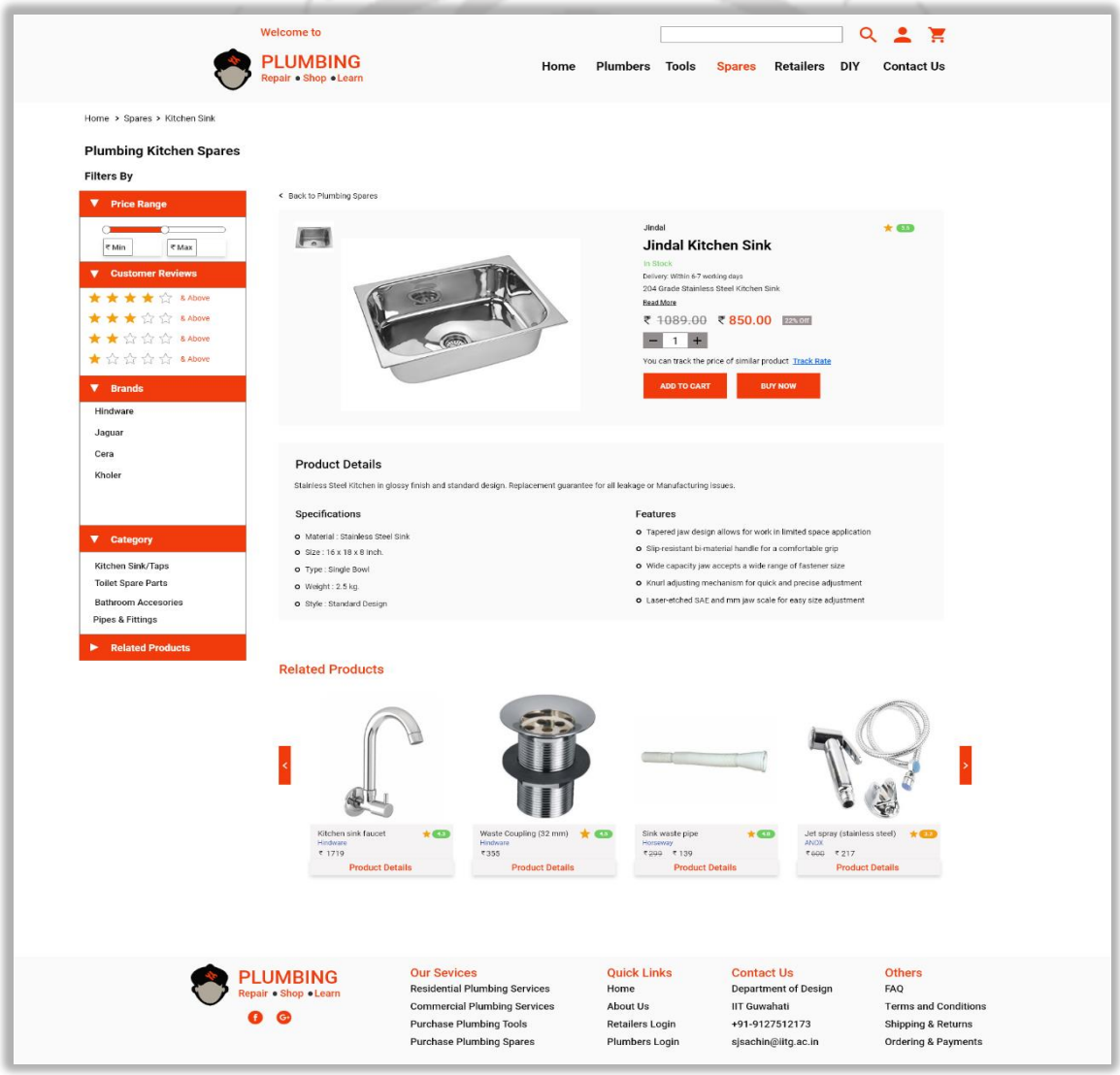


Figure 4.34: Product detailed page of domestic plumbing service system

Address and Payment details page: The customer can give details on the billing and the shipping address, as depicted in Figure 4.35. Billing address refers to the address where the customer can receive his bill. Shipping address refers to the address where the user can receive his product. Several payment options can be used, such as debit card, credit card, net banking, amazon pay, google pay or UPI payments. The customer can select any of the above payment methods. After selecting the mode of payment, buyer now fills in the payment details like card number, name on the card and CVV number. After reviewing the order, the customer can click on "Place Order". Once the payment is made customer gets a confirmation message "Your order is successfully placed".

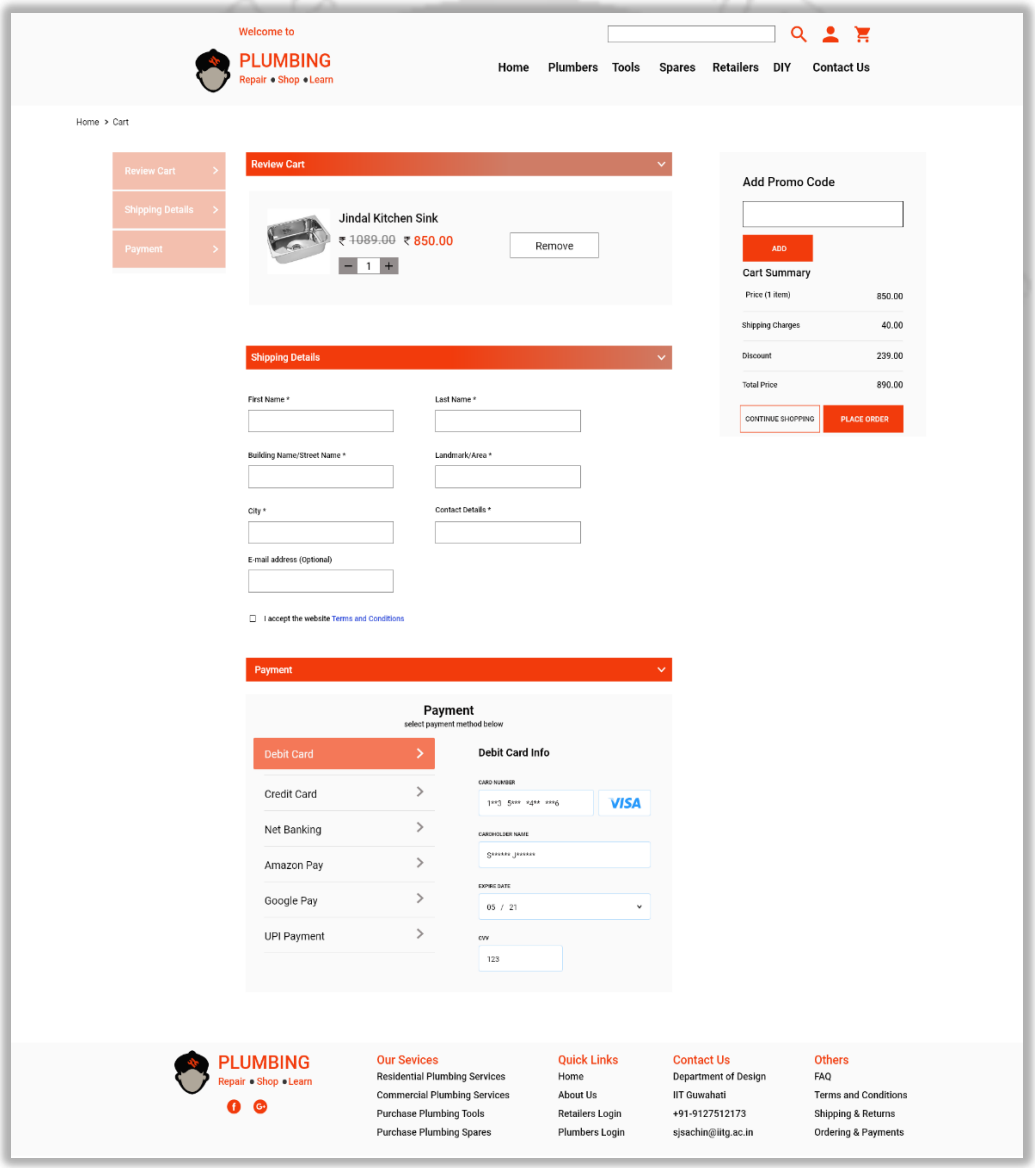


Figure 4.35: Address and payment details page of domestic plumbing service system

Service & Order status page: Customers can log in to their account by providing username and password credentials. Here, customers can view and keep track of their product and service details. Customers can reschedule the service date and time by selecting “services”. Besides, Customers can cancel the service request, as shown in Figure 4.36 and Figure 4.37.

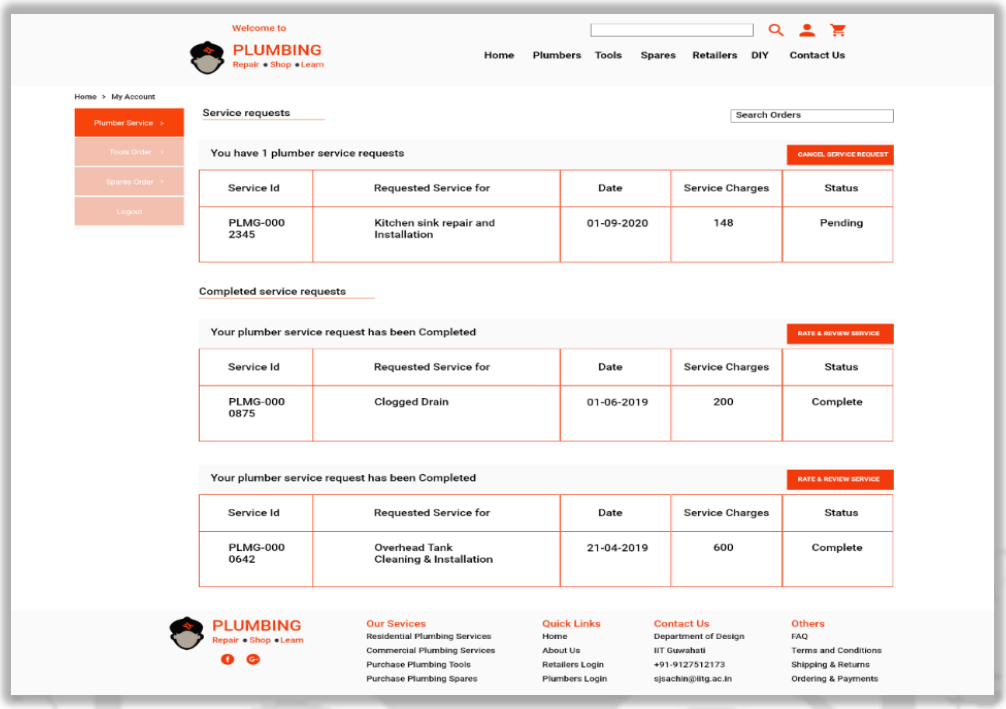


Figure 4.36: Plumber service status of domestic plumbing service system

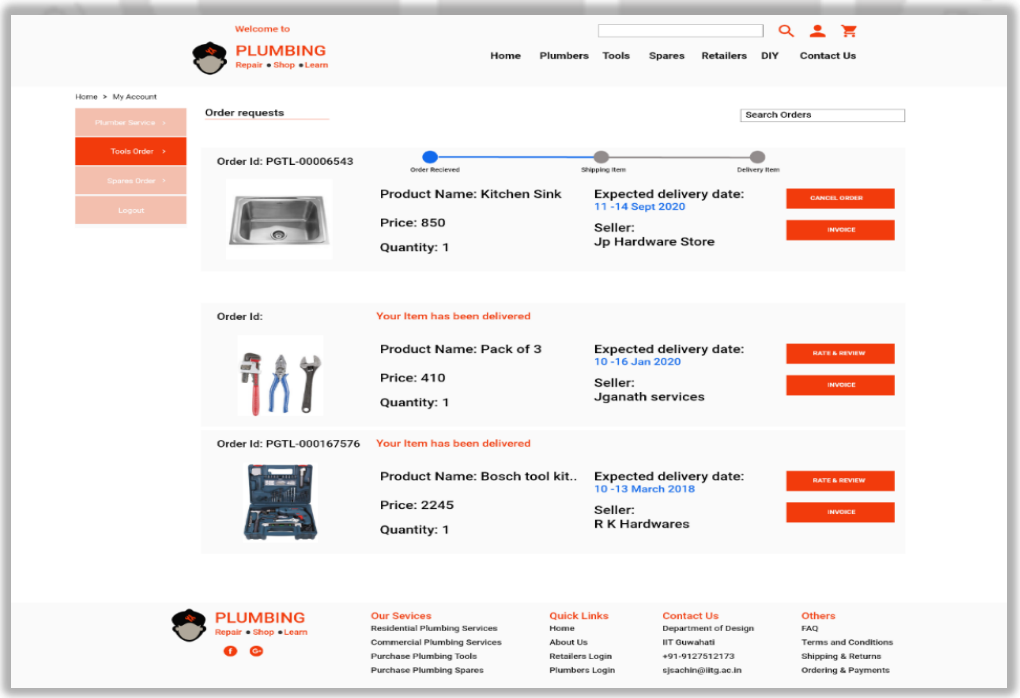


Figure 4.37: Plumbing tools/spares status of domestic plumbing service system

Retailers page: Customers arrive on this page by selecting 'Retailers' from the menu. Here, customers can contact directly to the retailers for the procurement of spares and tools. Customers can filter the retailers' search by location, pin-code and ratings. In addition, customers can browse the retailers and access the necessary information like viz. retailers address, contact details, ratings, retailers working hours, website and directions to the retailers' shop, as illustrated in Figure 4.38.

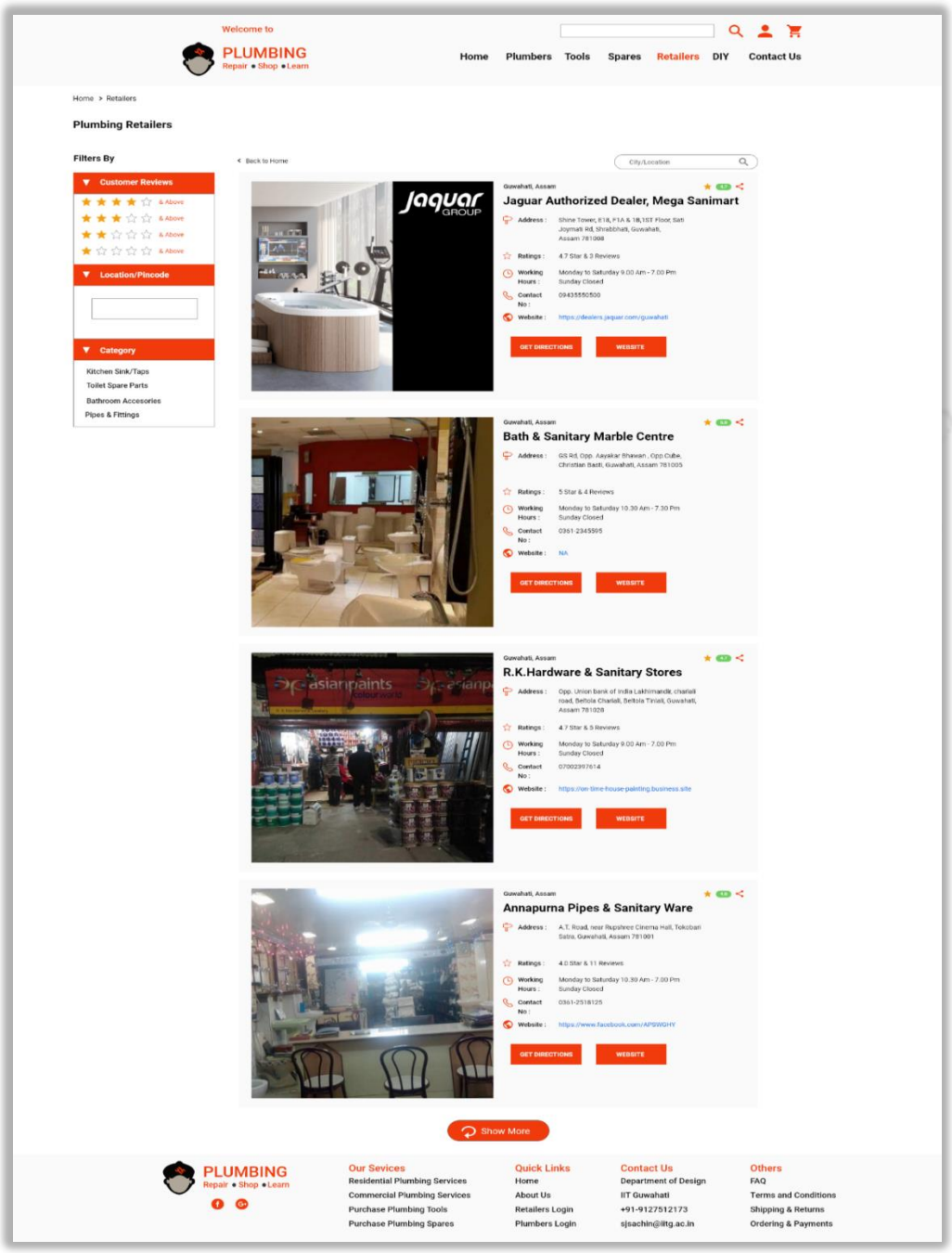


Figure 4.38: Retailers page of domestic plumbing service system

DIY page: Customers looking to resolve minor plumbing issues can access and view this page by selecting 'DIY' from the menu, as depicted in Figure 4.39. Here, a listing of minor plumbing issues is provided. Customers can select from the listing of the minor plumbing issues. Then, the description is shown for a plumbing issue, causes, step-by-step procedure with the images, tools and spares required with the images, download option for the tutorials in pdf and doc format. Related minor plumbing issues are also shown with the sliding animation.

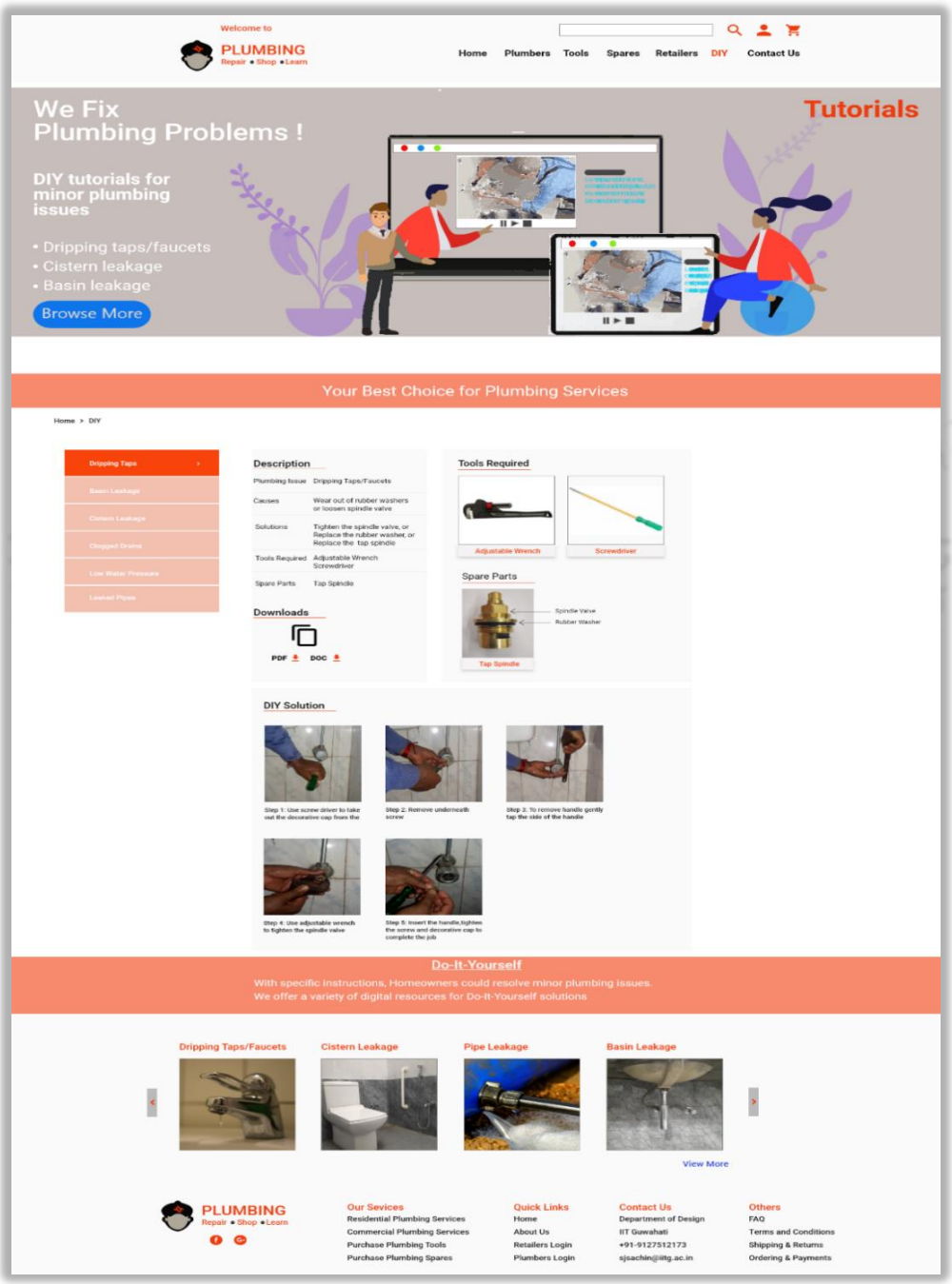


Figure 4.39: DIY tutorials page of domestic plumbing service system

Plumber registration page: A plumber looking for a listing as a service provider through the website platform can access this portal by selecting ‘plumber login’ on the website homepage in the footer section. As shown in Figure 4.40, a plumber could register himself as a service provider by providing necessary information. Once the background verification is completed, plumbers receive a service request from the customers, as shown in Figure 4.41. Plumbers can work on their terms, working hours, accept and cancel service requests.

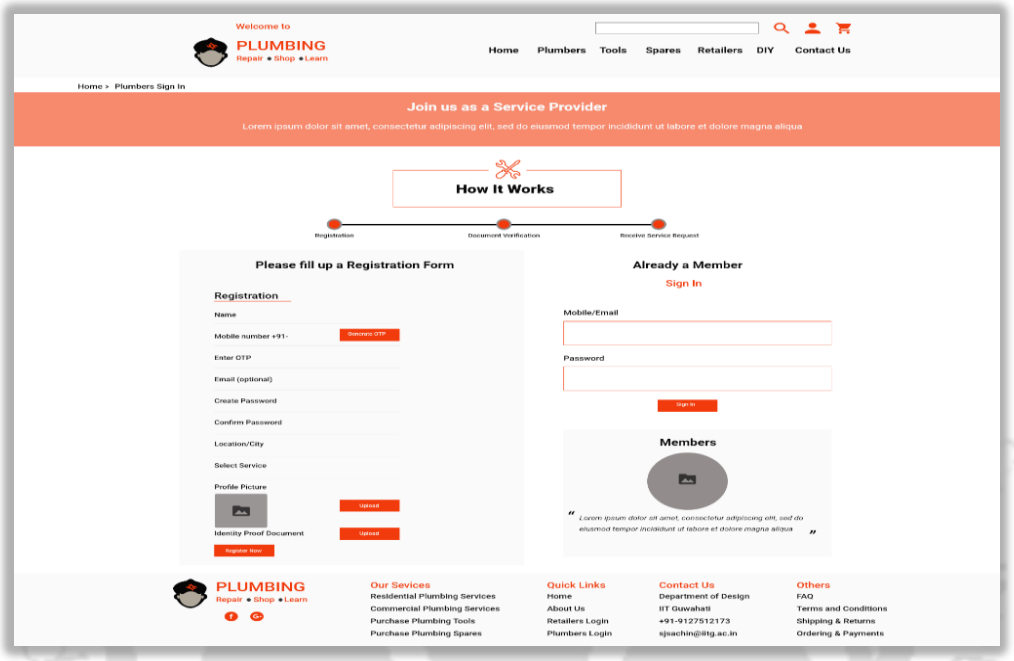


Figure 4.40: Plumbers sign in and sign up for domestic plumbing service system

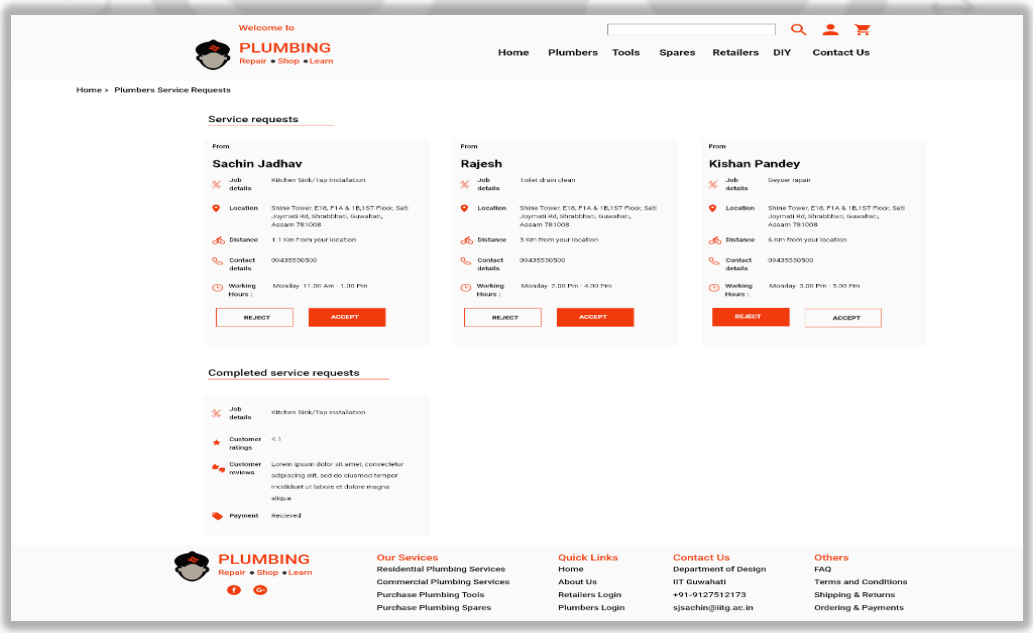


Figure 4.41: Plumbers dashboard of domestic plumbing service system

Retailer registration page: Retailers looking for expanding their business through the website platform can access this portal by selecting ‘retailers login’ on the website homepage in the footer section. As shown in Figure 4.42, the retailer can register their shop as a service provider by providing necessary information. Once the background verification is completed, the retailer receives an order request from the customers, as shown in Figure 4.43. The retailer can update their product stocks, upload product details, images, view order quantity and shipping details.

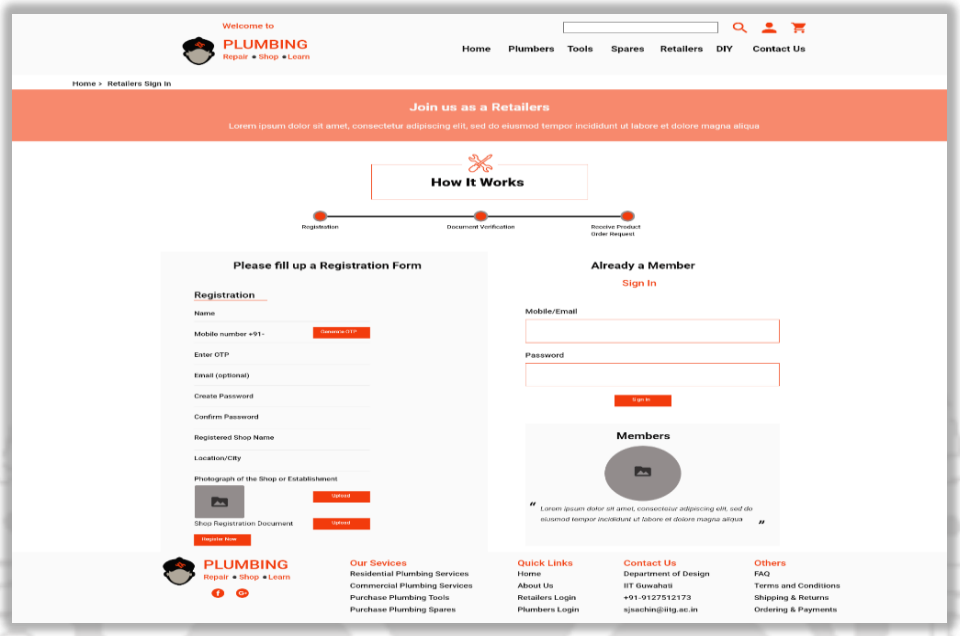


Figure 4.42: Retailers sign in and sign up for domestic plumbing service system

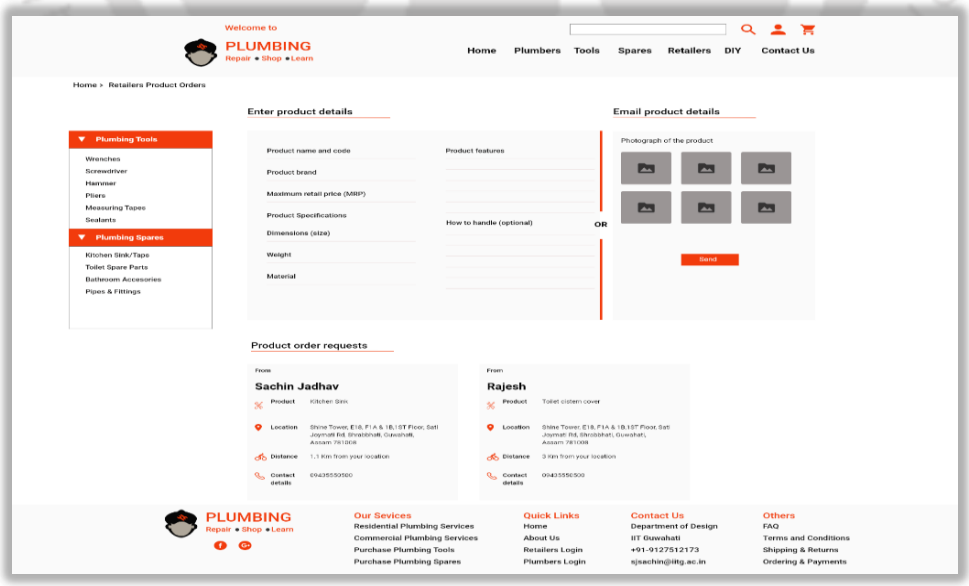


Figure 4.43: Retailers dashboard of domestic plumbing service system

4.4.5 Users Opinion & Feedback on PSS Solution for Domestic Plumbing Services

The validation of the PSS solution for domestic plumbing services was conducted through a questionnaire in two stages. First, the understanding and implementation of the e-commerce website for domestic plumbing services from customers. Second, the e-commerce business model review and recommendations from the expert users. Both the study was conducted through a web-based questionnaire. The following sections discuss and present the opinions and feedbacks on PSS solutions for domestic plumbing services.

4.4.5.1 Validation of E-commerce Website for Domestic Plumbing Services Through Customers

This study adopted the survey method. Hence, web-based questionnaire has been floated as the instruments to collect required data. There are three parts in the questionnaire (appendix 5, part A). The first part comprises the description of the survey purpose followed by the website demonstration. The second part contains 22 items that represent the website characteristics. The website characteristics are viz. context, content, loyalty, transactions, communication, ease of use, benchmarking, DIY and website promoter. Out of 22 items, four items were open-ended questions related to transactions, benchmarking and website promoter. Eighteen items were closed-ended questions with a 5-point Likert Scale measurement. Customers were asked to respond to the closed-ended questions. It contains "1" as strongly disagree with the statement, and "5" strongly agree with the statement. The third part contains the questions about the demographics of the customers.

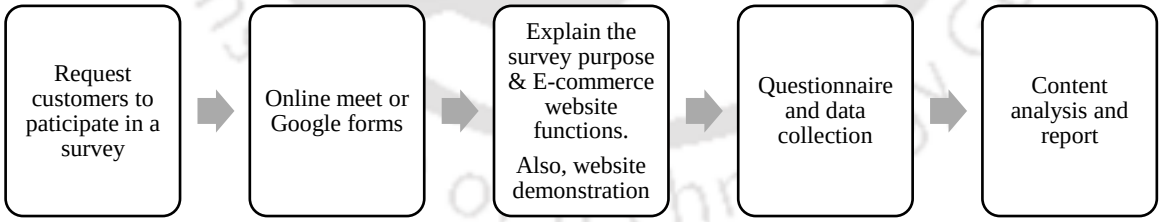


Figure 4.44: Schema for validation of E-commerce website for domestic plumbing services from customers

The survey plan is shown in Figure 4.44. The survey plan was initiated by requesting customers to participate in a survey. On a volunteer basis, customers were asked to submit feedback through online meet or google forms. The survey duration was 20 - 25 minutes. The e-commerce website functions were described to respondents through a video featuring website

demonstrations. It demonstrates all the features, all the menus and entire user journey in navigating through the website. The website demonstration video is available in the link (https://drive.google.com/file/d/1FBrF6bY3HxK6fm0RPHI-cLtflByfrc_a/view?usp=sharing). Questionnaires were electronically distributed to respondents and follow up was done regularly. After distributing the survey form to more than eighty customers, fifty were filled out and returned. Out of fifty survey forms, fourteen were incomplete and thus not included in this study. Following is the description of the demographic profile of the respondents. Figure 4.45 illustrates the respondent's location, gender, education and age-group.

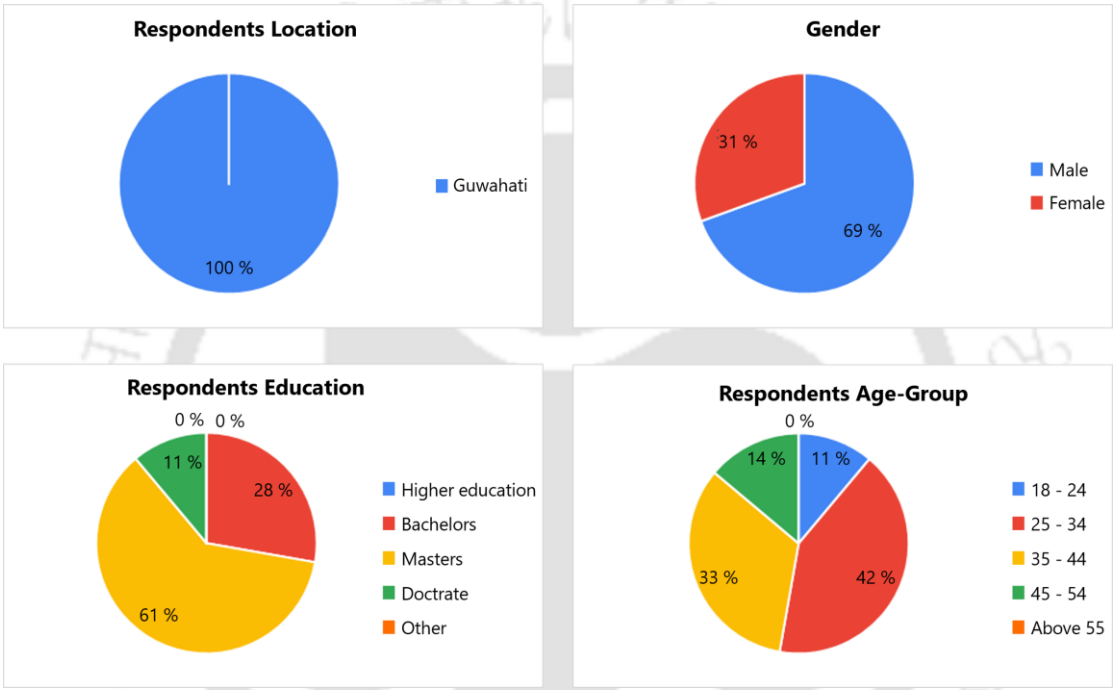


Figure 4.45: Demographic data of respondents

All the respondents belong to tier-II city. The gender distribution of respondents were 69% male and 31 % female. The respondent's education was categorized into higher education (0%), bachelor degree (28 %), master degree (61%), doctoral candidates (11 %) and others (0%). The respondent's age group of 18-24 and 45-54 were 11% and 14 %, whereas 25-34 and 35-44 were 42 % and 33 %. The extracted details of thirty-six website survey forms data were documented and discussed as shown below.

Q1: This website provides customers with online plumber booking and cancellation

It has been observed that 72.2 % respondents strongly agreed that the website provides online plumber booking and cancellation. In addition, 27.8 % respondents agreed to the above statement related to the website.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.72	5.00	5	0.454

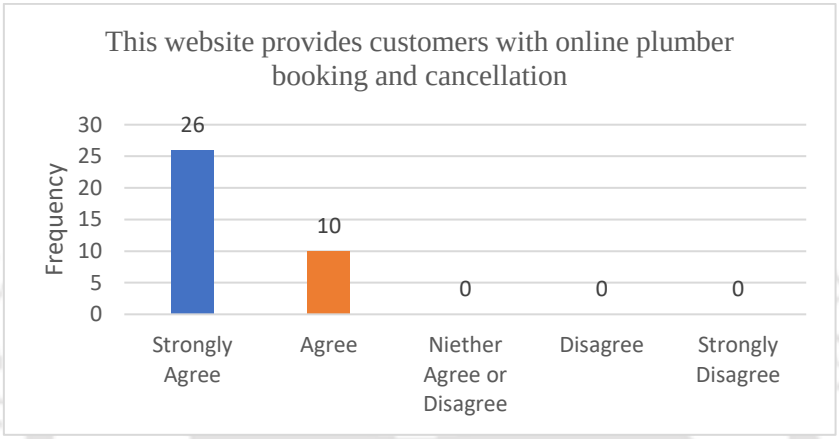


Figure 4.46: Website provides online plumber booking and cancellation

Q2: I find booking a plumber service through this website is convenient

It has been observed that 58.3 % respondents strongly agreed that booking a plumber service through this website is convenient. In addition, 41.7 % agreed to the above statement related to the website.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.58	5.00	5	0.500

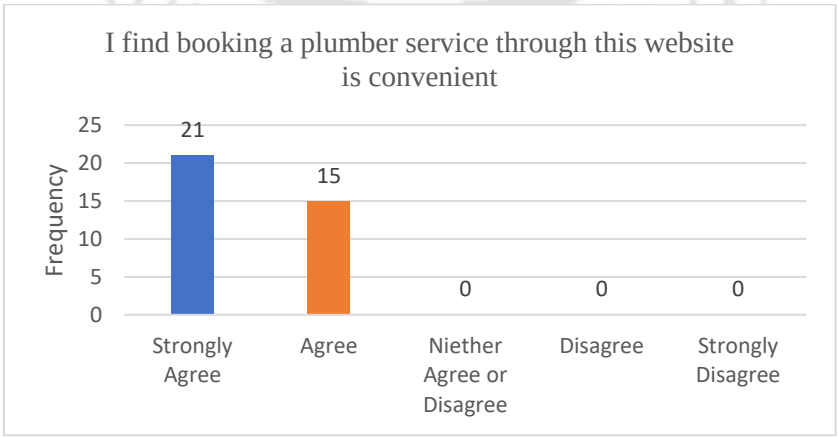


Figure 4.47: Booking a plumber service through this website is convenient

Q3: The layout of the website is self-explanatory and simple

It has been observed that 55.6 % respondents strongly agreed that the website is self-explanatory and straightforward. In addition, 41.7 % agreed to the above statement related to the website. However, 2.8 % respondent opined neither agree nor disagree.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.53	5.00	5	0.560

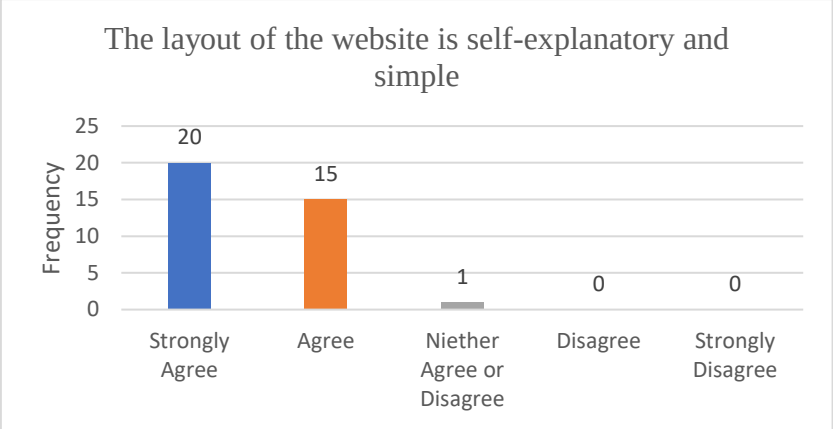


Figure 4.48: Website layout is self-explanatory and simple

Q4: The website presentation described the process of online plumber booking

The above statement was posed to understand customers opinion about ease of understanding the process of online plumbing booking on the website. In addition, 75 % respondents strongly agreed and 25 % respondents agreed with the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.75	5.00	5	0.439

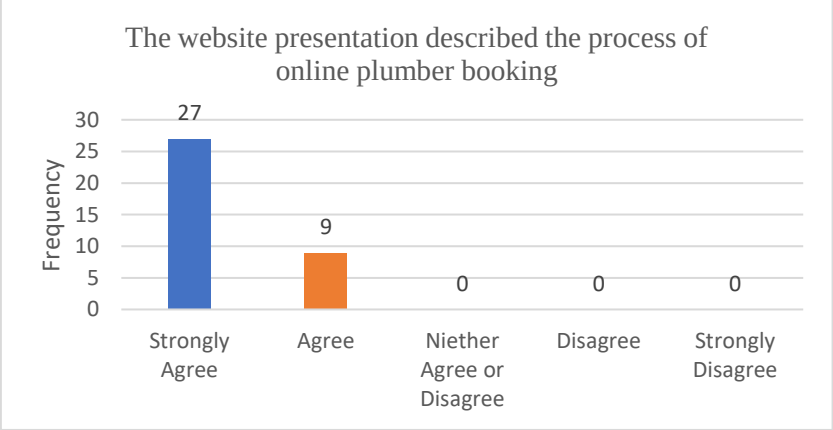


Figure 4.49: The process of online plumber booking is described

Q5: It is easy to navigate on this website

Customers were asked about ease of navigation and flow on the website. It has been observed that 55.6 % respondents strongly agreed and 41.7 % respondents agreed. However, 2.8 % respondents neither agreed nor disagreed.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.53	5.00	5	0.560

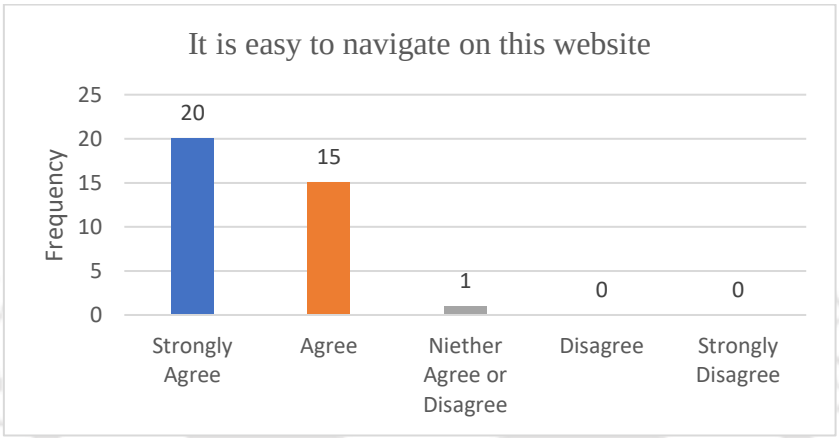


Figure 4.50: The website has ease of navigation

Q6: The website has a proper product and service categorization

It has been observed that 47.2 % respondents strongly agreed that the website has a suitable product and service categorization. In addition, 44.4 % respondents agreed. However, 8.3 % respondents neither agreed nor disagreed.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.39	4.00	5	0.645

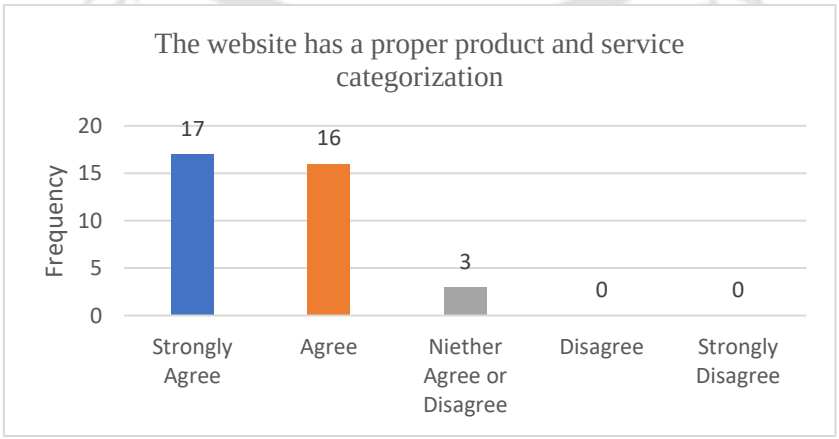


Figure 4.51: The website has a proper product and service categorization

Q7: The website features customers to contact the retailers conveniently and easily

Customers were asked about their opinion regarding convenience and ease of contacting retailers to procure plumbing tools and spares. It has been observed that 58.3% respondents strongly agreed, 36.1 % respondents agreed to the above statement. However, 5.6% respondents neither agreed nor disagreed to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.53	5.00	5	0.609

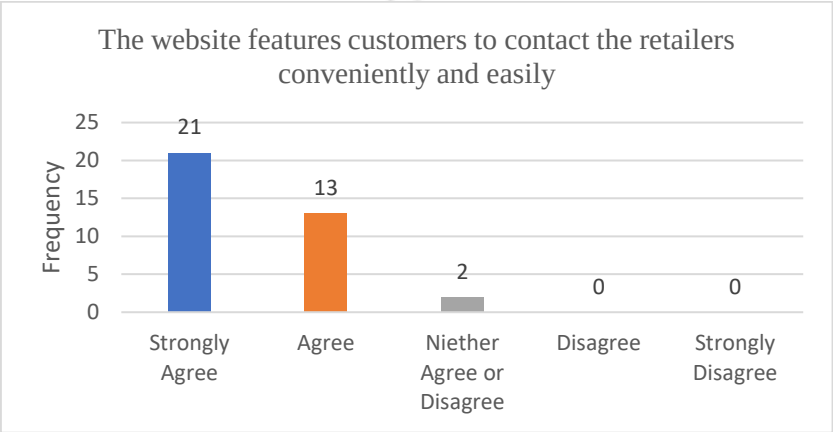


Figure 4.52: Website features customers to contact the retailers conveniently and easily

Q8: The website has a section on DIY for minor plumbing issues

It has been observed 80.5 % respondents strongly agreed that the website has a section on DIY for minor plumbing issues. In addition, 3.9 % respondents agreed to the above statement. However, 5.6 % respondents neither agreed nor disagreed.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.75	5.00	5	0.554

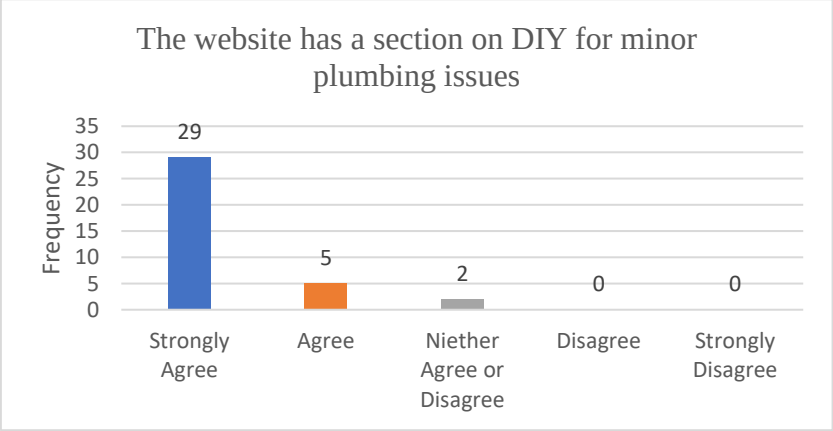


Figure 4.53: The website has a section on DIY for minor plumbing issues

Q9: The website provided customers to check order status

It has been observed that 80.5 % respondents strongly agreed that the website has provided customers to check the status of plumber service and online order status. In addition, 13.9 % respondents agreed to the above statement. However, 5.6 % respondents neither agreed nor disagreed to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.72	5.00	5	0.454

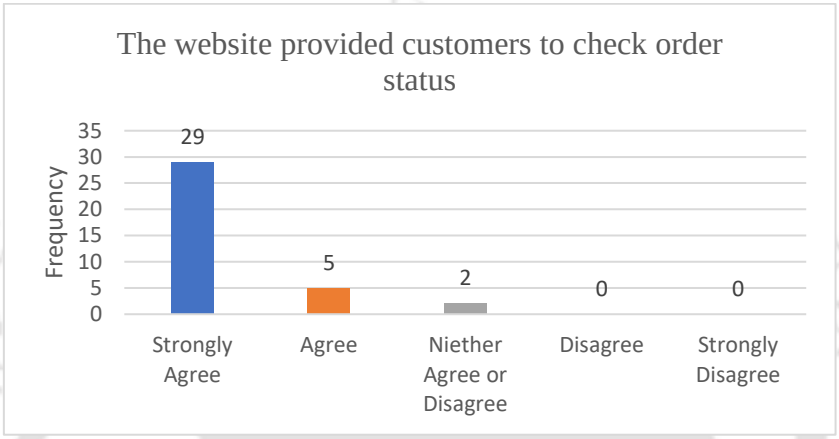


Figure 4.54: The website provided customers to check order status

Q10: The information on this website is relevant to the plumbing services and customers

It has been observed that 80.6 % respondents strongly agreed that the website is relevant to the plumbing services. In addition, 16.7 % respondents agreed to the above statement. However, 2.7 % respondents neither agreed nor disagreed to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.78	5.00	5	0.485

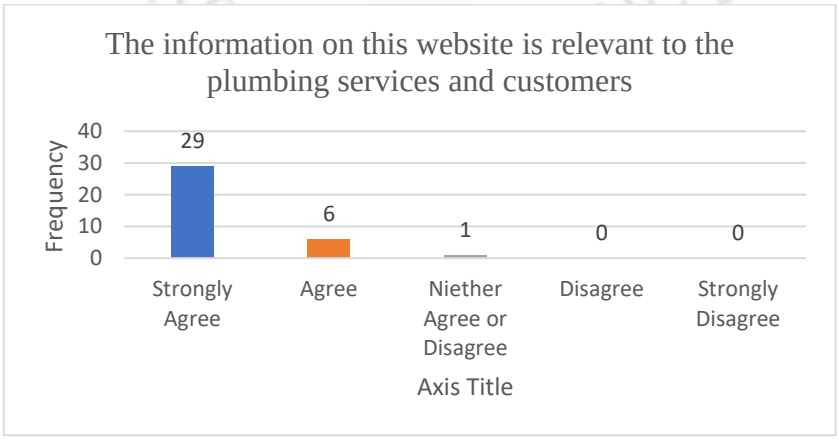


Figure 4.55: The information on this website is relevant to the plumbing services and customers

Q11: This website mentions information such as product and service details

It has been observed that 69.4 % respondents strongly agreed that the website mentioned product and service details. In addition, 30.6 % respondents agreed with the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.69	5.00	5	0.467

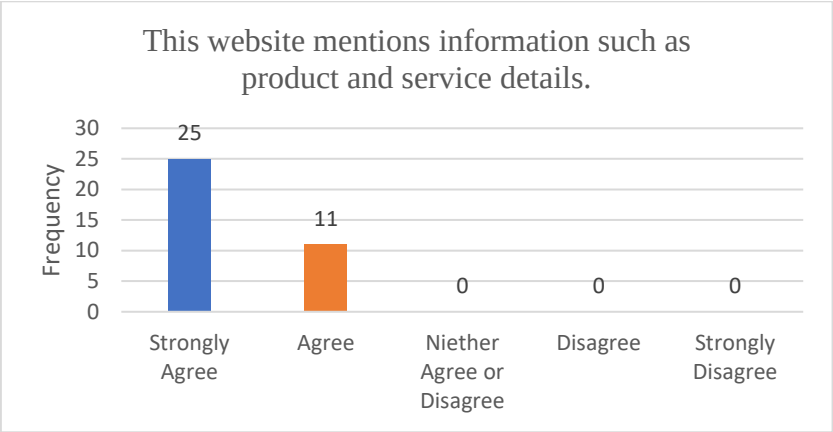


Figure 4.56: This website mentions information such as product and service details

Q12: I feel confident conducting business with this website

The majority of the respondents (58.3 %) strongly agreed to conduct business with the website of domestic plumbing services. In addition, 36.6 % respondents agreed to conduct business with website. However, 11.1 % respondents neither agreed nor disagreed to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.47	5.00	5	0.697

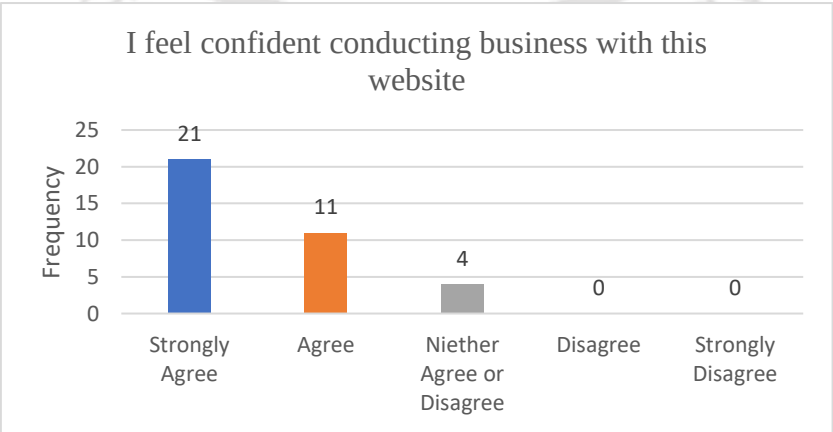


Figure 4.57: I feel confident conducting business with this website

Q13: The website provides channels for contact such as office address, email and phone number

It has been observed that 69.4 % respondents strongly agreed that the website provides channels for contact such as office address, email and phone number. In addition, 30.6 % respondents agreed with the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.69	5.00	5	0.467

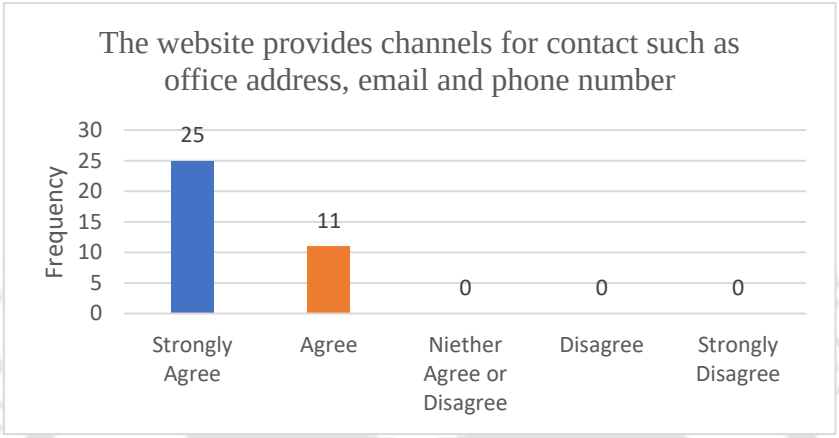


Figure 4.58: The website provides channels for contact

Q14: I will likely visit this website in the future

The majority of the respondents (63.8 %) strongly agreed to visit domestic plumbing services in the future. In addition, 30.6 % respondents agreed to visit the website in future. However, 5.6 % respondents neither agreed nor disagreed.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	4.58	5.00	5	0.604

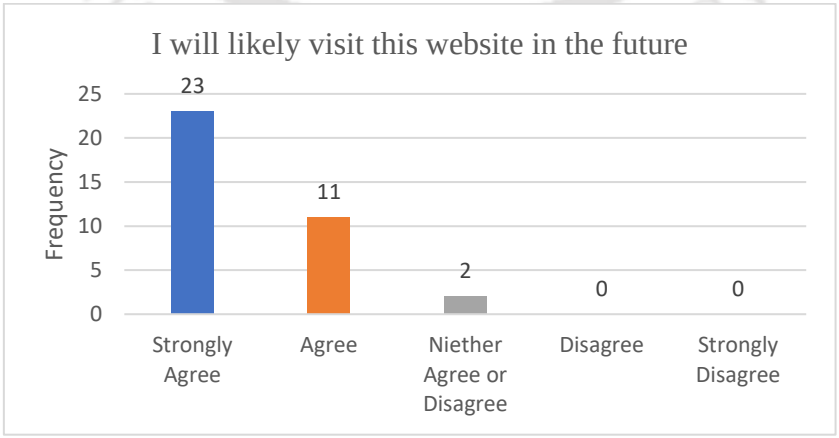


Figure 4.59: I will likely visit this website in the future

Q15: On a scale of 1 to 10, how likely is it that you would recommend this website to a friend or colleague. (Where 1 = Not Likely and 10 = Extremely Likely)

The above statement was posed to measure the Net Promoter Score (NPS). It is a measure used in the marketing strategy for increasing customer loyalty and satisfaction. The NPS is calculated by the following equation (NPS = % promoters - % of detractors). The percentage of the promoters for the developed e-commerce website is 88.9 %. The percentage of detractors for the developed e-commerce website is 11.1 %. Hence, the Net promoter Score is 77.8 % for the developed e-commerce website for domestic plumbing services.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	8.75	9.00	9	1.180

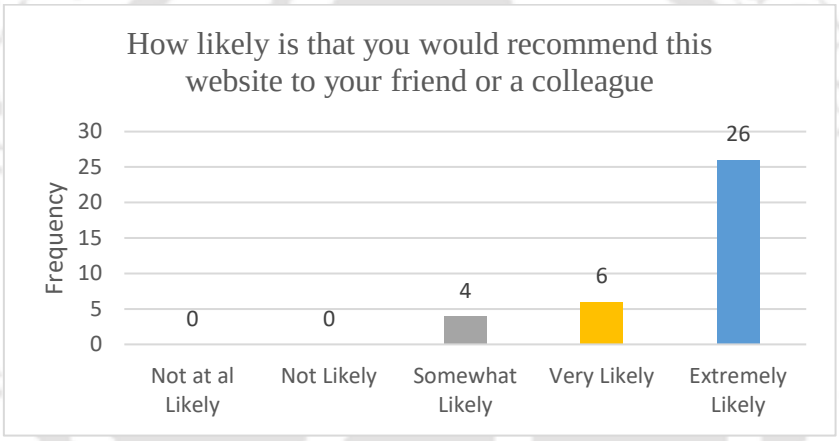


Figure 4.60: Net Promoter Score of the website

Q16: In your opinion, what additional features should have on this website?

Respondents suggested some additional features on the website, for instance, more DIY videos with online queries to resolve, plumbing products with cheaper alternatives, selection option of plumbers with portfolio, ratings and reviews. Respondents also opined that the option of chatbot could add extra value. Respondents also suggested to consider offers like redeem codes.

Q17: How likely would you request a plumber service through this website?

The possibility of requesting a plumber service through the website is 69.4 %. In addition, 27.8 % respondents opined 'somewhat likely'. However, 2.8 % respondents opined 'not likely' in response to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	2.67	3.00	3	0.535

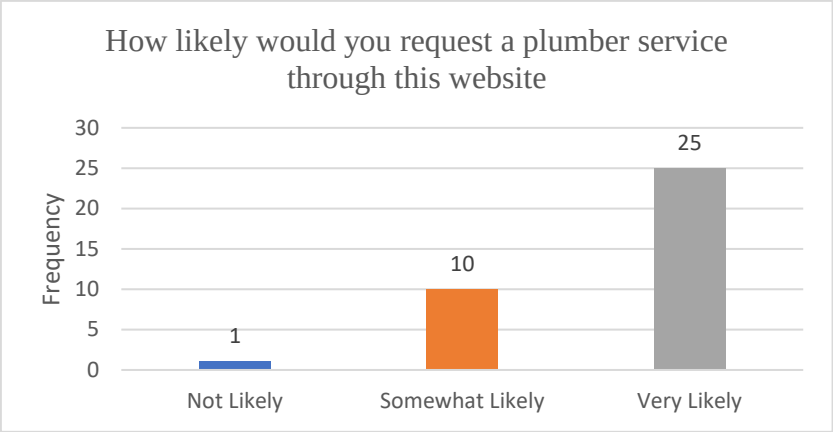


Figure 4.61: Plumber service request through the website

Q18: Is our pricing section clear?

The majority of the respondents (88.9 %) opined that the pricing section on the website is clear. However, 11.1 % respondents opined that the pricing section is not clear.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	1.11	1.00	1	0.319

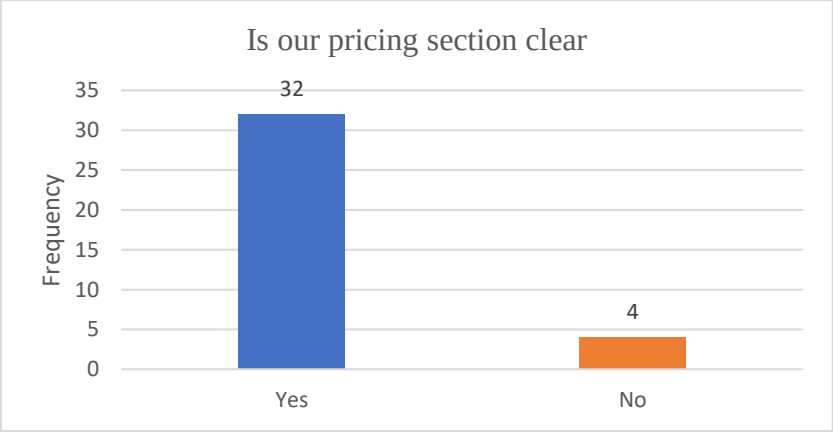


Figure 4.62: Website pricing section

Q19: How can we improve our pricing section?

The majority of the respondents are satisfied with the pricing section on the website. Respondents also suggested few measures to enhance the pricing section on the website such as viz. comparison of offering product and service prices with retail or competitor, to consider

promotional code or discount offers on the pricing section, minimum service charges or reasonable average price regard each plumber service.

Q20: What would you use as an alternative if our website is no longer available?

Currently, as per our knowledge, there is a scarce and availability of complete plumbing services and solutions. In other words, the complete plumbing services or solution comprises plumber service, online order of tools/spares, retailer's information and DIY on minor plumbing issues. Therefore, respondents said they would contact a local plumber for service if our website is no longer available. Nevertheless, customers would ask retailers for a reliable plumber, contact through society offices or residential buildings. Customers may also use websites like just dial or through search engines.

Q21: How likely would you consider doing DIY for minor plumbing issues?

It has been observed that 41.7 % respondents opined that they are 'very likely' to consider doing DIY for minor plumbing issues. In addition, 52.8 % respondents opined 'somewhat likely'. However, 5.6 % respondents opined 'not likely' to the above statement.

Descriptive Statistics				
N	Mean	Median	Mode	Std. Deviation
36	2.36	2.00	2	.593

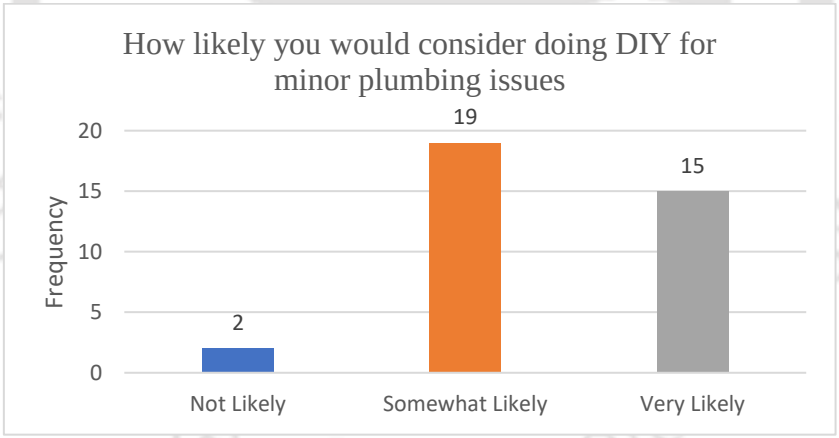


Figure 4.63: Consideration of DIY for minor plumbing issues

Q22: In your opinion, what makes us stand out from other similar websites?

The respondents have positive responses and satisfaction towards the developed website for domestic plumbing services. The majority of the respondents mentioned that the website is a one-stop solution for all plumbing issues because it includes both e-commerce and services on the same platform. It includes DIY tutorials and retailer's information on the website. Nevertheless, DIY expands to the concept of a one-stop-shop aiming to help customers solve

minor issues independently. The website offers to book plumber services and it has a clean layout, simple, easy navigation, clear and organized information. Moreover, few respondents said that they had not found any similar website for plumbing services. It presents a detailed categorization of services, self-explanation and a user-friendly website.

4.4.5.2 E-commerce business model review and recommendations through experts

This study presents e-commerce business model reviews and recommendations through expert users. Figure 4.64 illustrates schema for evaluation of PSS business model and e-commerce website. Seven experts were chosen based on relevant experiences related to product and service management, service delivery and operations, strategic management and consultants. Experts were identified through peer connections and shortlisted on basis of job descriptions, past experiences and area of specialization.

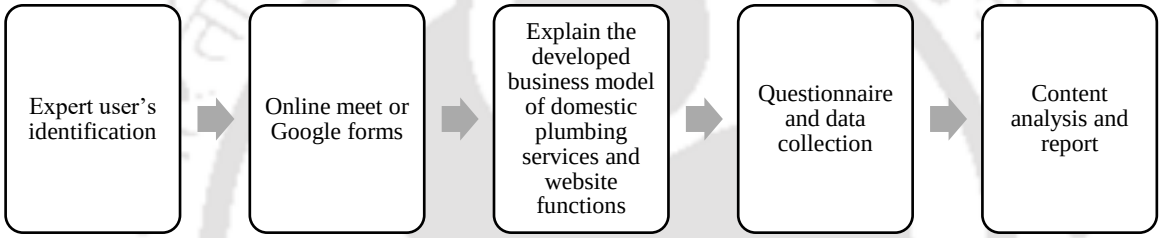


Figure 4.64: Schema for evaluation of PSS business model and e-commerce website

Table 4.18: Expert users' profile

Particulars	Organization	Designation	Job role	Age-group	Relevant experiences
Expert user 1	Fractal Analytics	Data Analyst	Market insights analyst	25-34	Experienced Consultant and history of working in the Technology, Retail and Healthcare industry
Expert user 2	General Motors (GM)	Manager	Aftersales service	35-44	Service delivery, operations and management
Expert user 3	General Electrical (GE)	Manager	Product Management	25-34	Experienced in product management activities such as market research, competitive differentiation, positioning, branding and pricing analysis
Expert user 4	Linde India	Manager	Supply chain management	35-44	Supply chain and logistics
Expert user 5	TWIB Technologies	Business Head	Project Lead	35-44	Service delivery and operations
Expert user 6	Wipro Limited	Senior Executive	Strategy Consultant	25-34	To develop and implement IT strategies, newer initiatives and standard processes
Expert user 7	Goldman Sachs, India	Associate and Analyst	Franchise Management & Strategy	25-34	Global Markets Management & Strategy. Securities Management & Strategy

The review and recommendations on the e-commerce business model and the website were conducted through a web-based questionnaire. Web-based questionnaire was floated as the instruments to collect required data. Ten expert users were identified and approached to participate in the survey. In response, seven expert users agreed to review and recommend on e-commerce business model and the website. The expert users profile is tabulated in Table 4.18. The duration of discussion with each expert user was 40-50 minutes. The discussion started with explanation of the purpose of the survey, followed by description of the business model components and what it does, and demonstration of the website functions. Data were collected through a questionnaire (Appendix 5, part B) developed in Google forms. Questions 1-5 were asked regarding the developed e-commerce business model to review and collect recommendations from experts. Hence, the questions designed were qualitative and subjective. The questions helped us to understand whether the developed e-commerce business plan was feasible for operational activities. It also helped us to understand prospects of specific business areas. The extracted details were documented and discussed, as shown below.

Q1: In general, what is your understanding and views on the developed business model for domestic plumbing services?

Based on the explanation and discussion on the above statement, all seven respondents mentioned that it is a unique business model. It offers e-commerce of plumber service, plumbing tools/spares and provides nearest retailer information. The highlight is DIY, since there are many instances where customers cannot find the nearest plumber in their area and have to expand their search, which is a tedious task. The simple solution is 'DIY' if the problem is not complicated and can be fixed with minimal tools.

The website provides information on the tools required for fixing a plumbing issue and an online booking option. The website also helps local plumbers get in touch with potential customers, which is a great idea! and thereby creating a win-win situation for both the customer & the plumber. It is a plumbing service that provides services including tools, spares accessories and systematic tracking of the entire service loop. Besides, the business specializes in a particular sector providing 1-1 services and can be scaled easily to different regions. It can be the new 'plumber' specialists in India, which is easy to use with options from DIY. Almost everyone in India needs it (businesses and homes alike).

Q2: Is the idea worth considering for the market launch?

All seven expert users said that the idea is worth considering for the market launch.

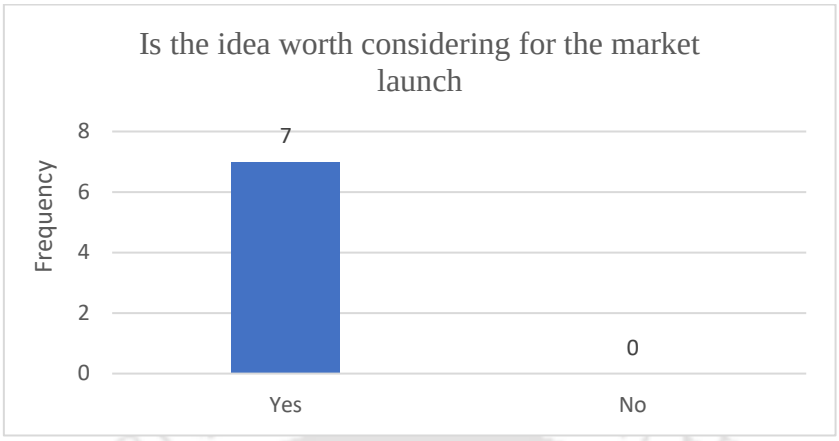


Figure 4.65: PSS business model and e-commerce website for market launch

Q3: What are the additional areas to focus on for implementing the developed business model of domestic plumbing services?

The expert users suggest additional areas for enhancing the proposed business model. The additional areas suggested are such as viz. fast service delivery, post-service follow-ups, app-based ratings of service personnel, contracts to ensure a fixed source of revenue for the business. If the website platform is operational, the business model can include other services like mason, carpentry, and many more similar services. There needs to be a commission from the retailer side for directing customers to them. Because giving out retailer information for free may invite risk resulting into loss of revenue. Promotional codes or referral codes could be added.

From a customer perspective, the website is promising. Nevertheless, from an internal view of the firm, inventory management of spares may pose challenges. In most scenarios, people who live in non-rented houses usually call the plumbers who would have done the plumbing work when the house was built. Hence, engaging with potential customers can enhance the customer lifecycle. “Laying out plumbing designs” can be added as a service for new homemakers.

Q4: Which are the factors that motivate customers to use on-demand plumbing services?

Several factors motivate customers to use on-demand plumbing services. These are viz. availability of experienced, reliable plumber and unreasonable service charges. The ease of finding a plumber and the ability to schedule a plumber visit helps immensely the working population. Customers cannot fix a plumbing issue independently and they do not know how to fix it. Customers do not have the time to fix a leak since they are busy. Besides, ease of

approach and guarantee of repair, quality, cost, convenience and delivery factors always motivate customers to use on-demand plumbing services.

Q5: Any other comments and suggestions you would like to share?

Respondents opined that estimated service delivery time display on the website would help to manage customer queries. Implementation of optimization techniques for service operation management may enhance the business. Post-service follow-up on feedback on quality of service, technician's behaviour and skills would lead to better customer delight. Collaboration with an established organization in the business of plumbing spares and tools will strengthen the proposed business model. This kind of service has more demand in urban cities due to presence of apartment societies. Many apartment societies already have round-the-clock facility management teams. Therefore, the proposed business model may be integrated with such facility team management of apartment societies.

4.4.5.3 Summary on validation of PSS Solution for Domestic Plumbing Services

In the previous sections (4.4.5.1 and 4.4.5.2), validation of the PSS solution of domestic plumbing services is presented in two parts. The developed e-commerce business model of domestic plumbing services is validated through the expert users and e-commerce website of domestic plumbing services through the customers. The findings through a web-based questionnaire were found to be satisfactory. We can observe that most of the respondents are optimistic about the e-commerce website for domestic plumbing services. The website offers to book plumber services, it has a clean layout, simple, easy navigation, clear and organized information. Moreover, few respondents said that they had not found any similar website for plumbing services.

Based on the survey results, we can infer that the developed business model of domestic plumbing services is worth considering for the market launch. The e-commerce website of domestic plumbing services is working as per the present prerequisites of understanding, functionality and implementation. The following points are collated, which are discussed and presented in the previous sections.

- The context on the website was found effective by both the customers and expert users. It has an organized structure, detailed product and service categorization, easy to use, and provides retailers information and DIY tutorials on minor plumbing issues.

- The content on the website was found adequately by the customers. It has the process of online plumber booking and customers can check order status. In addition, it has information such as price, product/service details and quantity.
- The majority of the respondents agreed to conduct business with the website and likely visit the website in the future.
- The majority of the respondents are satisfied with the pricing section on the website. To enhance the pricing section on the website, respondents suggested few measures.
- Customers agreed that the website provides channels for contact such as office address, email and phone number. The website features customers to contact the retailers conveniently and quickly.
- The website provides ease of navigation, flow and convenience in booking a plumber service.
- In contrast with the other similar websites, our designed and developed website is a one-stop solution for all plumbing issues because it includes both e-commerce and services on the same platform. It includes DIY tutorials and retailer's information on the website.
- The customers are very likely to consider doing DIY for minor plumbing issues. The Net Promoter Score for the website is 77.8 %.
- From a customer perspective, the website is promising. Besides, expert users recommend additional areas on implementing the business model. Such as viz. fast service delivery, post-service follow-ups, app based on the rating of service personnel, use of social media for marketing purposes and factors that motivate customers to use on-demand plumbing services.

Chapter 5

5 Conclusion, Limitations and Future Scope of Work

This research concludes a systematic product service system design framework inspired by design management. The framework includes structured and systematic selection and flow of methods as follows; User Research > Rough Group AHP > Scenario Planning > Design Brief > Stakeholder Mapping > Service Blueprint > Data Flow Diagrams > UI/UX > Benchmarking > Business Model Canvas > SWOT. The research also demonstrates the successful implementation of the proposed framework resulting in design and development of e-commerce business in domestic plumbing services in India. This chapter summarizes the main findings of the current research concerning the research questions, research contributions, limitations and future scope of work.

The business organizers may adapt Product Service System (PSS) approaches, emphasizing service-oriented business to gain competitive advantage, generate sustainable business opportunities and fulfil customer needs. An integrated perspective in developing a service process through PSS appears one of the most feasible approaches for achieving sustainable solutions.

5.1 Research Findings

In this section, collated research findings are presented in line with the research questions. The two research questions were formulated to address the research gaps found during the literature review. The existing PSS design research lacks in describing, detailing and utilization of design methods and processes. Besides, the procedure to support designers throughout the various activities that characterize the PSS service development process is also missing. A service system design in the context of e-commerce through PSS approaches is scarce.

Research Question 1: What is the strategic selection and integrative perspective of design methods to develop a service process from the Product-Service System design in the context of strategic design management?

Research Finding 1: The findings presented in chapter 4 address the first research question. It provides an analysis of existing PSS design models/frameworks. It shows an integrated perspective of PSS service development. It provides justifications and reasons for considering the methods/tools/techniques in the proposed service system design from PSS perspective. It shows how it can be used to design an integrated PSS design in e-commerce through a case

example of domestic plumbing. Figure 5.1 shows the structure and roadmap for selection and application of design methods in Product Service System (PSS) Design. It clearly shows service system design framework with design methods and activities.

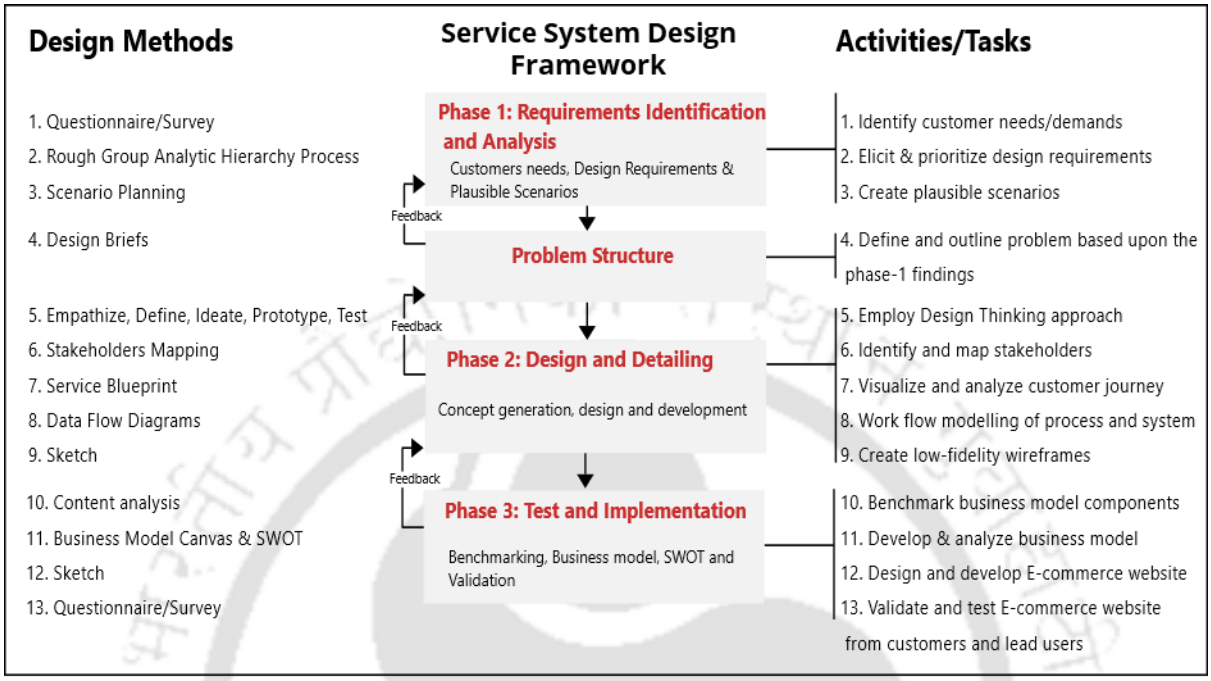


Figure 5.1: Service system design framework with design methods and activities

This study also concludes application of design thinking through stakeholder mapping, service blueprint, data flow and wireframe techniques in developing e-commerce service design. Figure 4.10 shows the mapping of the design thinking approach with the proposed PSS service design. It has been observed that in each specific phase of PSS service design, two steps of design thinking were merging. This has been described in detail in section 4.3 (*PSS Design and Detailing of Domestic Plumbing Services).*

Service Design is a multi-disciplinary, customer-centric and participatory approach. In general, service design discusses integrating products, services, networks and actors' interfaces with the systems and processes. Service system design consists of distinct perspectives. It involves an integrated perceptive of design management, service design, design thinking, information system and structured system analysis and design. As shown in Figure 5.2, the service system design covers six areas to emphasize. These are viz. target market, stakeholders, service concept, technology, infrastructure and service encounters. Its effectiveness is based on ideas, vision, perceptions and shared values.

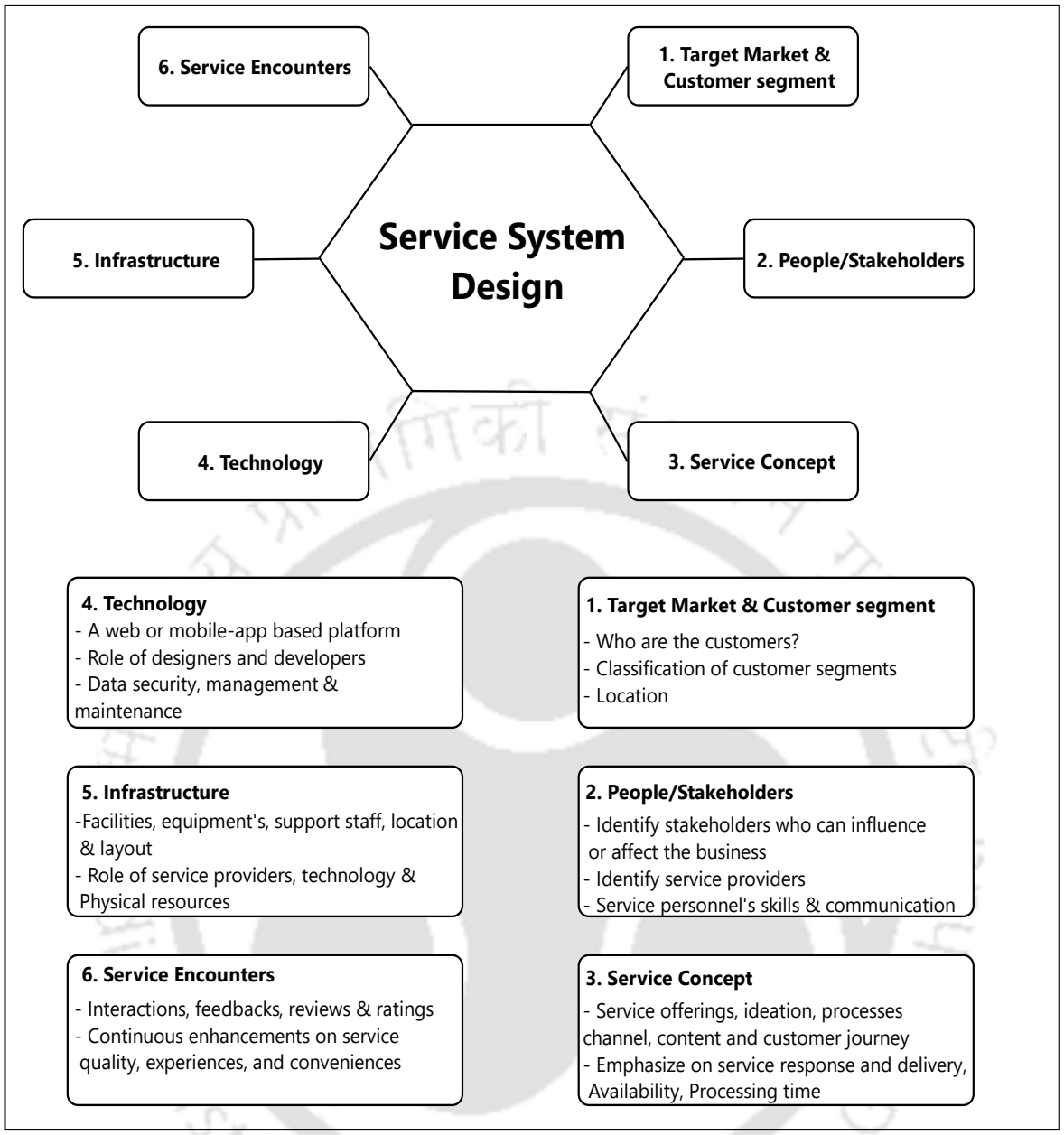


Figure 5.2: Service System Design

Research Question 2: How do integrative perspective of design methods complement and function in synergy in developing a service system design from PSS perspective for domestic plumbing services?

The contributions of integrated design methods in the proposed service system design framework for domestic plumbing services are presented in this section.

The first phase of the proposed service system design framework is requirements identification and analysis. Customers need, elicitation and prioritization of design requirements and plausible future scenarios were presented in this phase.

- User behavior analyses reveal complex relationships between the variables of domestic plumbing services. The most frequent plumbing issues found in the research are dripping faucets and low water pressure.
- In this thesis, a methodology to determine how to prioritize the various aspects of PSS is described and demonstrated in the case of domestic plumbing services. The result of Rough group AHP study shows the product-related, service-related and system-related priority design requirements. The study reveals that the most important product-related design requirements are efficiency, flexibility and reusability. The study reveals that service-related design requirements are response/delivery, availability and processing time. It was observed that the system-related design requirements are skills, communication of plumber and location.
- The scenario planning study identified the driving forces of change and trends for domestic plumbing from four perspectives: political, economic, social and technological. Two scenarios were created for the plumbing service system viz, 1) existing domestic plumbing services in the era of growth of on-demand services 2) domestic plumbing services in the era of DIY. The scenario planning exercise revealed opportunity of innovation in on-demand domestic plumbing services considering recent and future trends.
- Three design briefs were outlined based on the results of phase 1 (requirements identification and analysis). These are viz. plumbing toolkit designing and development, App-based skill-sharing development and E-commerce website for domestic plumbing.

The second phase primarily concentrates on applying design thinking through stakeholder mapping, service blueprint, data flow and wireframe approach in designing and developing the e-commerce business model.

- The importance of defining project stakeholders and understanding their expectations for the plumbing service system has been discussed in the stakeholders mapping study. The use of stakeholder mapping has been shown in analyzing the Power Vs. Interest matrix.
- Service blueprint enables the accurate description and provides customer journey of domestic plumbing service system so that all the stakeholders can easily understand the operation of the business process.

- Data Flow Diagrams (DFDs) represent the decomposition of the system under development into processes, flow and data stores. Wireframes aid the necessary first step in formally establishing a visual design for the e-commerce website.

The third phase of the proposed service system design framework is test and implementation. This phase emphasizes market launch. Hence, the business model development and analysis of B2C e-commerce is addressed in this phase. E-commerce website design and validation for the same is presented.

- Benchmarking various business elements for B2C e-commerce asserted in developing a business model for domestic plumbing services. Further, SWOT analysis for the developed business model showed strategic planning and identified the existing internal and external resources.
- Business model canvas was developed for the on-demand domestic plumbing services. The key elements for plumbing services are depicted through the business model canvas, as shown in Figure 5.3. It represents value proposition, customer interfaces, internal management and financial aspects.
- A web application was developed as a PSS solution for domestic plumbing services. Validation of PSS solutions for domestic plumbing services was conducted with quantitative and qualitative research, where, potential customers and experts were involved. The validation results reveal fair understanding and implementation opportunity of the B2C e-commerce solution for domestic plumbing services.

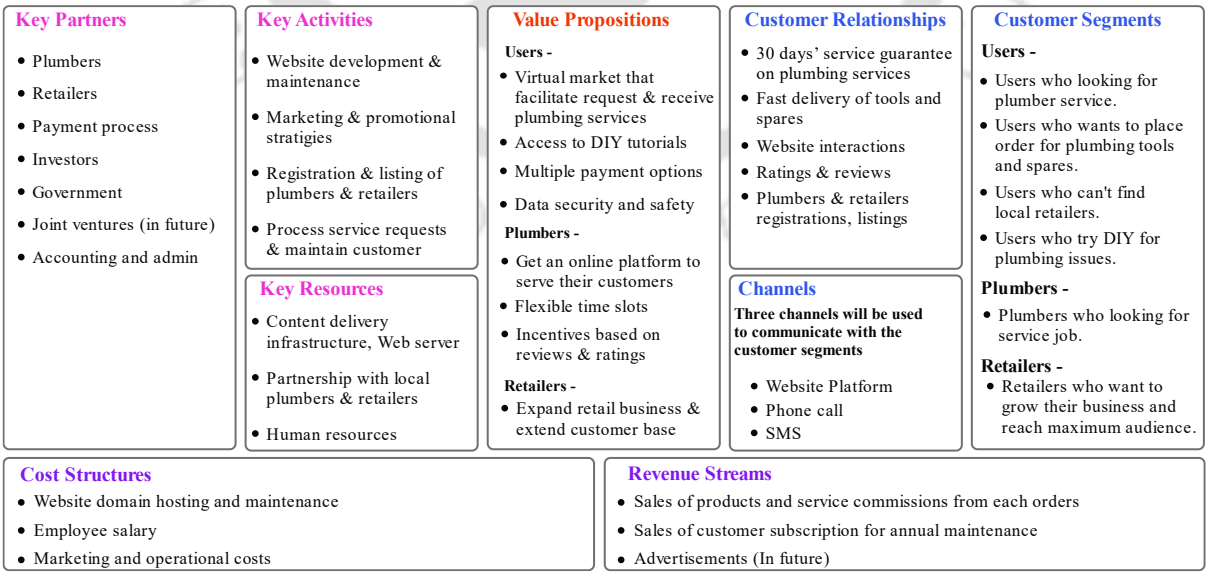


Figure 5.3:Reproduced from figure 4.26, Chapter 4

5.2 Research Contributions

The thesis offers two main contributions in line with research and design viz.: (1) PSS service design framework inspired by design management (2) service and system design for the domestic plumbing sector in the Indian context. The following sections present the contributions as follows,

5.2.1 Research Contributions: Service System Design Framework from PSS Perspective Inspired by Design Management

The shift towards PSS from the traditional sale of products depends on developing PSS capabilities, which is different from the traditional manufacturers' perspective (Marques et al., 2013) (Rapaccini et al., 2013). In addition, the service processes are under-designed and ineffectively employed in the business context. Besides, the existing PSS design methodologies have limited industrial applications, and this is due to the ability to explain the design process and practical guidance to PSS designers (Tran and Park, 2014) (Trevisan and Brissaud 2016). Within the PSS design literature, most models or frameworks emphasize a specific phase of the design process. There is a need to combine PSS approaches into design activities, defining an organized procedure to guide designers throughout the various activities that characterize the whole PSS service development process. The PSS development models were available in the literature for the manufacturing, automobile industries, tourism, and service sectors. Service system design framework for an e-commerce business is scarce.

This study addresses the aforesaid research gap. The study provides a roadmap for application of strategic design management approach in design and development of PSS service design. The current research analyzed the PSS design and development models to feature activities and design methods. The service system framework for e-commerce businesses and organizations is outlined. The proposed framework of integrative perspective of design methods provides a structured approach for PSS designers and business organizers. This study provides systematic selection and integration of design methods for PSS service design process. Therefore, the proposed framework consists of a more detailed step-by-step guideline for PSS developers that cover all main stages of the design process. The proposed PSS service development process integrated various design methods for PSS service design from strategic design management perspective. The proposed service development process model includes three phases: (i) PSS requirements identification & analysis, (ii) PSS design & detailing and (iii) PSS test and implementation.

This research contributes to the literature of PSS as a new framework for PSS service design. The framework acts as a guideline for PSS designers in design and development of PSS service design process. The proposed framework will be very effective in PSS design for similar service sectors such as electrical maintenance, home appliances and carpentry etc. The design methods and processes presented in this thesis will benefit students and service design practitioners.

5.2.2 Design Contributions: Service and System Design for the Domestic Plumbing Sector in the Indian Context

The proposed service system design framework from PSS perspective reported in thesis was experimented and tested in the development of service and system design for the domestic plumbing in the Indian context.

The research contribution of this study has been successfully translated to design contribution in the form of e-commerce website for domestic plumbing sector in Indian context. The website www.fixplumbing.in has been developed following the structured proposed framework for PSS service design. The effectiveness of the design solution/design contribution was methodically validated. The validation result has been found satisfactory.

5.3 Limitations and Future Scope of Work

This study was conducted in India and considered only domestic plumbing as a case example. Therefore, the proposed service system design framework, developed e-commerce business model and strategies could have cultural and demographic influences. Moreover, PSS design consists of environmental aspects and these are not included in the current research. However, the research focuses on theory-building in developing a service process based upon PSS. It demonstrated the proposed framework for domestic plumbing. The maintenance and post-service operations of an e-commerce website for domestic plumbing were not covered in the research. In the user behavior study, the data related to plumbing service was limited to Guwahati city. Only 160 respondent's opinion were collected. In the benchmark study, the data presented of business model components were accessible to the general public and hence the actual data of organization business model components may vary and depends on dynamic market trends. The validation of the developed e-commerce website was limited to responses from customers and expert users. The other stakeholders, such as plumbers and retailers, were not included in the survey. The participants in the survey for validating the e-commerce website

was limited to thirty-six. Only seven expert users participated in the survey for validating the e-commerce business model and the website. A comparative study is not conducted between the developed e-commerce website and similar websites like UrbanCompany. In contrast with other similar websites, the developed e-commerce website is different from the following perspective.

1. It provides services in the niche area of plumbing service only. Therefore, the focus is only on the plumbing.
2. It integrates traditional and local plumbing retailers in the eco-system
3. It emphasizes on developing capabilities of the customers for resolving minor plumbing issues through DIY.
4. It is designed considering the user behavior and context of semi-urban, tier -II cities and towns.

Therefore, there is a scope of experimentation and validation of the developed e-commerce website in other semi-urban, tier-II cities and towns. The future research trajectories may include more case studies of home services to generalize the proposed service system design framework. As a first step, the proposed framework may be experimented and tested for PSS design in similar service sectors such as electrical maintenance, home appliances and carpentry etc. The future work may be extended to optimization of service operations management; in particular, from the perspective of after-sales service issues and maintenance.

Appendix 1

Questionnaire for the study of consumer behavior related to domestic plumbing services

Purpose: This survey will help my research work on a 'product-service system' regarding plumbing services in India's major cities. Your responses will be kept confidential and solely related to the academic concern. Please indicate your responses to the following statements by circling the options.

1. Over the last year, how many times have you called for the corrective maintenance?
   - Never called
   - 1 or 2 times
   - 3 or 4 times
   - More than 4 times

2. Over the last year, how many times have you called for the preventive maintenance?
   - Never called
   - 1 or 2 times
   - 3 or 4 times
   - More than 4 times

3. Over the last year, if you had a plumbing service, how long did it take to fix? (Dripping faucets, clogged drains, leaky pipes etc.,)
   - 0 to 3 hours
   - 4 to 8 hours
   - More than 24 hours
   - More than 2 days

4. Plumbing service representative was responsiveness with helping my issues
   - Strongly disagree
   - Disagree
   - Disagree somewhat
   - Neither agree nor disagree
   - Agree somewhat
   - Agree
   - Strongly agree

5. To fix issues with plumbing, mode of contact made with servicemen is
   - Walk-in
   - Recommendation
   - Telephone
   - Mobile-App
   - Other

6. Over the last year, which plumbing problem occurred most often? (Where, 1 = Never, & 7 = Most often)

	1	2	3	4	5	6	7
Dripping Faucets							
Low water pressure							
Running toilets							
Slow or clogged drains							
Leaky pipes							
Other 1							
Other 2							

7. What are the needs/expectations towards plumbing services? (Importance ratings: 1= Least, 5 = Most)

_____
_____
_____
_____
_____

Respondent's Information

Name:

Occupation:

Locality:

Gender:

- Male
- Female

Age Group

- 18-24
- 25-34
- 35-44
- 45-54
- 55-64

Residential Typology:

- Detached house
- Attached house
- Apartment blocks
- Residential building
- Other

Appendix 2

Chi-Square test and One-Way ANOVA test results

1. Chi-square test

- Number of times called for preventive maintenance * Resident typology Cross tabulation

			Resident typology				Total
			Detached house	Attached house	Apartment blocks	Residential buildings	
Number of times called for preventive maintenance	Never called	Count	52	29	22	7	110
		% within Number of times called for preventive maintenance	47.3%	26.4%	20.0%	6.4%	100.0%
		% within Resident typology	83.9%	74.4%	56.4%	35.0%	68.8%
		% of Total	32.5%	18.1%	13.8%	4.4%	68.8%
	1 or 2 times	Count	3	5	9	8	25
		% within Number of times called for preventive maintenance	12.0%	20.0%	36.0%	32.0%	100.0%
		% within Resident typology	4.8%	12.8%	23.1%	40.0%	15.6%
		% of Total	1.9%	3.1%	5.6%	5.0%	15.6%
	More than 3 times	Count	7	5	8	5	25
		% within Number of times called for preventive maintenance	28.0%	20.0%	32.0%	20.0%	100.0%
		% within Resident typology	11.3%	12.8%	20.5%	25.0%	15.6%
		% of Total	4.4%	3.1%	5.0%	3.1%	15.6%
Total		Count	62	39	39	20	160
		% within Number of times called for preventive maintenance	38.8%	24.4%	24.4%	12.5%	100.0%
		% within Resident typology	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	38.8%	24.4%	24.4%	12.5%	100.0%

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	22.885	6	.001
Likelihood Ratio	22.644	6	.001
Linear-by-Linear Association	12.822	1	.000
N of Valid Cases	160		

- Servicemen responding to customer plumbing issues * Resident typology Cross tabulation

			Resident typology				Total
			Detached house	Attached house	Apartment blocks	Residential buildings	
Servicemen responding to customer plumbing issues	Disagree	Count	7	12	9	4	32
		% within Servicemen responding to customer plumbing issues	21.9%	37.5%	28.1%	12.5%	100.0%
		% within Resident typology	11.3%	30.8%	23.1%	20.0%	20.0%
		% of Total	4.4%	7.5%	5.6%	2.5%	20.0%
	Disagree somewhat	Count	4	8	6	5	23
		% within Servicemen responding to customer plumbing issues	17.4%	34.8%	26.1%	21.7%	100.0%
		% within Resident typology	6.5%	20.5%	15.4%	25.0%	14.4%
		% of Total	2.5%	5.0%	3.8%	3.1%	14.4%
	Neither agree nor disagree	Count	10	5	9	7	31
		% within Servicemen responding to customer plumbing issues	32.3%	16.1%	29.0%	22.6%	100.0%
		% within Resident typology	16.1%	12.8%	23.1%	35.0%	19.4%
		% of Total	6.2%	3.1%	5.6%	4.4%	19.4%
	Agree somewhat	Count	21	8	9	2	40
		% within Servicemen responding to customer plumbing issues	52.5%	20.0%	22.5%	5.0%	100.0%
		% within Resident typology	33.9%	20.5%	23.1%	10.0%	25.0%
		% of Total	13.1%	5.0%	5.6%	1.2%	25.0%
	Agree	Count	20	6	6	2	34
		% within Servicemen responding to customer plumbing issues	58.8%	17.6%	17.6%	5.9%	100.0%
		% within Resident typology	32.3%	15.4%	15.4%	10.0%	21.2%
		% of Total	12.5%	3.8%	3.8%	1.2%	21.2%
Total		Count	62	39	39	20	160
		% within Servicemen responding to customer plumbing issues	38.8%	24.4%	24.4%	12.5%	100.0%
		% within Resident typology	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	38.8%	24.4%	24.4%	12.5%	100.0%

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.237	12	.019
Likelihood Ratio	24.581	12	.017
Linear-by-Linear Association	10.598	1	.001
N of Valid Cases	160		

- Time taken to fix plumbing issues * Customer occupation Cross tabulation

			Customer occupation				Total
			Housewife	Self employed	Business	Retired	
Time taken to fix plumbing issues	0 to 3 Hours	Count	6	14	11	6	37
		% within Time taken to fix plumbing issues	16.2%	37.8%	29.7%	16.2%	100.0%
		% within Customer occupation	20.0%	25.0%	18.0%	46.2%	23.1%
		% of Total	3.8%	8.8%	6.9%	3.8%	23.1%
	4 to 8 Hours	Count	11	13	25	3	52
		% within Time taken to fix plumbing issues	21.2%	25.0%	48.1%	5.8%	100.0%
		% within Customer occupation	36.7%	23.2%	41.0%	23.1%	32.5%
		% of Total	6.9%	8.1%	15.6%	1.9%	32.5%
	More than 24 Hours	Count	13	19	16	1	49
		% within Time taken to fix plumbing issues	26.5%	38.8%	32.7%	2.0%	100.0%
		% within Customer occupation	43.3%	33.9%	26.2%	7.7%	30.6%
		% of Total	8.1%	11.9%	10.0%	0.6%	30.6%
	More than 2 days	Count	0	10	9	3	22
		% within Time taken to fix plumbing issues	0.0%	45.5%	40.9%	13.6%	100.0%
		% within Customer occupation	0.0%	17.9%	14.8%	23.1%	13.8%
		% of Total	0.0%	6.2%	5.6%	1.9%	13.8%
Total		Count	30	56	61	13	160
		% within Time taken to fix plumbing issues	18.8%	35.0%	38.1%	8.1%	100.0%
		% within Customer occupation	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	18.8%	35.0%	38.1%	8.1%	100.0%

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	17.307	9	.044
Likelihood Ratio	21.509	9	.011
Linear-by-Linear Association	.032	1	.858
N of Valid Cases	160		

- Time taken to fix plumbing issues * Customer age group Cross tabulation

			Customer age group				Total
			25 - 34	35 - 44	45 - 54	55 - 64	
Time taken to fix plumbing issues	0 to 3 Hours	Count	8	13	8	8	37
		% within Time taken to fix plumbing issues	21.6%	35.1%	21.6%	21.6%	100.0%
		% within Customer age group	27.6%	19.4%	16.7%	50.0%	23.1%
		% of Total	5.0%	8.1%	5.0%	5.0%	23.1%
	4 to 8 Hours	Count	7	22	19	4	52
		% within Time taken to fix plumbing issues	13.5%	42.3%	36.5%	7.7%	100.0%
		% within Customer age group	24.1%	32.8%	39.6%	25.0%	32.5%
		% of Total	4.4%	13.8%	11.9%	2.5%	32.5%
	More than 24 Hours	Count	8	29	9	3	49
		% within Time taken to fix plumbing issues	16.3%	59.2%	18.4%	6.1%	100.0%
		% within Customer age group	27.6%	43.3%	18.8%	18.8%	30.6%
		% of Total	5.0%	18.1%	5.6%	1.9%	30.6%
	More than 2 days	Count	6	3	12	1	22
		% within Time taken to fix plumbing issues	27.3%	13.6%	54.5%	4.5%	100.0%
		% within Customer age group	20.7%	4.5%	25.0%	6.2%	13.8%
		% of Total	3.8%	1.9%	7.5%	0.6%	13.8%
Total		Count	29	67	48	16	160
		% within Time taken to fix plumbing issues	18.1%	41.9%	30.0%	10.0%	100.0%
		% within Customer age group	100.0%	100.0%	100.0%	100.0%	100.0%
		% of Total	18.1%	41.9%	30.0%	10.0%	100.0%

Chi-Square Tests			
	Value	df	Asymp. Sig. (2-sided)
Pearson Chi-Square	24.976	9	.003
Likelihood Ratio	24.600	9	.003
Linear-by-Linear Association	.972	1	.324
N of Valid Cases	160		

2. One-Way ANOVA test results

- Frequency of dripping faucets issue vs occupation

An analysis of variance showed that the effect of occupation on dripping faucet issue was significant, F (3,156) = 4.375, p = 0.005

Descriptives								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Housewife	30	4.57	1.223	.223	4.11	5.02	1	7
Self employed	56	4.20	1.762	.236	3.72	4.67	1	7
Business	61	4.18	1.555	.199	3.78	4.58	1	7
Retired	13	2.69	1.653	.458	1.69	3.69	1	6
Total	160	4.14	1.635	.129	3.88	4.39	1	7

ANOVA					
Frequency of dripping faucets issue					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	32.983	3	10.994	4.375	.005
Within Groups	391.992	156	2.513		
Total	424.975	159			

Post Hoc Test

Multiple Comparisons						
Dependent Variable: Frequency of dripping faucets issue Tukey HSD						
(I) Customer occupation	(J) Customer occupation	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Housewife	Self employed	.370	.359	.731	-.56	1.30
	Business	.386	.353	.694	-.53	1.30
	Retired	1.874*	.526	.003	.51	3.24
Self employed	Housewife	-.370	.359	.731	-1.30	.56
	Business	.016	.293	1.000	-.75	.78
	Retired	1.504*	.488	.013	.24	2.77
Business	Housewife	-.386	.353	.694	-1.30	.53
	Self employed	-.016	.293	1.000	-.78	.75
	Retired	1.488*	.484	.013	.23	2.75
Retired	Housewife	-1.874*	.526	.003	-3.24	-.51
	Self employed	-1.504*	.488	.013	-2.77	-.24
	Business	-1.488*	.484	.013	-2.75	-.23

- Frequency of dripping faucets issue vs residential typology

An analysis of variance showed that the effect of resident typology on dripping faucet issue was significant, F (3,156) = 2.859, p = 0.039

Descriptives								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Detached house	62	3.76	1.771	.225	3.31	4.21	1	7
Attached house	39	4.13	1.576	.252	3.62	4.64	1	7
Apartment blocks	39	4.72	1.413	.226	4.26	5.18	1	7
Residential buildings	20	4.20	1.473	.329	3.51	4.89	1	6
Total	160	4.14	1.635	.129	3.88	4.39	1	7

ANOVA					
Frequency of dripping faucets issue					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	22.148	3	7.383	2.859	.039
Within Groups	402.827	156	2.582		
Total	424.975	159			

Post Hoc Test

Multiple Comparisons						
Dependent Variable: Frequency of dripping faucets issue Tukey HSD						
(I) Resident typology	(J) Resident typology	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Detached house	Attached house	-.370	.328	.673	-1.22	.48
	Apartment blocks	-.960*	.328	.021	-1.81	-.11
	Residential buildings	-.442	.413	.709	-1.52	.63
Attached house	Detached house	.370	.328	.673	-.48	1.22
	Apartment blocks	-.590	.364	.370	-1.53	.36
	Residential buildings	-.072	.442	.998	-1.22	1.08
Apartment blocks	Detached house	.960*	.328	.021	.11	1.81
	Attached house	.590	.364	.370	-.36	1.53
	Residential buildings	.518	.442	.645	-.63	1.67
Residential buildings	Detached house	.442	.413	.709	-.63	1.52
	Attached house	.072	.442	.998	-1.08	1.22
	Apartment blocks	-.518	.442	.645	-1.67	.63
*. The mean difference is significant at the 0.05 level.						

- Frequency of running toilets vs locality

An analysis of variance showed that the effect of locality on running toilet issue was significant, F (2,157) = 3.402, p = 0.036

Descriptives								
	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Very old	56	2.82	1.585	.212	2.40	3.25	1	6
Old	30	3.17	1.704	.311	2.53	3.80	1	6
New	74	3.62	1.870	.217	3.19	4.05	1	7
Total	160	3.26	1.771	.140	2.98	3.53	1	7

ANOVA					
Frequency of running toilets					
	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	20.707	2	10.354	3.402	.036
Within Groups	477.786	157	3.043		
Total	498.494	159			

Post Hoc Test

Multiple Comparisons						
Dependent Variable: Frequency of running toilets Tukey HSD						
(I) Customer residence area	(J) Customer residence area	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Very old	Old	-.345	.395	.657	-1.28	.59
	New	-.800*	.309	.028	-1.53	-.07
Old	very old	.345	.395	.657	-.59	1.28
	New	-.455	.378	.452	-1.35	.44
New	very old	.800*	.309	.028	.07	1.53
	Old	.455	.378	.452	-.44	1.35
*. The mean difference is significant at the 0.05 level.						

- Frequency of leaky pipes vs residential typology

An analysis of variance showed that the effect of resident typology on leaky pipes issue was significant, F (3,156) = 4.160, p = 0.004

Descriptives

Frequency of leaky pipes issue

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
Detached house	62	2.47	1.808	.230	2.01	2.93	1	6
Attached house	39	2.64	1.842	.295	2.04	3.24	1	6
Apartment blocks	39	2.90	1.714	.274	2.34	3.45	1	7
Residential buildings	20	4.15	1.814	.406	3.30	5.00	1	7
Total	160	2.83	1.855	.147	2.54	3.11	1	7

ANOVA

Frequency of leaky pipes issue

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	44.550	3	14.850	4.610	.004
Within Groups	502.550	156	3.221		
Total	547.100	159			

Post Hoc Test

Multiple Comparisons

Dependent Variable: Frequency of leaky pipes issue
Tukey HSD

(I) Resident typology	(J) Resident typology	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Detached house	Attached house	-.173	.367	.965	-1.13	.78
	Apartment blocks	-.430	.367	.646	-1.38	.52
	Residential buildings	-1.682*	.462	.002	-2.88	-.48
Attached house	Detached house	.173	.367	.965	-.78	1.13
	Apartment blocks	-.256	.406	.922	-1.31	.80
	Residential buildings	-1.509*	.494	.014	-2.79	-.23
Apartment blocks	Detached house	.430	.367	.646	-.52	1.38
	Attached house	.256	.406	.922	-.80	1.31
	Residential buildings	-1.253	.494	.058	-2.53	.03
Residential buildings	Detached house	1.682*	.462	.002	.48	2.88
	Attached house	1.509*	.494	.014	.23	2.79
	Apartment blocks	1.253	.494	.058	-.03	2.53

*. The mean difference is significant at the 0.05 level.

Appendix 3

Questionnaire for experts on design requirements for domestic plumbing services

Purpose: The purpose of this questionnaire to collect data on the importance scale for the pairwise comparison. The pairwise comparison is of design requirements for domestic plumbing services. The collected data would help prioritize design requirements for consideration in the early phases of PSS design. This survey will help my research work on 'product-service system' regarding plumbing services in India's major cities. Your responses will be kept confidential and solely related to the academic concern. Please indicate your responses to the following statements by circling the options.

Example 1: If criteria 'A' is more important than criteria 'B' and if importance scale is 5 then,

	Criteria	***Importance Scale***	***Criteria***
i.	A	9 8 7 6 ⑤ 4 3 2 1 2 3 4 5 6 7 8 9	B

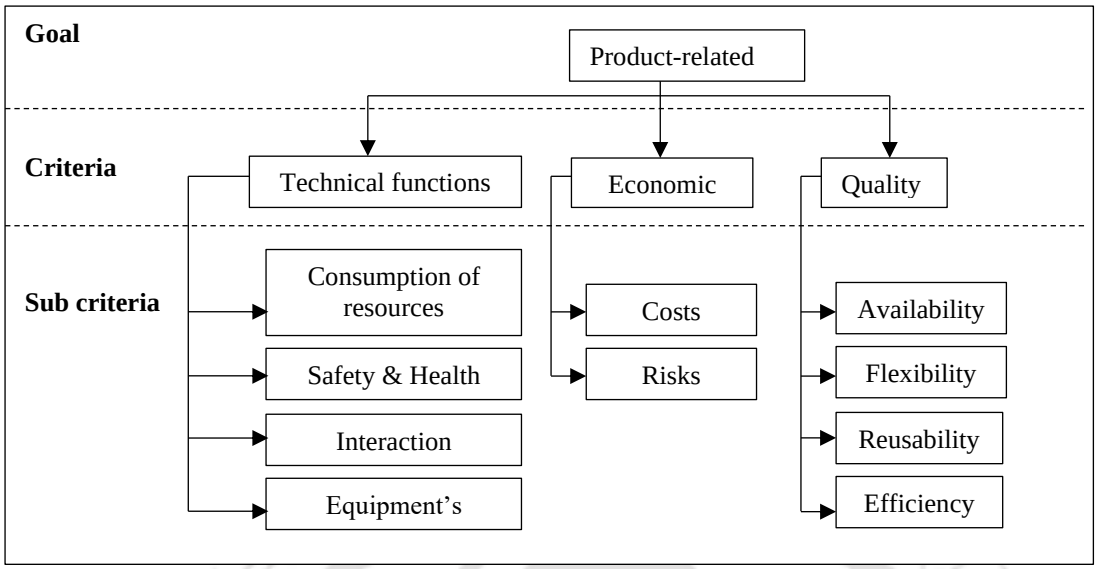
Example 2: If criteria 'D' is more important than criteria 'C' and if importance scale is 7 then,

	Criteria	***Importance Scale***	***Criteria***
i.	C	9 8 7 6 5 4 3 2 1 2 3 4 5 6 ⑦ 8 9	D

Table: Rating scale and Explanations

Importance Scale	**Definition of Importance Scale**
1	Equally Important Preferred
3	Moderately Important Preferred
5	Strongly Important Preferred
7	Very Strongly Important Preferred
9	Extremely Important Preferred
2,4,6,8	Intermediate value between two judgements

Questionnaire



1.) How important are the **product-related** criteria in comparison?

	Criteria	***Importance Scale***																	***Criteria***
i.	Technical functions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Economic
ii.	Technical functions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality
iii.	Economic	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Quality

2.) How important are the **Technical function** sub-criteria in comparison?

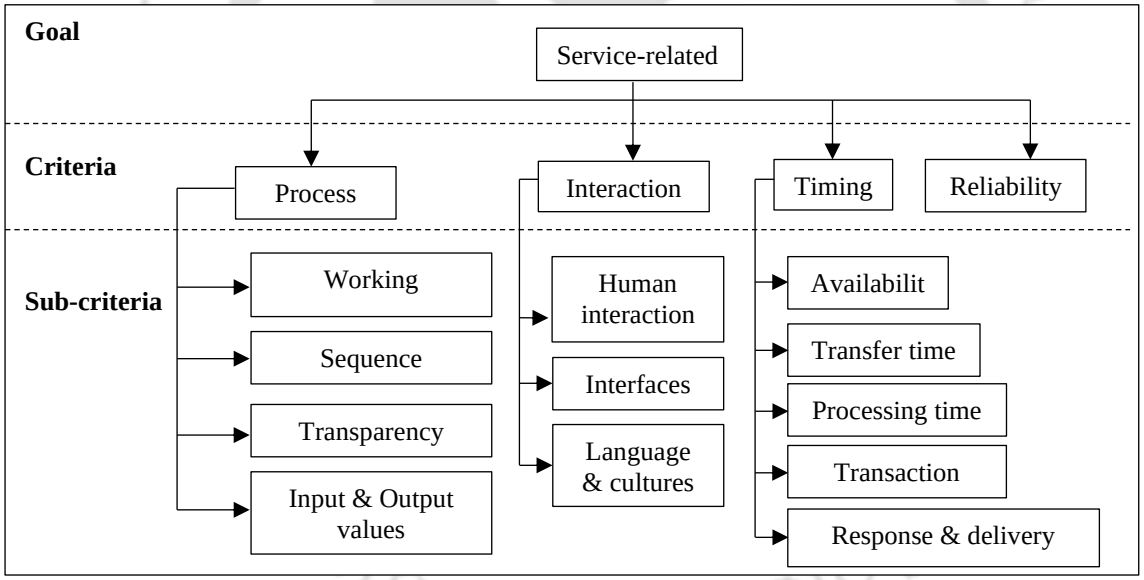
	Sub-criteria	***Importance Scale***																	***Sub-criteria***
i	Consumption of resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Safety & Health
ii	Consumption of resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Interaction
iii	Consumption of resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Equipment's
iv	Safety & Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Interaction
v	Safety & Health	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Equipment's
vi	Interaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Equipment's

3.) How important are the **Economic** sub-criteria in comparison?

	Sub-criteria	**Importance Scale**																**Sub-criteria**
i.	Costs	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Risks

4.) How important are the **Quality** sub-criteria in comparison?

	Sub-criteria	***Importance Scale***																***Sub-criteria***
i.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Flexibility
ii.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reusability
iii.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Efficiency
iv.	Flexibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reusability
v.	Flexibility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Efficiency
vi.	Reusability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Efficiency



5.) How important are the **service related** criteria in comparison?

	Criteria	***Importance Scale***																***Criteria***
i.	Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Interaction
ii.	Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Timing
iii.	Process	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability
iv.	Interaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Timing
v.	Interaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability
vi.	Timing	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Reliability

6.) How important are the **Process** sub-criteria in comparison?

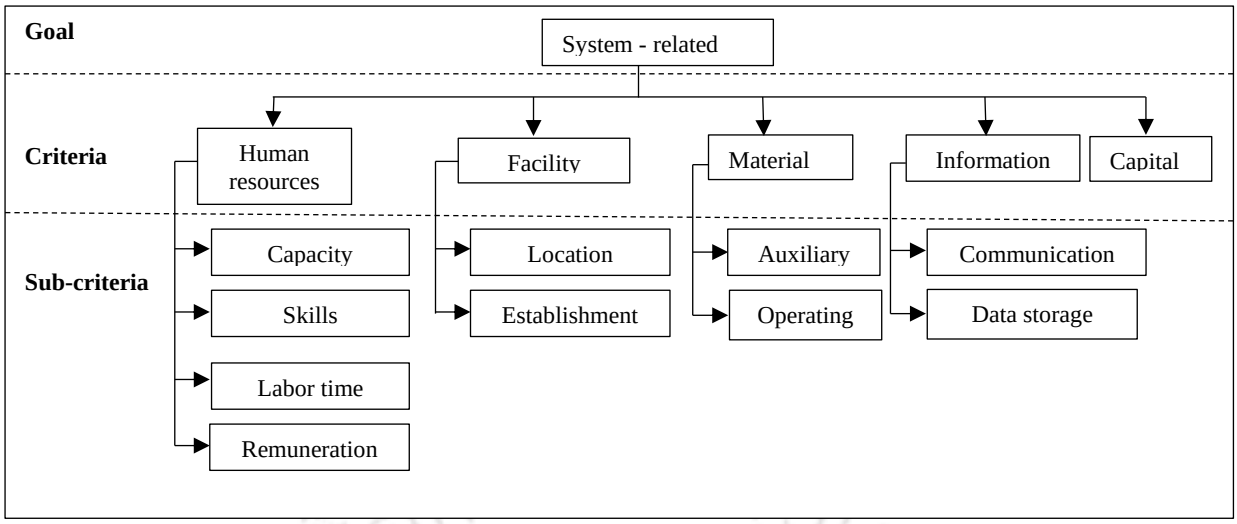
	Sub-criteria	*Importance Scale*																	*Sub-criteria*
i	Working conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Sequence
ii	Working conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transparency
iii	Working conditions	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Input & output values
iv	Sequence	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transparency
v	Sequence	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Input & output values
vi	Transparency	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Input & output values

7.) How important are the **Interaction** sub-criteria in comparison?

	Sub-criteria	*Importance Scale*																	*Sub-criteria*
i.	Human interaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Interfaces
ii.	Human interaction	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Language & culture
iii.	Interfaces	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Language & culture

8.) How important are the **Timing** sub-criteria in comparison?

	Sub-criteria	*Importance Scale*																	*Sub-criteria*
i.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transfer time
ii.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Processing time
iii.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transaction time
iv.	Availability	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Response & delivery
v.	Transfer time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Processing time
vi.	Transfer time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transaction time
vii.	Transfer time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Response & delivery
viii.	Processing time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Transaction time
ix.	Processing time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Response & delivery
x.	Transaction time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Response & delivery



9.) How important are the **system-related** criteria in comparison?

	Criteria	*Importance Scale*																	*Criteria*
i.	Human resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Facility
ii.	Human resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Material
iii.	Human resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Information
iv.	Human resources	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capital
v.	Facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Material
vi.	Facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Information
vii.	Facility	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capital
viii.	Material	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Information
ix.	Material	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capital
x.	Information	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Capital

10.) How important are the **Human resources** sub-criteria in comparison?

	Sub-criteria	*Importance Scale*																	*Sub-criteria*
i.	Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Skills
ii.	Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Labor time
iii.	Capacity	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Remuneration
iv.	Skills	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Labor time
v.	Skills	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Remuneration
vi.	Labor time	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Remuneration

11.) How important are the **Facilities** sub-criteria in comparison?

Sub-criteria	*Importance Scale*	*Sub-criteria*
i. Location	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Establishments

12.) How important are the **Material** sub-criteria in comparison?

Sub-criteria	*Importance Scale*	*Sub-criteria*
i. Auxiliary	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Operating

13.) How important are the **Information** sub-criteria in comparison?

Sub-criteria	*Importance Scale*	*Sub-criteria*
i. Communication	9 8 7 6 5 4 3 2 1 2 3 4 5 6 7 8 9	Data storage

EXPERT'S DETAIL

Name	
Designation	
Experience	
Place	

Appendix 4

Expert's based decision matrixes pairwise comparison of design requirements for domestic plumbing services

First level hierarchical structure of **product-related** design requirements viz., technical functions, economic and quality.

$$A^1=\begin{bmatrix}1 & 5 & 1/3\\ 1/5 & 1 & 1/7\\ 3 & 7 & 1\end{bmatrix}$$
$\lambda = 3.066, CR = .063 < 0.1$

$$A^2=\begin{bmatrix}1 & 2 & 1\\ 1/2 & 1 & 1/2\\ 1 & 2 & 1\end{bmatrix}$$
$\lambda = 3., CR = .00 < 0.1$

$$A^3=\begin{bmatrix}1 & 1 & 1/7\\ 1 & 1 & 1/3\\ 7 & 3 & 1\end{bmatrix}$$
$\lambda = 3.082, CR = .078 < 0.1$

$$A^4=\begin{bmatrix}1 & 1 & 1/5\\ 1 & 1 & 1/6\\ 5 & 6 & 1\end{bmatrix}$$
$\lambda = 3.004, CR = .004 < 0.1$

$$A^5=\begin{bmatrix}1 & 4 & 1/3\\ 1/4 & 1 & 1/6\\ 3 & 6 & 1\end{bmatrix}$$
$\lambda = 3.054, CR = .052 < 0.1$

Second level hierarchical structure of **product-related technical functions** design requirements viz., consumption of resources, safety and health, interactions, and equipment's.

$$A^1=\begin{bmatrix}1 & 1/3 & 3 & 7\\ 3 & 1 & 7 & 9\\ 1/3 & 1/7 & 1 & 5\\ 1/7 & 1/9 & 1/5 & 1\end{bmatrix}$$
$\lambda = 4.213, CR = .079 < 0.1$

$$A^2=\begin{bmatrix}1 & 3 & 2 & 2\\ 1/3 & 1 & 2 & 2\\ 1/2 & 1/2 & 1 & 2\\ 1/2 & 1/2 & 1/2 & 1\end{bmatrix}$$
$\lambda = 4.216, CR = .080 < 0.1$

$$A^3=\begin{bmatrix}1 & 1 & 7 & 3\\ 1 & 1 & 8 & 2\\ 1/7 & 1/8 & 1 & 1\\ 1/3 & 1/2 & 1 & 1\end{bmatrix}$$
$\lambda = 4.187, CR = .070 < 0.1$

$$A^4=\begin{bmatrix}1 & 6 & 2 & 5\\ 6 & 1 & 5 & 7\\ 1/2 & 1/5 & 1 & 2\\ 1/5 & 1/7 & 1/2 & 1\end{bmatrix}$$
$\lambda = 4.202, CR = .075 < 0.1$

$$A^5=\begin{bmatrix}1 & 6 & 2 & 5\\ 6 & 1 & 5 & 7\\ 1/2 & 1/5 & 1 & 2\\ 1/5 & 1/7 & 1/2 & 1\end{bmatrix}$$
$\lambda = 4.202, CR = .075 < 0.1$

Second level hierarchical structure of **product-related economic** design requirements viz., cost and risks

$$A^1=\begin{bmatrix}1 & 7\\ 1/7 & 1\end{bmatrix}$$
$\lambda = 2, CR = .00 < 0.1$

$$A^2=\begin{bmatrix}1 & 1/2\\ 2 & 1\end{bmatrix}$$
$\lambda = 2, CR = .00 < 0.1$

$$A^3=\begin{bmatrix}1 & 7\\ 1/7 & 1\end{bmatrix}$$
$\lambda = 2, CR = .00 < 0.1$

$$A^4=\begin{bmatrix}1 & 1/7\\ 7 & 1\end{bmatrix}$$
$\lambda = 2, CR = .00 < 0.1$

$$A^5=\begin{bmatrix}1 & 1/7\\ 7 & 1\end{bmatrix}$$
$\lambda = 2, CR = .00 < 0.1$

Second level hierarchical structure of **product-related quality** design requirements viz., availability, flexibility, reusability and efficiency.

$$A^1=\begin{bmatrix}1 & 1 & 1/5 & 1/4\\ 1 & 1 & 1/5 & 1/5\\ 5 & 5 & 1 & 1/3\\ 4 & 5 & 3 & 1\end{bmatrix} \quad \lambda=4.193, CR=.072<0.1$$

$$A^2=\begin{bmatrix}1 & 1/2 & 5 & 1\\ 2 & 1 & 3 & 1/2\\ 1/5 & 1/3 & 1 & 1/5\\ 1 & 2 & 5 & 1\end{bmatrix} \quad \lambda=4.220, CR=.082<0.1$$

$$A^3=\begin{bmatrix}1 & 5 & 2 & 1/2\\ 1/5 & 1 & 1/4 & 1/3\\ 1/2 & 4 & 1 & 1\\ 2 & 3 & 1 & 1\end{bmatrix} \quad \lambda=4.235, CR=.088<0.1$$

$$A^4=\begin{bmatrix}1 & 1/8 & 1/8 & 1/3\\ 8 & 1 & 5 & 7\\ 8 & 1 & 1 & 1\\ 3 & 1 & 1 & 1\end{bmatrix} \quad \lambda=4.125, CR=.046<0.1$$

$$A^5=\begin{bmatrix}1 & 1/8 & 1/8 & 1/3\\ 8 & 1 & 5 & 7\\ 8 & 1 & 1 & 1\\ 3 & 1 & 1 & 1\end{bmatrix} \quad \lambda=4.125, CR=.046<0.1$$

First level hierarchical structure of **service-related** design requirements viz., process, interaction, timing, reliability.

$$A^1=\begin{bmatrix}1 & 1/3 & 1/2 & 1/3\\ 3 & 1 & 1 & 1/4\\ 2 & 1 & 1 & 1/5\\ 3 & 4 & 5 & 1\end{bmatrix} \quad \lambda=4.23, CR=.087<0.1$$

$$A^2=\begin{bmatrix}1 & 1/3 & 1/5 & 1/5\\ 3 & 1 & 1 & 1/2\\ 5 & 1 & 1 & 2\\ 5 & 2 & 1/2 & 1\end{bmatrix} \quad \lambda=4.173, CR=.064<0.1$$

$$A^3=\begin{bmatrix}1 & 1/5 & 1/9 & 1/7\\ 5 & 1 & 1/7 & 1/5\\ 9 & 7 & 1 & 1\\ 7 & 5 & 1 & 1\end{bmatrix} \quad \lambda=4.249, CR=.093<0.1$$

$$A^4=\begin{bmatrix}1 & 1/4 & 1/7 & 1/5\\ 4 & 1 & 1/3 & 1/4\\ 7 & 3 & 1 & 1\\ 5 & 4 & 1 & 1\end{bmatrix} \quad \lambda=4.119, CR=.044<0.1$$

$$A^5=\begin{bmatrix}1 & 1/4 & 1/7 & 1/5\\ 4 & 1 & 1/3 & 1/4\\ 7 & 3 & 1 & 1\\ 5 & 4 & 1 & 1\end{bmatrix} \quad \lambda=4.119, CR=.044<0.1$$

Second level hierarchical structure of **service-related process** design requirements viz., working conditions, sequence, transparency, input and output values.

$$A^1=\begin{bmatrix}1 & 2 & 1/2 & 1/5\\ 1/2 & 1 & 1 & 1/3\\ 2 & 1 & 1 & 1/3\\ 5 & 3 & 3 & 1\end{bmatrix} \quad \lambda=4.226, CR=.084<0.1$$

$$A^2=\begin{bmatrix}1 & 1/3 & 1/3 & 1/2\\ 3 & 1 & 1 & 1/3\\ 3 & 1 & 1 & 1/2\\ 2 & 3 & 2 & 1\end{bmatrix} \quad \lambda=4.237, CR=.088<0.1$$

$$A^3=\begin{bmatrix}1 & 1/3 & 1 & 2\\ 3 & 1 & 5 & 7\\ 1 & 1/5 & 1 & 1/2\\ 1/2 & 1/7 & 2 & 1\end{bmatrix} \quad \lambda=4.216, CR=.080<0.1$$

$$A^4=\begin{bmatrix}1 & 1/3 & 1 & 1/3\\ 3 & 1 & 2 & 1/3\\ 1 & 1/2 & 1 & 1/5\\ 3 & 3 & 5 & 1\end{bmatrix} \quad \lambda=4.107, CR=.040<0.1$$

$$A^5=\begin{bmatrix}1 & 1/3 & 1 & 1/3\\ 3 & 1 & 2 & 1/3\\ 1 & 1/2 & 1 & 1/5\\ 3 & 3 & 5 & 1\end{bmatrix} \quad \lambda=4.107, CR=.040<0.1$$

Second level hierarchical structure of **service-related interaction** design requirements viz., human interactions, interfaces, language and culture.

$$A^1=\begin{bmatrix}1 & 6 & 1\\ 1/6 & 1 & 1/5\\ 1 & 5 & 1\end{bmatrix} \quad \lambda = 3.0046, CR = .036 < 0.1$$

$$A^2=\begin{bmatrix}1 & 1/3 & 3\\ 3 & 1 & 5\\ 1/3 & 1/5 & 1\end{bmatrix} \quad \lambda = 3.039, CR = .037 < 0.1$$

$$A^3=\begin{bmatrix}1 & 7 & 3\\ 1/7 & 1 & 1\\ 1/3 & 1 & 1\end{bmatrix} \quad \lambda = 3.082, CR = .078 < 0.1$$

$$A^4=\begin{bmatrix}1 & 5 & 1\\ 1/5 & 1 & 1/3\\ 1 & 3 & 1\end{bmatrix} \quad \lambda = 3.029, CR = .028 < 0.1$$

$$A^5=\begin{bmatrix}1 & 5 & 1\\ 1/5 & 1 & 1/3\\ 1 & 3 & 1\end{bmatrix} \quad \lambda = 3.029, CR = .028 < 0.1$$

Second level hierarchical structure of **service-related timing** design requirements viz., availability, transfer time, processing time, transaction time, response and delivery.

$$A^1=\begin{bmatrix}1 & 3 & 1 & 7 & 4\\ 1/3 & 1 & 1/3 & 3 & 1\\ 1 & 3 & 1 & 1 & 1\\ 1/7 & 1/3 & 1/4 & 1 & 1/5\\ 1/4 & 1 & 1 & 5 & 1\end{bmatrix} \quad \lambda = 5.234, CR = .052 < 0.1$$

$$A^2=\begin{bmatrix}1 & 1/5 & 3 & 1 & 1\\ 5 & 1 & 1/3 & 1/4 & 1/4\\ 3 & 3 & 1 & 3 & 3\\ 1 & 4 & 1/3 & 1 & 2\\ 1 & 4 & 1/3 & 1/2 & 1\end{bmatrix} \quad \lambda = 5.341, CR = .076 < 0.1$$

$$A^3=\begin{bmatrix}1 & 7 & 3 & 1 & 3\\ 1/7 & 1 & 1/5 & 1/7 & 1/7\\ 1/3 & 5 & 1 & 1/7 & 1/7\\ 1 & 7 & 7 & 1 & 1\\ 3 & 7 & 7 & 1 & 1\end{bmatrix} \quad \lambda = 5.383, CR = .086 < 0.1$$

$$A^4=\begin{bmatrix}1 & 5 & 2 & 1 & 1/3\\ 1/5 & 1 & 1/3 & 1/3 & 1/4\\ 1/2 & 3 & 1 & 2 & 3\\ 1 & 3 & 1/2 & 1 & 1/5\\ 3 & 4 & 3 & 5 & 1\end{bmatrix} \quad \lambda = 5.314, CR = .070 < 0.1$$

$$A^5=\begin{bmatrix}1 & 5 & 2 & 1 & 1/3\\ 1/5 & 1 & 1/3 & 1/3 & 1/4\\ 1/2 & 3 & 1 & 2 & 3\\ 1 & 3 & 1/2 & 1 & 1/5\\ 3 & 4 & 3 & 5 & 1\end{bmatrix} \quad \lambda = 5.314, CR = .070 < 0.1$$

First level hierarchical structure of **system-related** design requirements viz., human resources, facility, material, information and capital.

$$A^1=\begin{bmatrix}1 & 5 & 3 & 2 & 1\\ 1/5 & 1 & 1 & 1/5 & 1/3\\ 1/3 & 1 & 1 & 1/3 & 1\\ 1/2 & 5 & 3 & 1 & 2\\ 1 & 3 & 1 & 1/2 & 1\end{bmatrix} \quad \lambda = 5.258, CR = .058 < 0.1$$

$$A^2=\begin{bmatrix}1 & 1/5 & 1/3 & 1/5 & 1/3\\ 5 & 1 & 1/3 & 1/4 & 1/4\\ 3 & 1/2 & 1 & 1/2 & 1/3\\ 5 & 1/2 & 2 & 1 & 1/3\\ 3 & 1 & 3 & 3 & 1\end{bmatrix} \quad \lambda = 5.245, CR = .055 < 0.1$$

$$A^3=\begin{bmatrix}1 & 3 & 1 & 1 & 2\\ 1/3 & 1 & 1 & 2 & 1\\ 1 & 1 & 1 & 1 & 1\\ 1 & 1/2 & 1 & 1 & 1\\ 2 & 1 & 1 & 1 & 1\end{bmatrix} \quad \lambda = 5.412, CR = .092 < 0.1$$

$$A^4=\begin{bmatrix}1 & 1/5 & 1/2 & 1/3 & 1/2\\ 5 & 1 & 3 & 2 & 1\\ 2 & 1/3 & 1 & 1/5 & 1/3\\ 3 & 1/2 & 5 & 1 & 3\\ 2 & 1 & 3 & 1/3 & 1\end{bmatrix} \quad \lambda = 5.373, CR = .083 < 0.1$$

$$A^5=\begin{bmatrix}1 & 1/5 & 1/2 & 1/3 & 1/2\\ 5 & 1 & 3 & 2 & 1\\ 2 & 1/3 & 1 & 1/5 & 1/3\\ 3 & 1/2 & 5 & 1 & 3\\ 2 & 1 & 3 & 1/3 & 1\end{bmatrix} \quad \lambda = 5.373, CR = .083 < 0.1$$

Second level hierarchical structure of **system-related human resources** design requirements viz., capacity, skills, labor time, remuneration.

$$A^1=\begin{bmatrix}1 & 1/9 & 1/3 & 1/3\\ 9 & 1 & 1/9 & 1/9\\ 3 & 9 & 1 & 2\\ 3 & 9 & 1/2 & 1\end{bmatrix}\quad \lambda=4.223, CR=.083<0.1$$

$$A^2=\begin{bmatrix}1 & 1/7 & 1/4 & 1/2\\ 7 & 1 & 2 & 1/3\\ 4 & 1/2 & 1 & 1/2\\ 2 & 1 & 2 & 1\end{bmatrix}\quad \lambda=4.233, CR=.087<0.1$$

$$A^3=\begin{bmatrix}1 & 1/4 & 1 & 1\\ 4 & 1 & 5 & 1\\ 1 & 1/5 & 1 & 1/3\\ 1 & 1 & 3 & 1\end{bmatrix}\quad \lambda=4.224, CR=.083<0.1$$

$$A^4=\begin{bmatrix}1 & 1/8 & 1/5 & 1/3\\ 8 & 1 & 3 & 3\\ 5 & 1/3 & 1 & 1\\ 3 & 1/3 & 1 & 1\end{bmatrix}\quad \lambda=4.0427, CR=.012<0.1$$

$$A^5=\begin{bmatrix}1 & 1/8 & 1/5 & 1/3\\ 8 & 1 & 3 & 3\\ 5 & 1/3 & 1 & 1\\ 3 & 1/3 & 1 & 1\end{bmatrix}\quad \lambda=4.0427, CR=.012<0.1$$

The second level hierarchical structure of **system-related facility** design requirements is viz., location and establishments.

$$A^1=\begin{bmatrix}1 & 1/3\\ 3 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^2=\begin{bmatrix}1 & 3\\ 1/3 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^3=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^4=\begin{bmatrix}1 & 5\\ 1/5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^5=\begin{bmatrix}1 & 5\\ 1/5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

The second level hierarchical structure of **system-related material** design requirements viz., auxiliary and operating material.

$$A^1=\begin{bmatrix}1 & 1/5\\ 5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^2=\begin{bmatrix}1 & 1/3\\ 3 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^3=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^4=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^5=\begin{bmatrix}1 & 1\\ 1 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

The second level hierarchical structure of **system-related information** design requirements is viz., communication and data storage.

$$A^1=\begin{bmatrix}1 & 3\\ 1/3 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^2=\begin{bmatrix}1 & 5\\ 1/5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^3=\begin{bmatrix}1 & 1/5\\ 5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^4=\begin{bmatrix}1 & 5\\ 1/5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

$$A^5=\begin{bmatrix}1 & 5\\ 1/5 & 1\end{bmatrix}\quad \lambda=2, CR=.00<0.1$$

Appendix 5

Part A: Website survey questionnaire for customers

Hello, I Sachin, a research scholar from IIT-Guwahati, where I work on a 'Product-Service System' design. Through this brief survey could help me to enhance the user understanding and implementation of the website. Your honest responses to this survey would be valuable to my research contributions. Your responses will be kept confidential and solely related to academic concerns. This survey should take no longer than 15 minutes.

To begin, please click on the below link to view the website demonstration.

https://drive.google.com/file/d/1FBrF6bY3HxK6fm0RPHI-cLtflByfrc_a/view?usp=sharing

- For each of the following statements, please indicate how much you agree or disagree that the statement applies to this website. (Where, 1 = strongly disagree & 5 = strongly agree)

	Strongly disagree				Strongly agree
This website provides customers with online plumber booking and cancellation	1	2	3	4	5
I find booking a plumber service through this website is convenient	1	2	3	4	5
The layout of the website is self-explanatory and simple	1	2	3	4	5
The website presentation described the process of online plumber booking	1	2	3	4	5
It is easy to navigate on this website	1	2	3	4	5
The website has a proper product and service categorization	1	2	3	4	5
The website features customers to contact the retailers conveniently and easily	1	2	3	4	5
The website has a section on DIY for minor plumbing issues	1	2	3	4	5
The website provided customers to check order status	1	2	3	4	5
The information on this website is relevant to the plumbing services and customers	1	2	3	4	5
This website mentions information such as product and service details.	1	2	3	4	5
I feel confident conducting business with this website	1	2	3	4	5
The website provides channels for contact such as office address, email and phone number	1	2	3	4	5
I will likely visit this website in the future	1	2	3	4	5

- How likely is that you would recommend this website to your friend or a colleague?

Not at all likely								Extremely likely	
1	2	3	4	5	6	7	8	9	10

- In your opinion, what additional features should have on this website?

_____

_____

_____

- How likely would you request a plumber service through this website?

o Not likely
o Somewhat likely
o Very likely

- Is our pricing section clear?

o Yes
o No

- How can we improve our pricing section?

_____

_____

_____

- What would you use as an alternative if our website is no longer available?

_____

_____

_____

- How likely you would consider doing DIY for minor plumbing issues?

o Not likely
o Somewhat likely
o Very likely

- In your opinion, what makes us stand out from other similar websites?

_____

_____

_____

Respondents Information

Name:

Gender:

Age Group:

Location:

Email:

Part B: E-Commerce Business Model Review & Recommendations Questionnaire for Expert Users

Survey Purpose: To evaluate the developed business model of domestic plumbing services for the market launch. Also, to understand the factors or elements to consider or include in the developed business model. Besides, Implementation of the website in this context.
You can review and recommend based on your product/service/system industrial experience (not restricted to plumbing services) and the managerial perspective.
Your honest responses to this survey would be valuable to my research contributions. Your responses will be kept confidential and solely related to academic concerns. We thank you for your valuable time & giving feedback regarding our work.

We have developed an E-Commerce Business Model, what it does is,

- It allows customers to book on-demand plumber services, order online plumbing tools and spares, access to DIY tutorials to resolve minor plumbing issues. minor plumbing issues such as, dripping faucets leakage, Toilet or Kitchen drain, leaked pipes, water pressure issues etc.
- It provides nearby plumbing retailers information to customers.
- It provides plumbers and retailers registration and listing

- In general, what is your understanding and views on the developed business model for domestic plumbing services?

  _____

  _____

  _____

- Is the idea worth considering for the market launch?
  - ○ Yes
  - ○ No

- What are the additional areas to focus on for implementing the developed business model of domestic plumbing services?

  _____

  _____

  _____

- Which are the factors that motivate customers to use on-demand plumbing services?

_____

_____

_____

- Any other comments and suggestions you would like to share?

_____

_____

_____

Respondents Information

Name:

Gender:

Age Group:

Organization:

Designation & job role:

Publications

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