

# **Evolving design Heuristics for Graphical User Interfaces of smart devices -A semantic approach**

A thesis submitted in partial fulfilment of the requirements for the degree of

**Doctor of Philosophy**

By

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## DECLARATION

I hereby declare that the work contained in this thesis entitled “Evolving design Heuristics for Graphical User Interfaces of smart devices -A semantic approach” is my own work done under the supervision of Professor Pradeep G. Yammiyavar, at the Department of Design, Indian Institute of Technology Guwahati (IITG), Assam.

I hereby declare that to the best of my knowledge, it contains no materials previously published or written by another person, or a substantial proportion of material which have been accepted for the award of any other degree or diploma at IITG or any other educational institute, except where the due acknowledgment is made in this thesis. Any contribution made to the research made by others, with whom I have worked at IITG or elsewhere, is explicitly acknowledged in the thesis. I also hereby declare that the intellectual content of this thesis is the product of my own work, and as per general norms of reporting research findings, due acknowledgements have been made wherever the research findings of other researchers have been cited in this thesis.

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## CERTIFICATE

This is to certify that the work contained in this thesis entitled “Evolving design Heuristics for Graphical User Interfaces of smart devices -A semantic approach” submitted by Mr. Venkateshwarlu Varala to the Indian Institute of Technology Guwahati, Assam (India) for the award of the degree of Doctor of Philosophy has been carried out under my supervision. This work has not been submitted elsewhere for the award of any other degree or diploma.

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## *Thesis Summary*

Product graphical user interfaces (GUI) are the first point of contact for the human-machine interaction. In our day-to-day lives, we come across several Information communication Technology (ICT) products such as mobile phones, music players, smart meters, etc. with graphical user interfaces that facilitate ease of use of technology. These interfaces are designed to serve several categories of user groups across the globe. While the purpose of a GUI is to communicate meaning in the best way possible and to create a bond with their users, yet we see several users or user groups finding the interaction difficult and ambiguous. There could be several reasons for such unpleasant experiences. While that is the current scenario, with the advancements in technology such as the Internet of Things (IoT), interaction with these products is expected to change drastically. With IoT technology, user interaction with ICT products is possible from anywhere in the world without a requirement for a dedicated single graphical user interface, which brings in much more dynamism and complexity across different platforms of interaction. It is predicted that the world will have more than 50 billion IoT enabled products by 2020.

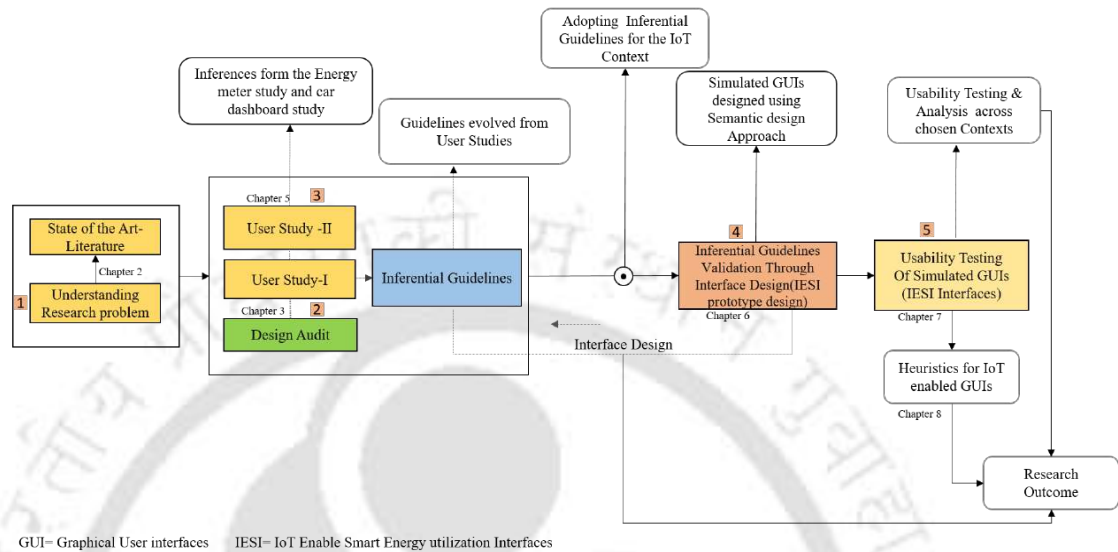
India is a country where we see user groups with diversity in culture, linguistic and Socio-economics differences. In Indian scenario, it is often observed that a single interface is being used by multiple user groups across different contexts such as Rural and Urban. Studies indicate that these interfaces are mostly westernized in nature, built on heavy text English mostly using complex terminology and having limited or no customization. Considering the individual user differences and needs across strata, a question arises as whether the existing interfaces are able to cater the needs of diverse Indian user groups. With the existing GUIs in the Indian context it is questionable as how the Indian user groups adopt to the future IoT based product GUIs. If not can a GUI be designed that takes all aspects such as language difference, literacy difference etc. into consideration. If so what and how a GUI designer proceed?

State of the art review was conducted to understand the nature of the problem and find research direction and the gaps. Through state of the art review, it is found that there exists no specific designing guidelines or heuristics with respect to meaning related issues in the Indian context especially for Instrument and GUI designers. With user-centric design research approach and semantic design methods this thesis is trying to address the research gaps. This Thesis has its focus on the IOT devices and their interface. The thesis is not on IOT technology as such. It attempts to study the change in Interaction form the Analogues era interfaces transiting into digital era interfaces with the intent that this will lead to IOT based device interfaces that may eventually use mediums such as Virtual Reality, Augmented Reality and Holographic.

This Thesis attempts to answer the following Questions:

- RQ1. Which are the variables that affect the semantics of the graphical user interfaces in particular product Graphical User interfaces like Energy Meters (Electrical consumption indicators).
- RQ2. Are there any identifiable sentiments common to a social group / segment which influence the semantics interpretation of GUI's in everyday products - for example a household energy meter? If so, how do they affect the perception of graphical user interfaces in terms of their liking, functional, and acceptance ratings, given a segment of users.
- RQ3. Can we model these user perceptions and sentiments, across different segments of users say for example Rural & Urban?
- RQ.4 Given a user segment can a design method or heuristics be developed which can be used to design, measure and test the Semantic efficiency, Usability rating of products like smart meter GUI in IOT use context that designers can make use of it.

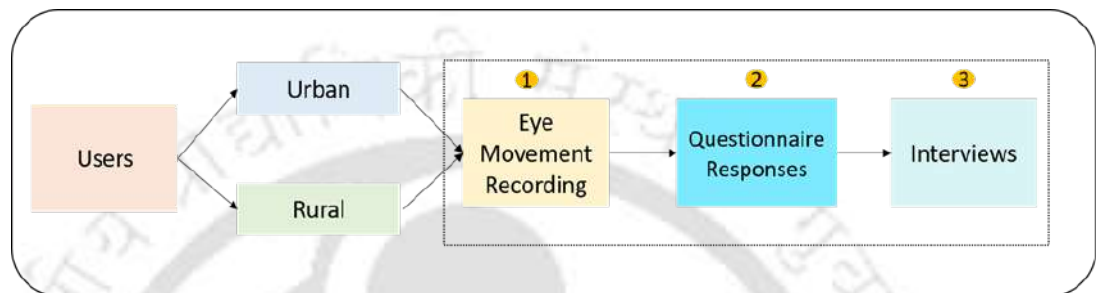
Figure below shows the methodology and stages covered in this thesis.



A Field-based User Study to Find out Problem Areas of Interaction was conducted with electricity meter interfaces among various Indian user groups with an aim to understand type of problems with respect to Information understanding and interacting with user interfaces. Study was conducted with 30 subjects drawn from rural and urban areas of India. Study reveals that there exists several issues related to readability, users understanding of meaning of the information, information relevancy, trust issues and usability. Further investigation to understand the variables that affect the meaning, seams (units of visual meanings) that are needed to incorporate to enhance the meaning and to find heuristics that are being actively considered in design to address the issues related to Indian usage scenario. Findings from the study reveal some of the cultural and usability related problem areas which are explored further in the following studies.

User Study-II that utilized three types of user-data gathering methods. It had specific objectives of understanding users with respect to their information priorities, preferences and expectations in an information system GUI context. For this study, set of automobile dashboard interfaces were chosen. These interfaces were chosen for

the study due to larger user base across strata, their utility value in day-to-day life and usage impact. Semantic word analysis was done on the unstructured interviews to understand how the subjects interpreted what they understood. The study is conducted with two categories of Indian user contexts namely Rural and Urban as is shown in Figure below.



Segregated interface design guidelines specific to user groups, context of use, information design resulted from the user studies mentioned. Using these semantic based guidelines simulated IoT enabled energy smart energy utilization interfaces were designed.

Set of posits and hypothesis were formulated to test and evaluate simulated interfaces through a usability study with target users. Usability validation framework for the interfaces was built on ISO 9241:11 standard (Bevan, Carter, & Harker, 2015) where three key parameters that are, efficiency, effectiveness and user satisfaction are measured in the study after performing set of tasks. TAM was used as the Framework.

Results showed that all the variables PU, PEOU, IS, OIS and IU are rated high across all the user groups indicating user intentions of satisfaction, use and acceptance of the interfaces. The results indicate that the IESI interfaces designed using inferential guidelines found to be acceptable by satisfied rural and urban users.

The contributions of this thesis are mainly in formulating a validated framework for designing IOT based devices interfaces. It derived Design guidelines for GUIs of IOT devices especially for diverse Indian population condition.

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### **List of Abbreviations**

2D: 2-Dimensional

3D: 3-Dimensional

ATM: Automatic Teller Machine

DSRM: Design Science Research Methodology

EESL: Energy Efficiency Services Limited

EMR: Eye Movement Recording

GUI: Graphical User Interface

HCD: Human Centred Design

HCI: Human Computer Interaction

ICT: Information Communication Technology

IESI: IoT Enabled Smart Energy Utilization Interfaces

IoT: Internet of Things

IS: Information Quality

IU: Intention to Use

KWh: Kilo Watt Hour

OIS: Over all Information Satisfaction

PEOU: Perceived Ease of Use

PU: Perceived Usefulness

SMNP: Smart Meter National Programme

SUS: System Usability Scale

TAM: Technology Acceptance Model

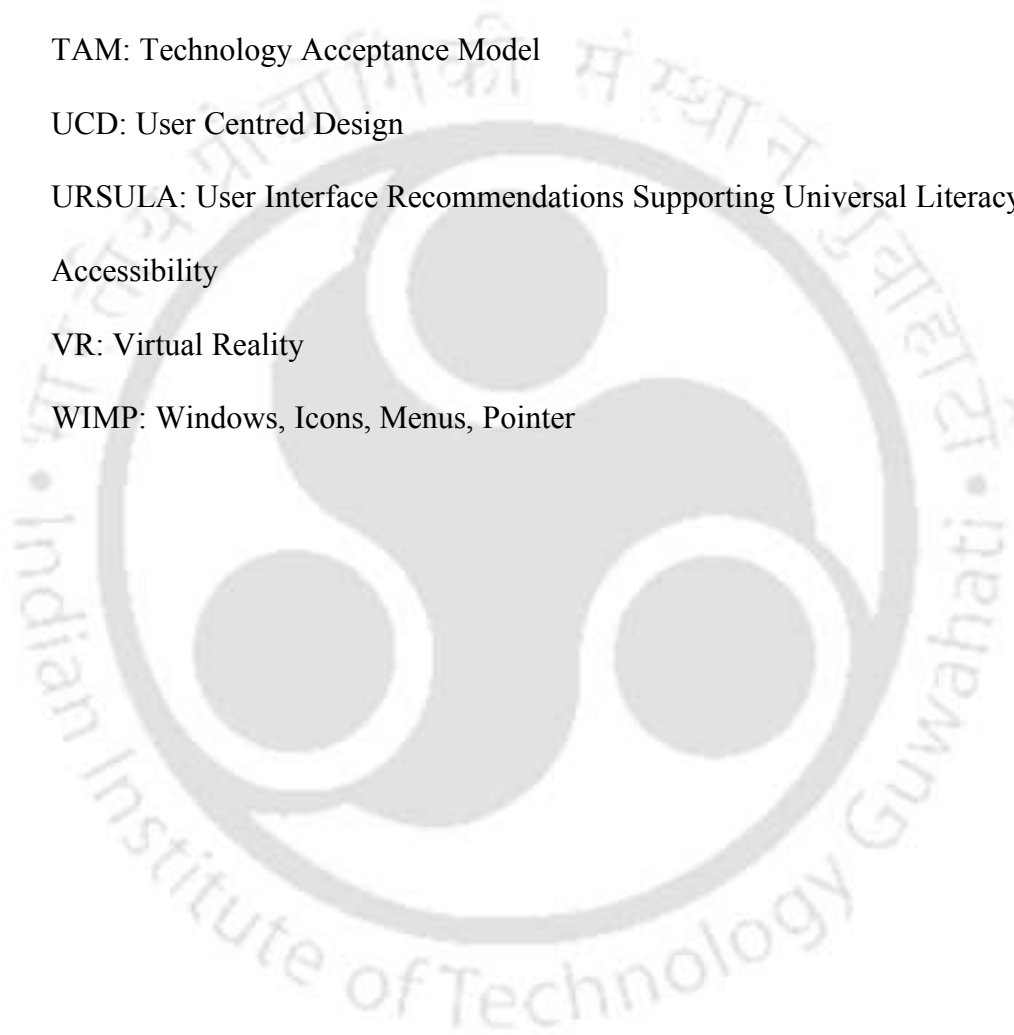
UCD: User Centred Design

URSULA: User Interface Recommendations Supporting Universal Literacy

Accessibility

VR: Virtual Reality

WIMP: Windows, Icons, Menus, Pointer





# 1. Introduction

*Abstract: This chapter introduces the research context and the motivation for this research.*

## 1.1 Introduction to research context

Communication is a basic activity of conveying or transmitting information between two or more entities (Shannon, 1948). through various mediums. These entities are of various types, that are natural organism such as human, animals etc. and artificial entities such as machines, artefacts etc. In this activity of communication, there are three basic functional elements. That are source where the message or piece of information originates, medium for transporting the information and destination. The aim of such activity is to exchange the ideas, thoughts, information, etc. of various origins. This transfer of information is of two types, first is one-way communication where the message is unidirectional and the second is two-way communication where the source and destination are involved in exchanging the information, which is often called as interactive communication or Interaction.

In Communication between natural entities such as human beings, information is conveyed by using means that are perceivable by the senses with a mutual understanding between the source and destination in real time. For example, a vocal language, gestures etc. are a system as well as means. It has been a practice since the ages that we use various secondary or artificial entities as a message or information carriers where a piece of information is preserved and used for various future purposes, for instance paintings, storyboards, written texts etc. As the time progressed, there has been numerous innovations of storing and delivering the information via numerous mediums with a constant development influenced by the technology.

Today there are artefacts where the message is one way, for instance a textbook and there are modern systems where the communication is of interactive in nature such as computer systems. In contemporary times, basic day-to-day activities has become dependent on information and information processors. Today numerous artificial systems and bots have come in to existence to process this information and assist us in day-to-day activities. Human interaction with these systems takes place via various perceivable means such as visual, auditory, tactile etc. These interactive means are often called as interface modalities or user interfaces (Bernsen, 1997).

Electronic products such as computers, mobile phones communicate through their frontend screens called control panels or Interfaces. These interfaces uses a combination of components such as buttons, keys, switches, pointers etc. or a graphical user interface (GUI) to interact and convey information. With the technological development, most of the current electronic product user interfaces are touch sensitive GUIs where interaction is effected on the interface itself with minimal or no-mechanical parts underneath.

Tangible products or artefacts are physical objects. These carry messages that are embedded into the products by a conscious effort of their designers through a design process. Messages are communicated via various physical attributes such as form, colour, texture and assistive elements such as text, graphics etc. in real three-dimensional plane. For instance, handle of a teacup, a mechanical switch with specific colour etc. A message can make a sense and invoke a meaning only when the product attributes are affecting the user.

GUIs communicates information using interactive visual components such as icons, signs, text etc. displayed on two-dimension plane. Computer systems use visual metaphors and cues to communicate. For example a trashcan icon as metaphor to delete something. A folder to represents storage space for data file etc. Whilst the purpose of a graphical user interface is to convey the system functions in a meaningful manner that make sense to their target users yet sometimes we come across interfaces

which are difficult to understand and operate. They fail to communicate or err while communicating thereby distorting the message. There may be several reasons for why an interface is not making any sense to a user.

With further advancement in technology such as Internet of Things (IoT), the interaction paradigm with the Information Communication Technology (ICT) products is changing. IoT is a technology paradigm where in IoT network numerous devices such as mobile systems, computers, sensors etc. inter connect for seamless inter communication and information transfer anywhere in the world by themselves. IoT has become a buzzword in recent times, it is predicted (Vestberg, 2010) that more than 50 billion devices will be IoT enabled by 2020. While this is the trend towards the technological advancement, acceptance of this type of sociotechnical systems depends on several things ,one such dimension is communication or the way they interact with their users. Here the acceptance or technology acceptance refers to readiness and willingness of individuals to use the technology or technological products to serve their needs. While IoT technology consist of numerous types of sensors, actuators, and many other hardware architecture which makes this technology a true Internet technology, user interactive part of this technology is largely done through graphical user interface based applications. Due to its technological nature of interconnectivity and seamless information sharing across cross platforms and devices, it makes interaction much more complex and dynamic with respect to user interaction. Studies indicate (Shin, 2014), (Ahmetoglu, Cob, & Ali, 2022), (Palm, Kronlid, Elf, & Brantnell, 2025) that development of this technology is still largely in technological domain but the true success of it depends on addressing the human context.

While IoT systems are making progress in developed countries, the situation in emerging markets is quite different. These countries , (Brewer et al., 2005; Warschauer & Ames, 2010) are rapidly gaining access to digital technologies, but without corresponding attention to local user needs or design relevance. Although devices have become more affordable and widely available, studies (Fonseca, 2004)

(Aleke 2011) (Nirmani I.A.P., 2025) highlight how their actual use and acceptance remain limited. A major reason for this is that the products introduced in these markets are often designed elsewhere, typically for users in developed regions and then directly deployed in vastly different socio-cultural and infrastructural contexts. As pointed out by (Warschauer & Ames, 2010) these technologies are not adapted or re-designed for these settings, and this gap is one of the key reasons why they fail to integrate meaningfully.

Brewer et al. (2005) discuss how digital systems in developing countries tend to fail not because of a lack of demand or interest, but because the design does not account for things like low digital literacy, unfamiliar interface logic. Fonseca's study of the Simputer in India and Computador Popular in Brazil shows this clearly, both projects aimed to support low-income users but ended up being too complex or misaligned with how people actually interact with technology. Similarly, (Parikh, Javid, K., Ghosh, & Toyama, 2006) also show that unless technologies are designed with local participation, simplified interfaces, and grounded understanding of users' contexts, their acceptance remains low.

India fits into this broader category of emerging markets where digital infrastructure is expanding quickly, but user-centred design still lags behind. Considering the Indian scenario where there exists several user groups, acceptance of such new product/technology across different strata of society is challenging. India is a country with more than one billion population with population diversity across culture and socio economics hence diverse user groups. In Indian scenario, it is often observed that a single interface is being used by multiple user groups across different contexts such as Rural and Urban. This is open to user dissatisfaction besides error in communication which intern reduces chances of the devices/technology being accepted by user. For instance, an electricity smart meter interface, an automatic teller machine (ATM) interface, a ticket reservation system user interface etc. Studies(Joshi, 2013) (Medhi, Sagar, & Toyama, 2006) indicate that these interfaces are mostly westernized in nature, built on heavy text English mostly using complex

terminology and having limited or no customization. With the existing GUIs in the Indian context, it is questionable as how the Indian user groups adopt to the future IoT based product GUIs. Thus, the Indian context compounds these universal communication challenges due to extensive linguistic diversity, varying literacy levels, and differing socio-economic backgrounds.

## **1.2 Motivation and need for this Research**

IoT has become a national policy for many countries across the globe and India is taking steps towards the same (NASSCOM, 2016). This technology has started revolutionising various sectors, especially in energy systems and smart city initiatives. Among the many applications of IoT, this thesis has chosen to work on domestic electricity energy meters as a focused example or test case to be experimented.

As interactive technologies like IoT become part of everyday life, especially in sectors like domestic energy, the interface between people and systems is becoming increasingly complex. These interfaces often serve as the only point of interaction between the user and technology. In countries like India, where user diversity is very high and a single system may be used across multiple socio-cultural contexts, interface design becomes a critical factor in technology adoption and usability.

This thesis takes up the challenge of understanding these user–interface gaps through the example of IoT-enabled energy meters.

Studies have shown that pushing advanced products into emerging markets without context-aware design leads to poor adoption (Brewer et al., 2005; Fonseca, 2004; Medhi et al., 2006) (Aedla, Bakhshi, & Das, 2024). In India, products like smart meters, ATMs, or ticket kiosks are often brought in with interfaces designed elsewhere, with limited attention to aspects like language variation, literacy levels, or

rural usage conditions. This makes them difficult for users to handle and reduces their trust and satisfaction.

In the Indian context, many of the current GUIs lack consideration of individual user variation- cultural, linguistic, and contextual. Existing design heuristics (e.g., Jakob Nielsen, 1993) are generic in nature, developed largely for desktop systems, and do not address the nuances of Indian usage scenarios or the demands of future IoT-enabled devices. While some literature (Huenerfauth, 2002; Medhi et al., 2006) (Garg, Garg, Srivastava, & Agarwal, 2023) has addressed user issues specific to India, these have been limited in scope- often focused on literacy or specific user sections. There remains a significant gap in research when it comes to understanding GUI usability and semantic effectiveness across India's diverse user groups.

Therefore, the motivation of this research is to address this usability and communication gap through a design approach rooted in user understanding- specifically targeting graphical user interfaces (GUIs) used in IoT environments. The energy meter is used here as a focus product to study the communication breakdown between users and interfaces and to propose empirically grounded design heuristics suited for Indian users.

While energy meters are the test case, the actual concern is much broader- the rapid increase in interconnected digital devices (IoT-enabled systems) presents new challenges in how information is communicated to users. As everyday products shift from mechanical to digital and interactive systems, the user interfaces- especially Graphical User Interfaces (GUIs)- become the main point of contact between people and technology. This interaction layer becomes critical to both user understanding and technology adoption.

### **Energy meters as test case**

Demand and consumption of domestic electrical energy is increasing at a faster rate along with the rise in population and their growing needs. On the other hand, its environmental impact has become a growing concern. In India, about 71% of the total

electrical energy is generated from non-renewable energy sources, causing 35.5% of the nation's total carbon footprint. India, being the second most populated country in the world, is seeing increasing pressure on its energy infrastructure. Around 40% of the total electricity generated is used in the domestic and agricultural sectors, and this demand is rising at a rate of 6.8% per annum (Indian Ministry of Statistics and Programme Implementation, 2015).

In this context, domestic energy meters, when part of an IoT network, are seen as potential devices to promote sustainability in the energy sector. Governments across the globe have been introducing programs aimed at encouraging energy-conscious behaviour through technological interventions like smart meters and IoT-enabled energy management systems. Studies (C. Fischer, 2008) (Mischos, Dalagdi, & Vrakas, 2023) estimate that about 20-30% of energy can be saved through timely and effective feedback on energy consumption.

However, these systems are ultimately accessed and operated by users, who vary widely in their backgrounds and capabilities. Considering the individual user differences and needs across strata, a key question arises: whether the existing interfaces are adequate to cater to the diverse Indian user base.

To investigate this larger question, we adopt a user-centric approach (P. Yammiyavar, 1998; P. G. Yammiyavar, Clemmensen, & Kumar, 2008). According to fundamental design axioms, the user is the final datum for all design decisions. Therefore, understanding the actual problems that Indian users face while interacting with existing GUI systems is the starting point. To that end, a user study was conducted with electricity meter interfaces among various Indian user groups. The goal was to examine how users understand the information presented on the interface and what issues emerge in usability and communication.

The study was conducted with 30 subjects drawn from both rural and urban India. It revealed several issues related to readability, understanding of the information, relevance of information, user trust, and overall usability. These findings suggest that there is a larger set of variables that influence how meaning is perceived, which in

turn affects technology adoption. The goal then is to identify the variables that influence semantic comprehension, understand the visual units (or seams) that help convey meaning, and build heuristics that can be applied in designing GUI systems for such usage contexts.

Design semantics, as a field, is concerned with the study of meanings and how they are communicated (Klaus Krippendorff, 1989). Studies (Ware, 2004; Pappachan & Ziefle, 2008) show that the interpretation of visual metaphors and cues differs across cultural groups, user strata, and usage conditions. These semantic differences can influence how effectively a GUI communicates function and purpose, especially when dealing with a wide spectrum of users. This is particularly important in GUI contexts where most interactions are based on visual metaphors and language. These gaps have been reviewed and discussed in Chapter 2

### **1.3 Aims and Objectives**

The aim of this research is to address the interface communication gaps observed in graphical user interfaces (GUIs) of IoT-enabled systems, particularly in the Indian context. The focus is on understanding user diversity across various Indian user groups and proposing heuristics for GUI design that reflect this diversity. While the study uses domestic electricity meters as the product test case, the broader goal is to propose guidelines that can enhance user satisfaction and support technology adoption across Indian user groups.

The thesis employs user modelling studies, a semantic design methodology (T. Karjalainen, 2007a), and usability evaluations, with an emphasis on meaning and interpretation of GUI content across user group variations such as: (i) level of education, (ii) cultural background, and (iii) context of use.

Through a series of user studies and design audits of existing GUIs, the work aims to infer validated guidelines for GUI design relevant to the Indian context. These

guidelines are then tested through simulated interface designs of IoT-enabled smart energy utilization systems. The thesis argues that such heuristics can help improve usability, user satisfaction, and facilitate technology adoption- defined here as the willingness of an individual to learn and acquire knowledge that enables the effective use of a technology or product. This process is influenced by multiple factors such as perceived usefulness, ease of use, and cultural or social norms.

## **Objectives**

1. Conduct user studies involving users across various user groups such as rural and urban to understand mental models and address key research questions.
2. Conduct design audits on existing GUIs to analyse their current structure and design rationale.
3. Infer GUI design guidelines based on user modelling studies.
4. Validate the inferred guidelines through simulated interface designs, using IoT-enabled smart energy utilization systems (IESI) as a test case.
5. Assess usability, user satisfaction, and technology acceptance of the simulated GUI interfaces.
6. Analyse data to draw inferences, test hypotheses, and validate the positions and research questions formulated in this thesis.

## **1.4 Chapter Summaries**

**Chapter 1: Introduction-** Introduces the context of the research topic, discusses motivation and the premises of the research. Summaries of all the chapters are presented.

**Chapter 2: State of the Art-Literature Review-** reviews various research studies in the areas of user interface design, design semantics. Discusses research gaps and opportunities. The Review ends by posing a set of research questions for further investigation in this thesis. Aims of the thesis have been outlined.

**Chapter 3: Design Research framework and Methodologies-** presents design research framework adopted to conduct the research. Outlines studies and experiments designed to answer the various research question raised.

**Chapter 4: User study I:-** presents a field-based user study conducted with purpose to understand the existing issues with respect to energy meter GUI interaction and information communicability. Design of the study, analysis and results are presented.

**Chapter 5: User Study II: User modelling -** presents user study conducted to understand the users from the two Indian contexts namely Urban and Rural. Study aimed at modelling-the users and Inferring GUI design guidelines for the contexts mentioned. Design of the study, analysis and results are presented. Inferred GUI design guidelines are presented at the end.

**Chapter 6: Designing of IESI prototype based on user studies and inferential guidelines-** presents the adoption of inferential guidelines for an IoT smart energy utilization scenario. Presents design process and methods adopted for designing the IESI prototype interfaces. A simulated prototype of IESI on hardware platform is presented.

**Chapter 7: Inferential Guidelines Validation through Usability studies on IESI prototypes-** presents experiment plan for evaluating and validating simulated IoT Enabled smart home interfaces that are designed using inferential design guidelines. It presents usability validation model, analysis of the data collected. It summarizes all the results and concludes with hypothesis testing and discussion.

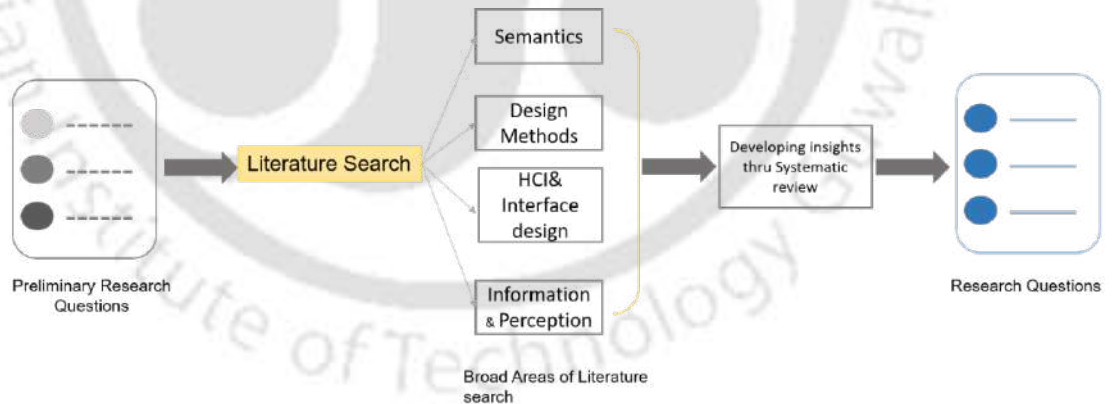
**Chapter 8: Contributions of the Thesis and Limitations-** presents contributions of the thesis and limitations

## 2. State of the Art- Literature review

*Abstract: This chapter identifies research gaps and opportunities at the end of a state-of-the-art literature review. Based on the literature review, research questions have been formulated for further investigation in this thesis. Aims of the thesis have been outlined.*

### 2.1 Introduction

Literature review helped us in understanding the nature of the problem, state of the art, identifying the gaps, opportunities and research questions in the Indian context. Various published literature (Established literature, books, knowledge bases, journals and published papers) in the relevant areas are referred. The literature reviewed in this thesis is categorized into the areas of interaction design, design semantics, semiotics, and cognitive studies of information visualization and perception. Fig 2.1 shows the literature review process followed in this thesis. An attempt is made to find research direction, understand the gaps and areas of knowledge that are necessary.



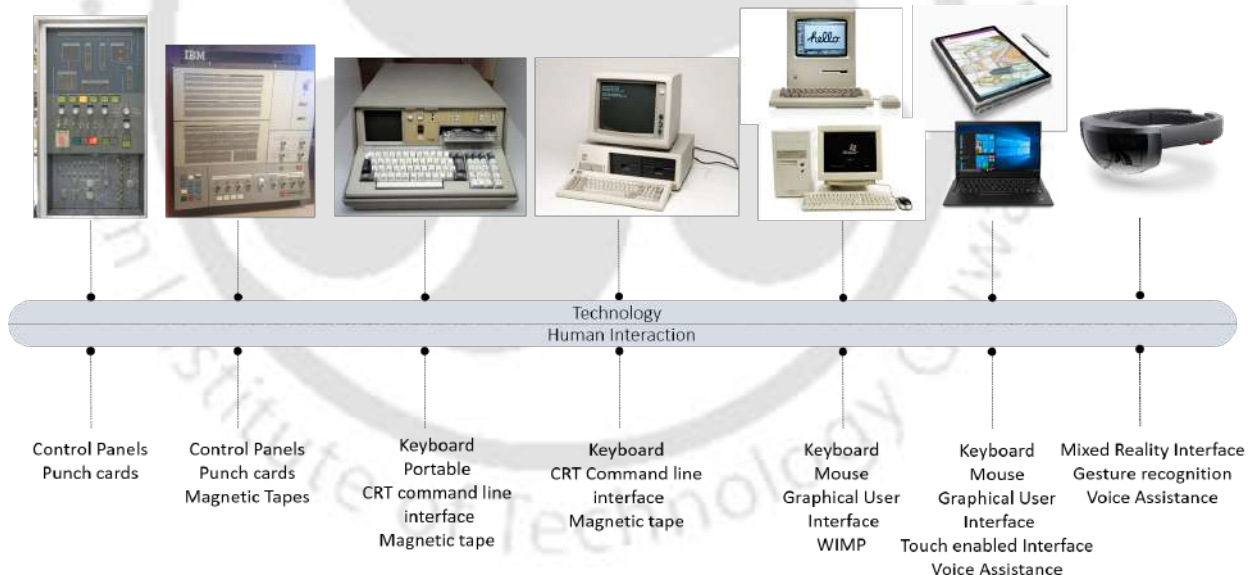
**Figure 2. 1 Literature review process utilized in this thesis Source: Author generated**

In this chapter, we attempt to understand human perception of information, factors affecting the perception of the information and effect on meaning-making/interpretation, design process and methods in the GUI context. State of the

art in this thesis discusses the current issues concerning GUIs interaction. Issues related to the information communicability and meaning, user-centric approaches to interface design for meaning, design methods and heuristics actively followed with an emphasis on meaning, heuristics specific to a cultural context such as Indian are reviewed.

## 2.2 Understanding evolution of user interface and interactions

Use of Information Communication Technology (ICT) /Electronic products such as televisions, computers, mobile phones, etc. has become an essential activity in our daily lives. With developments in technology, computers have become an integral part of the modern-day ICT/Electronic products. With developments in materials and manufacturing, size and scale of these products have reduced significantly and human interaction modalities have evolved significantly.



**Figure 2. 2 A timeline visualization showing evolution of computer user interfaces, human interactions and their current state Source: internet sources**

Earlier, human interaction with machines/system used to take place via interfaces known as control panels where mechanical switches, knobs, instrument gauges were

used to represent the system information and control (Grudin, 1990), for example first two pictures of IBM systems shown in Figure 2. 2. With the entry of computers (solid-state microprocessor and controller based) and interaction modalities such as Graphical User Interfaces, pointing devices, text entry keyboards etc. human interaction with systems /machines has significantly changed. Figure 2. 2 shows some of the influential technologies that represent the evolution of user interfaces to date. Interaction with the early stage of computers such as punch cards and command line interface system is more of an expert's job where one has to be trained meticulously. With the entry of the direct manipulation (Shneiderman, 1983) WIMP (Windows, Icons, Menus, Pointer) interfaces such as Macintosh and Windows, human interaction has become intuitive and the computers have become relatively usable by none expert users with minimal knowledge (Myers, 1998). Further advancements lead to the portable computers (Post WIMP) with new interaction modalities such as touch-enabled GUI, gestures, mixed reality, voice control etc. are embedded into the devices

Rapid growth in microprocessors scaling technology led to a reduced size of computers that made embedding computers into the products/appliances possible. Currently, a majority of the ICT/Electronic products are automated or computer controlled. New modalities such as gestures, speech are used for human interaction with the products. It is evident that developments in the computational technologies have certainly affected the way we interact with many products and systems that we use in our daily lives such as industrial systems, mobile phones, televisions, automobile dashboards, smart energy utilization to list few. For instance, observe the evolution of a household washing machine interface (shown in Figure 2. 3) and modalities for human interaction. In the process of automation, mechanical knobs on washing machine control panel are replaced by electronic switches and then followed by touch-enabled GUI interfaces.



**Figure 2. 3 A rough visualization showing evolution of a household washing machine user interface  
Source: Whirlpool Corporation**

With the further advancements, these products turned smart where they attained certain level of agency (Jia, Wu, Jung, Shapiro, & Sundar, 2012) (Chataut, Phoummalayvane, & Akl, 2023). With the latest developments in the internet technology such as IoT, remote interactions from anywhere on earth with multiple products/appliances is now going to be in trend (Gubbi, Buyya, Marusic, & Palaniswami, 2012), (Duguma & Bai, 2025). These developments in technology not only transformed the existing products but also introduced innovative products and services.

A holistic view of the developments across ICT/Electronic products, user base of these ICT/Electronic products is increasing day by day (Beardsley, Enriquez, Bonini, & Sandoval, 2010) for various reasons such as affordability, increasing trends of technological literacy, digitization of various services etc. It is reported that the user base of electronic and ICT products in emerging countries such as India is increasing at a faster rate. Studies Delponte, Grigolini, Moroni, & Vignetti, (2015), Chin & Fairlie, (2010) reported the increasing trends of product penetration in various ICT/Electronic products segments.

However, as cited multiple studies and surveys, user acceptance of ICT and electronic products in emergent countries is not merely uncertain - it is structurally challenged,

owing to socio-technical, infrastructural, and economic constraints, as elaborated in the three referenced studies.

Brewer et al. (2005), argue that ICT solutions designed for industrialized contexts have shown poor fit in developing regions, precisely because of a mismatch in infrastructural assumptions - availability of power, connectivity, device affordability, and most crucially, the usability of the interface itself. They note that most UI paradigms are task-specific and conceptually complex, making them inaccessible to populations with limited digital literacy. The paper identifies the need for simpler, low-cost shared devices (as opposed to personal computers), and emphasizes the value of speech-based or locally mediated interfaces for contexts like rural India. Brewer et al. explicitly mention the failure of both the Indian Simputer and the Brazilian Computador, Popular as personal devices, reinforcing the idea that while intent toward universal access may exist, UI design and contextual fit remain major deterrents to actual use.

Fonseca (2004) offers a comparative analysis of the Simputer (India) and the Computador Popular (Brazil), illustrating how top-down technology initiatives consistently fail to integrate users in a meaningful way. Conceived as a multilingual, portable ICT device for rural Indian communities, the Simputer aimed to bypass the linguistic and literacy barriers inherent in conventional computing. Yet its adoption remained low, owing to inadequate infrastructure, a misalignment with actual user needs, and interface complexities that still presumed a basic understanding of computing principles. In the Indian context, Fonseca shows how socio-economic diversity, language multiplicity, and widespread low literacy collectively undermine the usability of interfaces that do not account for these challenges.

Abascal et al. (2016), Koch et al.(2024) extend this critique by highlighting that universal accessibility frameworks frequently overlook contextual factors such as technology literacy levels, minority languages, and socio-political marginalization. They argue that “Design for All” falls short when it fails to address economic

conditions, aging or obsolete technologies, and the needs of non-standard language communities. Specifically referencing India, the authors acknowledge the potential of mobile technology as an accessible alternative - e.g., mobile-supported teaching tools or administrative services - but stress that interface design must adapt to shared access, minimal literacy, and low-end hardware. In such contexts, interfaces relying on screen-based navigation alone fall short. They propose inclusive strategies like simplified text, local language support, and interface adaptability as essential for true usability.

In summary, all three studies converge on the point that in countries like India, user acceptance of ICT is deeply intertwined with contextual interface design. Not only are devices expected to bridge infrastructure and literacy gaps, but they must also align with the cultural and practical ways users interact with technology. Designing for emergent users - particularly in rural and semi-urban India - requires a deliberate shift from text-heavy interfaces toward more inclusive, flexible, and socially-mediated interfaces.

In addition to the reviewed literature, this thesis acknowledges the emerging body of work on interaction design for IoT systems, particularly the shift towards “interaction without traditional interfaces”. As IoT artefacts increasingly embed computing invisibly into everyday objects, user behaviour itself becomes the primary input mode (Elayan, Aloqaily, Karray, & Guizani, 2023), (Davidoff, Lee, Yiu, Zimmerman, & Dey, 2006). Bakker et al. (2015) highlight that the absence of conventional screens, buttons, or gestures in some IoT setups calls for design methods that account for embedded, calm and peripheral interactions. This aligns with Weiser's, (1991) early notion of calm technology, where the interface recedes into the background of the user's attention. Studies such as Tolmie et al. (2016) further show that understanding user behaviour in real situations becomes central to designing meaningful IoT interactions. Recognising this, this thesis situates GUI design as only one part of a larger continuum, especially for IoT systems where interfaces may blend with environmental cues and sensor-driven feedback. While the focus remains on

graphical interfaces as the dominant visible point of interaction for smart energy devices, it is important to note that future iterations of such systems could increasingly rely on ambient and behaviour-driven input, thereby potentially reducing explicit user effort and shifting the nature of interface challenges altogether

However, literature also notes that when interfaces become too hidden or seamless, they bring new challenges for users. Rogers (2006) points out that if the system gives too little visible feedback, users can lose track of how it works, which affects trust and ease of use. Chalmers and MacColl (2003) (2004), argue that making everything invisible removes important cues that help users understand what the system is doing. Bdker and Klokmoose (2011), Angelini et al. (2017) also highlight that even with ambient or embedded systems, people still need visible elements to check status or confirm actions. Wiberg (2016) adds that human sense-making still depends on visual signs and layouts, even when technology is embedded or “disappears”. So, while IoT may reduce the need for some traditional interfaces, visual information remains important for helping users interact confidently and make sense of what the system does. This holds true especially in contexts like smart energy systems where people rely on clear visual feedback for control and decision-making.

### **2.3 Acceptance and adoption of ICT user interfaces in India**

In a digitally emerging country such as India, there are vast differences across user groups concerning digital literacy (Morris, 2013) and education literacy. Twenty-two different official languages are in use with wide varieties in the accent and dialect in India.

Acceptance and adoption of ICT / GUI based appliances in the Indian scenario is varied across the user groups. It is reported in studies Ranga & Pradhan, 2014, Gollakota & Doshi, 2014 that ICT / GUI based appliances acceptance and adoption rate is high among well-educated digital-literate user group. This educated digitally literate user group constitutes about less than 30% of the potential users and they are

described as global users who can intuitively adopt to any ICT/Interface. Studies conducted with various ICT projects or initiatives in India find that acceptance in rural India is still low citing to reasons such as complexity of the information , information lacking context relevancy, lack of user understanding, local practices and traditions etc. (Garai & Shadrach, 2006) (Pick, Gollakota, & Singh, 2014) , (Gollakota, Pick, & Sathyapriya, 2012). It is observed by Fonseca,Pal (2004) and others that among semi-skilled users that due to the perceived benefits of ICT, enthusiasm in users to adopt to non-customized devices declined in the long run pertaining to difficulties in understanding and users satisfaction. From the above discussion, it is evident that in India there exists multiple user groups with varied needs. Various authors and reports have highlighted issues concerning acceptance and adoption issues that are yet to be addressed.

Major ICT exporting countries ,design observations and market analysis reports that transposing the products from other markets to digitally emerging Indian never worked (Chavan, Gorney, Prabhu, & Arora, 2008) (Ishiwata, Awamura, & Takada, 2012) ( US Exports Report 2018 ) (Barquet, Gunnarsson, & Engström, 2025). It is recommended (Dias & Brewer, 2009) (Reinecke & Bernstein, 2011), that localization or customizing the interface design as per the user needs and cultural preferences would improve acceptance and user satisfaction. It is observed that the failed products in the Indian market seem to be missing the critical components in their designs such as understanding Indian users, needs, social and cultural norms.

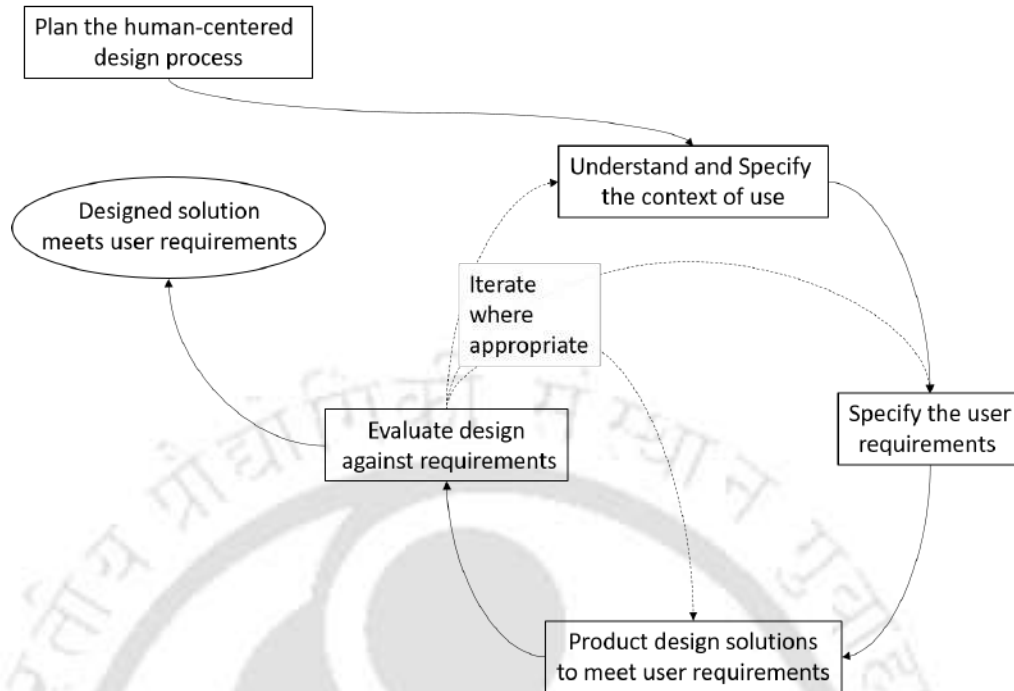
To understand the current issues pertaining to user interface design, it is imperative to understand the design process, designer and the user. The next section tries to review the above aspects from the perspective of user-centric design.

## 2.4 Understanding ‘design process’, ‘designer’ and ‘user’

GUI design falls in the creative design discipline of the multidisciplinary area of Human-Computer Interaction (HCI). The creative design aspect of HCI is known by the various terms such as interaction design, user experience design. International Standard Organisation (ISO) (ISO 9241-11:2018 Usability) recommends a User Centred Design (UCD) framework for designing Interactive systems (HCI) and defines it as designing interactive systems for the user needs satisfactions to achieve maximum usability.

UCD framework that outlines various process and methods for designing products systems or services keeps users at the centre. UCD specific to information systems has its origins in the seminal works of Norman & Draper (1986). As defined by the Norman (1986) ‘UCD of Interactive systems emphasizes that purpose of system is to serve the user but not a specific technology. The needs of the user should dominate the interface design and the needs of the interface design should dominate the design of entire system’. UCD framework of Information systems is standardized by the International Standards Organization (ISO) as Human Centred Design (HCD) of Interactive systems (ISO 13407 revised by ISO 9241-210:2010). HCD is a generic framework that recommends four key stages in the design process illustrated in Figure 2. 4 and key principles requirements to ensure a design process and design is user-centric.

As mentioned the UCD/HCD is a generic framework, individual methods and techniques at various stages in the design process are borrowed from the allied fields. Over the years the framework of HCD, user-centric design methods and techniques are under continues development and improvement (Gulliksen et al., 2003a) (Earthy, Jones, & Bevan, 2001). Number of studies (Vredenburg, Mao, Smith, & Carey, 2002) have recommended the HCD framework for designing the interactive systems. Researchers through numerous studies have contributed in developing and suggesting user centric methods pertaining to stages of interactive systems design.



**Figure 2. 4 Human-Centered Design (HCD) process, Fig sourced from (ISO 13407 standard)**

In user centric design approach the design of an interactive system starts with understanding the users' needs for a given context. In the context of interactive system design, understanding users is to know their requirements and preferences with respect to the information.

In design of interactive systems designers design interactions, interaction between a machine and user. The Aim of these interactions is to communicate the system functionalities to the user and user inputs back to the system via range of input and output modalities. Modalities that can generate and take the information that is perceivable and understood by the users. For instance, modalities used by systems to communicate with users are visual displays, audio sounds etc. Likewise, the modalities used by users to interact with the systems are text input, pointers, touch, speech, gestures etc. (Bernsen, 1997). Advancements in the technology has been changing the interactive systems dramatically with respective size, computing power and input output modalities, information visualization and interaction techniques.

Today interactive systems are mobile in nature that fits in to hands of the users and wearable. They equipped with multiple interactive modalities possible thru invisible peripherals also known as multimodal interactive devices, for instance, touch enabled GUI. Among various interactive modalities, vision based user interfaces such as GUI has been a dominant (Jaimes & Sebe, 2007) (Turk, 2014).

Designing GUI is a carefully orchestrated interplay between information (visual, audio, etc.), interaction and the architecture of the information. Therefore, in the context of GUI enabled products, it is the design of Information, Information architecture, Information flow that meets user requirements and preferences. It is the design of information that users can visually perceive, understand, and interact. It is the design of experience that user goes through while using the system. Therefore, to meet the user requirements UCD framework suggests an iterative approach, it suggests iteration and evaluation until the design meets the user requirements. However, indefinite iteration and evaluation at each stage is time consuming. Therefore, to reduce design and evaluation time designers use user models, design guidelines heuristics, design approach, etc. Such guidelines or heuristics need to evolve as technology change. In this thesis heuristics for design of GUIs of IoT enabled devices is being addressed.

## **2.5 State of methodological design tools in the Indian Contexts**

While there exists numerous user models, design and evaluation methods in HCI, substantial research works highlight significant issues that these tools are not universal and using these tools universally would result in poor usability and acceptance of ICTs (Irani, 2010) (Clemmensen, Hertzum, Hornbæk, Shi, & Yammiyavar, 2009) (Hertzum, Clemmensen, Hornbæk, Shi, Kumar & Yammiyavar 2007). These studies note that differences that naturally exists across various countries such as cultural differences, demographics, social relations, etc. affect the human perception and interpretation of ICTs.

As discussed in the section 2.3 several studies have suggested that designing for a specific context or user group requires methods and guidelines specific to that context or user group.

In the Indian context, there have been research efforts in identifying issues with user interfaces, developing design methods and guidelines.

A Research work conducted by Huenerfauth (2002) under URSULA (User Interface Recommendations Supporting Universal Literacy Accessibility) project specifically targets illiterate users in India. This work primarily suggests design recommendations on how to design mobile phone user interfaces for users who lacks written language literacy. Author presents a conceptual design approach where design recommendations suggested are developed through by hypothetical user scenario analysis. However, conceptual approach highly depends on designer's prior knowledge and experience in identifying issues with any interaction with the target users. Author suggests this approach to save design time however; suggested design approach lacks empirical evidence.

Medhi (2006) presents a set of guidelines to design mobile phone user interfaces primarily for illiterate users. This study employs an ethnographic design approach to understand users and their needs. It recommends text free interfaces for illiterate and semiliterate users, study notes that text free interfaces potentially bring computational technologies closer to illiterate users. However, this study was limited to user groups with limited education literacy.

Lalji & Good (2008) have reported work on designing mobile phone user interfaces for illiterate users in the in the Indian contexts. Author employs user centric design (UCD) approach, recommends, and highlights advantages of using the approach in this particular context. Author shares some of the important learnings and observations from the study such as understanding/importance of use context.

In majority of the studies discussed above, the literacy rate is seen as the interaction problem. Education literacy is seen as a primary barrier in meaning comprehension. Studies Pappachan & Ziefle ( 2008) , Janni Nielsen et al., (2006) highlights that culture, context influence human perception, therefore, the gaps in meaning comprehension is not only a problem of literacy but also the non-consideration of user background, context, culture. Several studies Gollakota & Doshi(2014), Yammiyavar P, Arora&Vaishnav (2006), in the Indian context have highlighted that user interfaces of various applications are not only difficult for the illiterate population but they are also difficult for the educated user group. It is noted that interface design lack understanding of Indian contextual semantics, which makes an interface challenging for users to comprehend, and seldom included any specific ques that are cultural, context-specific.

As it discussed in the section 2.2 it highlights gaps with respect to understanding the user groups in the digitally emerging countries. Studies Devanuj & Joshi, (2013), highlights gaps concerning understanding diverse Indian user groups therefore lack of user models, specific design approaches, design guidelines and heuristics. A user model is a knowledge of average user interaction behaviour that reside inside interactive systems in the computational environment. In principle, user models are the result of a substantial data collection of user preferences /user behaviour belonging to a certain culture or user group. Likewise, design guidelines and heuristics results from successful design in terms of user acceptance and satisfaction of certain user groups. User data and models helps the designers in aligning the interactive systems model to that of users. Number of studies (Allen, 1997) (G. Fischer, 2001) have highlighted the importance of understanding users and user modelling in the design process.

## **2.6 Understanding GUI design and Interpretation - Semantic perspective**

Studies Bourges-Waldegg & Scrivener (1998) Marcus (2006) highlight that when a user interface design is targeting a more extensive user base or cross-cultural HCI

design, meaning and semantics of the information is critical for success of the user interface. It is noted that while certain things are universal, differences that exist in the HCI design is in the way information is represented and these representations are deeply rooted in various culturally specific contexts.

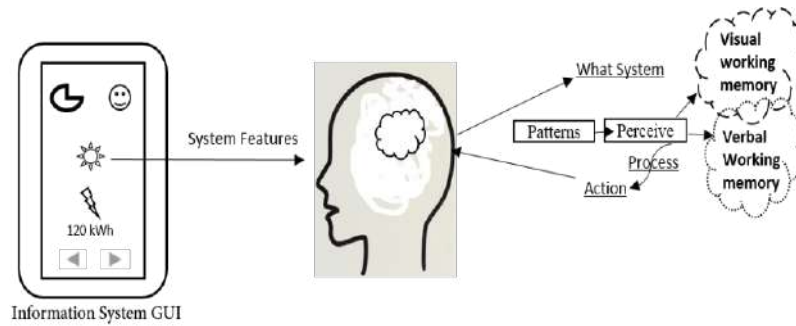
Design semantics is field of study introduced by Krippendorff & Butter (1984) (Klaus Krippendorff, 2006) (Klaus Krippendorff, 1989) and defined as a vocabulary and a user centric design methodology for designing artefacts in view of the meaning they could acquire for their user. Product semantics is a user centric design approach.

The concept of design semantics originated form an idea that the products should carry a message to their users and meanings that convey as how products should be used. Application of product semantics has been reported in the user interface design where it is has been highlighted that a semantic approach in user centric design plays a crucial role in successful design and creates a bond with their users Yammiyavar (1999). Notable works by Andersen, (1992), de Souza, (1993) have highlighted the importance of meaning based user interfaced design.

Following section attempts to understand how the user perception and meaning interpretation is affected by the culture-specific contexts such as social practices, living setups, sentiments etc.

Information Interaction –cognitive perspective:

Interpretation information starts with the cognitive process of perception as shown in the figure 2.5.



**Figure 2. 5 Cognitive processes of Perception (Adopted from Information Visualization, Colin ware, 2004)**

Studies from cognitive sciences that human memory plays a major role in perception of the world around them. Memories are the accumulations of human experiences which are shaped by evolutionary experiences and continuously sculpted by numerous living experiences from culture, living conditions etc. (Logothetis, 2010). Findings in the cognitive studies Ware, (2004), Nisbett & Miyamoto, (2005) , Phelps, Ling, & Carrasco, (2006) Zadra & Clore (2011) highlights that the perception and interpreted meaning is influenced by the various aspects that are wired in to the memory due to cultural practices, socioeconomic conditions etc. For instance, sentiments are emotional responses to a certain stimulus evoked due to a long-term intimate connection to that stimulus such as a symbol, color (Broad, 1959). Sentiments can be personal or common to a social group and can be used by designers to communicate information and enhance user experience (Yammiyavar, 2005).

GUI based information systems communicate their function by making use of metaphorical information elements such as icons, widgets, text, colour, animations and various other visual representations. An interface takes shape by the way these information elements are composed together using right visual cues. When a user is interacting with interface all this elements come together collectively in to the user perception and they evoke a meaning (Figure 2. 6).

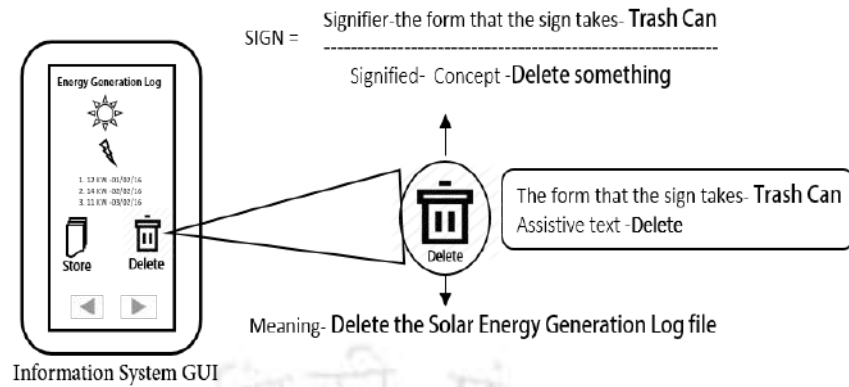


Figure 2. 6 Communication Elements in GUI (Source: Author generated)

The communication will be a successful episode of interaction if the intended meaning that a designer wanted to communicate matches with the evoked meaning of the user. To design a user interface that evokes right meaning the designer need to understand users or user models (T. Karjalainen, 2007a) (Crilly, 2011). Discussion in the section 2.5 highlights that there are gaps with respect to understanding users from the digitally emerging countries and interface designs seldom included any specific ques that are cultural, context-specific.

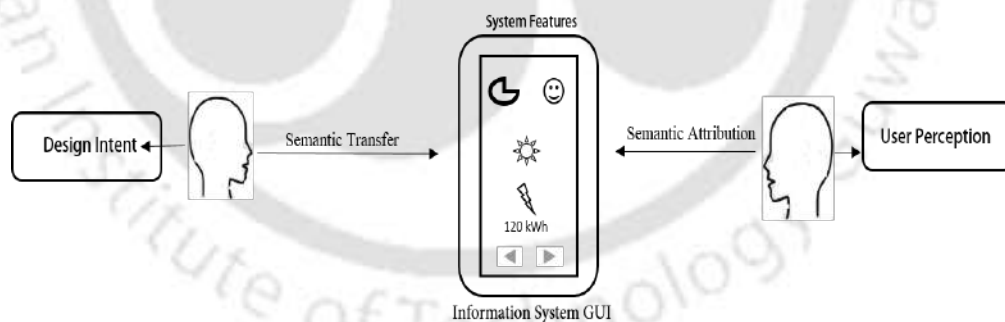


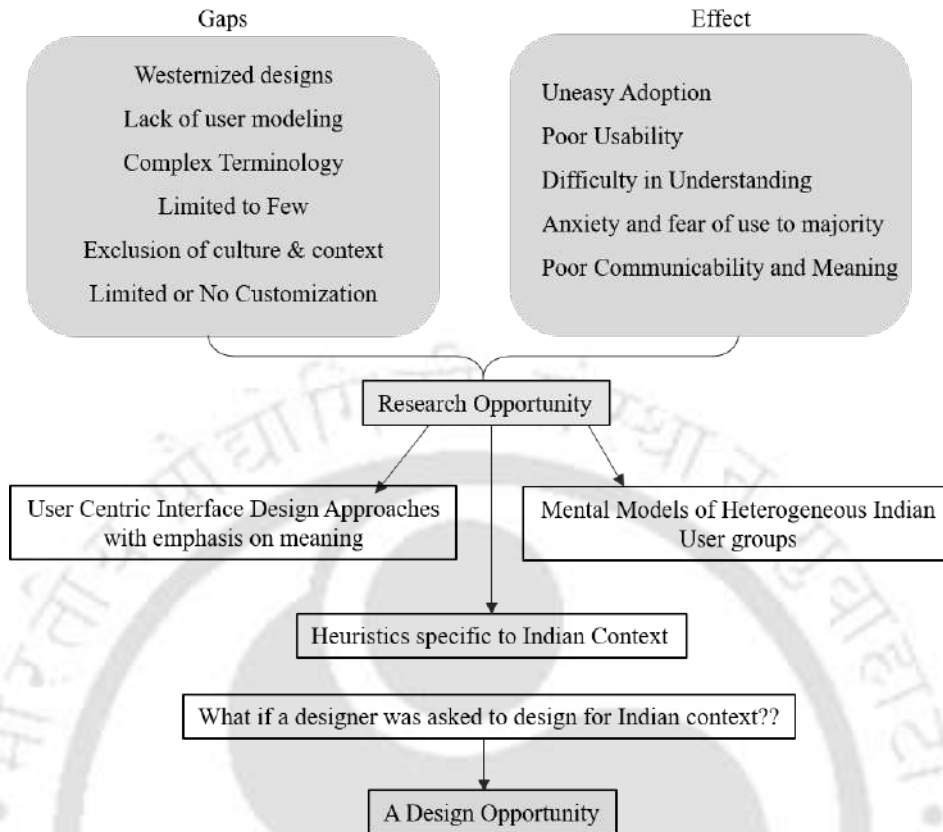
Figure 2. 7 Semantic Transfer and Attribution (Adopted form Karjalainen 2007)

When there exists gaps with respect understanding users, designs result in semantic distortion that may convey a distorted meaning or meanings that are not sensible to the users. Therefore, understanding users and their culture-specific contexts such as

social practices, living setups, sentiments etc. is critical to design interfaces that are meaningful.

## **2.7 Insights from the state of the art review -gaps and opportunities**

State of the art review conducted in this chapter of understanding the evolution of the user interfaces, current trends in user interaction and the penetration of the GUI based ICT /electronic products in the digitally emerging countries such as India. The main question arises from the present status of user adoption and technology acceptance of existing ICT /electronic products across Indian diverse user groups. Gaps are observed with respect to the nature of current ICT/electronic products user interface designs, their ability to communicate the GUI information in a way user can understand to cater to the needs of diverse user groups in India. There are significant research gaps as seen from the literature review depicted in Figure 2.8 , which are need to be addressed. They invoke significant research questions – described in Section 2.8 that follow next.



**Figure 2. 8 Research gaps and Opportunities Source: Author generated**

Fig 2 depicts the gaps found in state of the art and the research opportunities

There have been few significant works trying to address the issues with respect to interface design in various Indian contexts. However, these works are limited to mostly language and illiterate user groups. It is observed from the literature review that the semantics of the meaning is varied across cultures and cultural contexts, social practices and sentiments of a user group have a significant influence on human information perception and meaning interpretation.

Gaps are observed from the literature review that interface designs in the India lack understanding of Indian contextual semantics, and seldom included any specific ques that are cultural, context-specific. There is dearth of works reported with respects to the variables that affect the semantics across various Indian user groups and lack of

emphasis on meaning in designing complex user information systems such as smart energy meters especially while addressing the diverse Indian users. This thesis therefore intends to understand and identify variables that affect the semantics of the graphical user interfaces and attempts to identify the sentiments common to a social groups.

Secondly, Design guidelines or heuristics are often used in UCD to reduce the design time. A number constraints and limitations that have been observed in reported design guidelines and methods on interface design with respect to lack of emphasis on user interface semantics with an inclusion of Indian cultural contexts. It is also noticed that lack conclusive and empirically validated evidences in terms of usability evaluations and user acceptance tests. Therefore, this thesis intends to understand user models and draw design guidelines form the use modelling studies and empirically validate them thru a usability, user acceptance test.

## **2.8 Research Questions**

Based on the research gaps identified from the literature review following fundamental research questions are formulated to be investigated in this thesis.

- RQ1. Which variables affect the semantics of graphical user interfaces in products such as energy meters?
- RQ2. What identifiable sentiments common to a social group or segment influence the semantic interpretation of everyday product GUIs- such as a household energy meter- in terms of their liking, functional, and acceptance ratings?
- RQ3. Can we model user perceptions and sentiments across different segments of users, for example rural and urban?

- RQ4. Given a user segment, can a design method or heuristics be developed to design, measure, and test the semantic efficiency and usability rating of products like smart meter GUIs in an IoT use context that designers can use?



### 3. Design Research Framework and Methodologies

*Abstract: This chapter presents methodology adopted to conduct the research; it explains experiments design to answer the various research question raised, experiment procedure, prototypes/instruments design for the various experiments, tools designed, experiment protocols are outlined.*

#### **3.1 Design Research Methodology and Framework to investigate Research Questions**

To address the research questions mentioned in chapter 2 , a design based research methodology is adopted from research theories Design Science Research Methodology (DSRM) (Peffer, Tuunanen, Rothenberger, & Chatterjee, 2007) with an emphasis on user centric design (UCD) approach (Norman & Draper, 1986), (ISO 9241-210:2010). These two frameworks, though developed for different purposes, are intentionally blended to suit the dual nature of the research. Suited methods are drawn according to the context - which in this thesis is about understanding the users and user groups to develop design guidelines, and validate these guidelines by applying them in designing the Graphical User Interfaces (GUI) of IoT-enabled smart devices, ensuring their communicability to users across the rural and urban population context of India

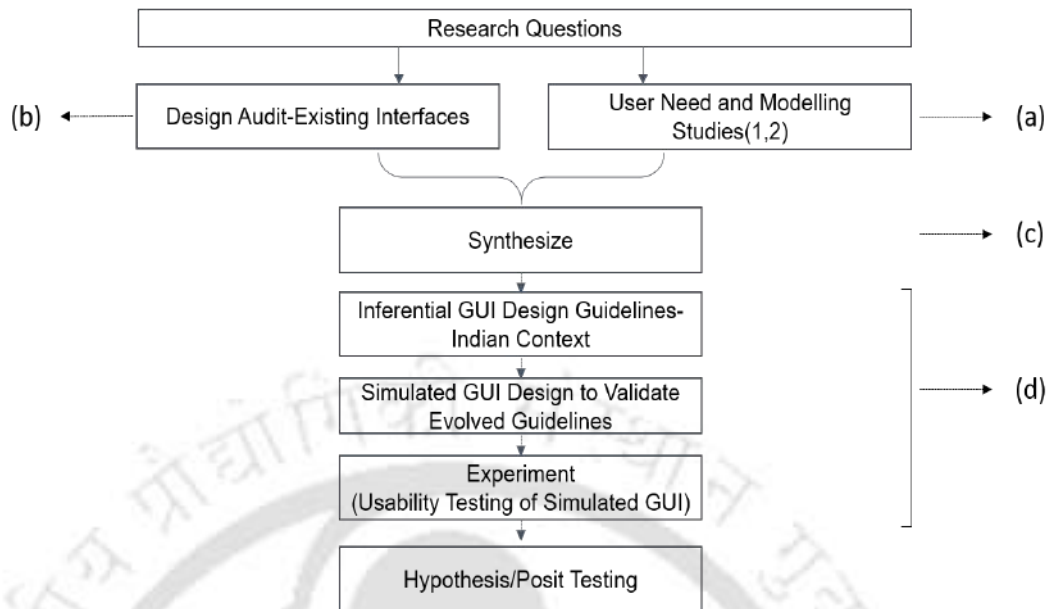
DSRM defines the stages needed to conduct research in the context of information systems. where the aim is not only to understand a problem but also to create, evaluate, and refine artefacts that offer solutions to those problems. It provides a structured pathway for the research process. It starts with identifying and motivating the problem, moves into designing a solution, and then moves further towards evaluation and communicating the findings. The outcome from using DSRM usually results in a design theory, model, or method which can be reused or adapted for similar contexts. In this research, the artefact is the design framework and interface guidelines for smart energy devices tailored to urban and rural Indian users.

However, while DSRM offers a rigorous structure for problem-solving and artefact development, it does not by default ensure that the artefact is grounded in real user needs. This is where the User-Centred Design (UCD) approach becomes essential. As defined in ISO 9241-210:2010, UCD ensures the system is developed by focusing on users' needs, preferences, contexts, and feedback at every stage of the design cycle. UCD is not just a set of methods but a philosophy that places the user at the center of decision-making, making it particularly suitable where interface communicability and adoption by diverse user groups (including low-literate rural users) is essential.

Thus, the combination of DSRM and UCD is both necessary and intentional in this thesis. DSRM helps structure the overall research process and guides how actionable design knowledge is derived, whereas UCD makes sure this knowledge is validated and shaped along with users, which increases its effectiveness and practical applicability. In the context of this study, where understanding cultural, linguistic, and technological diversity is crucial

Based on the Research objectives, methods at various stages in a flow can be categorized as follows,

- a) Methods of Understanding user needs and Modelling
- b) Methods to analyse existing Interfaces
- c) Methods to analyse and Synthesize the results of above stages and draw design guidelines
- d) Methods to design an experiment to statistically analysis and validated the evolved design guidelines.



**Figure 3. 1 Methods followed at various stages in this thesis**

Methods and tools are drawn from human-centric design approach, design semantics, and usability engineering. Both qualitative and quantitative data collection methods(Maxwell & Miller, 2008) were utilized in this thesis as it is practiced in the user centric design.

Figure 3. 2 shows the detailed research plan being followed in this thesis. Design and rationale of each stage of the research process are elaborated in the forthcoming chapters.

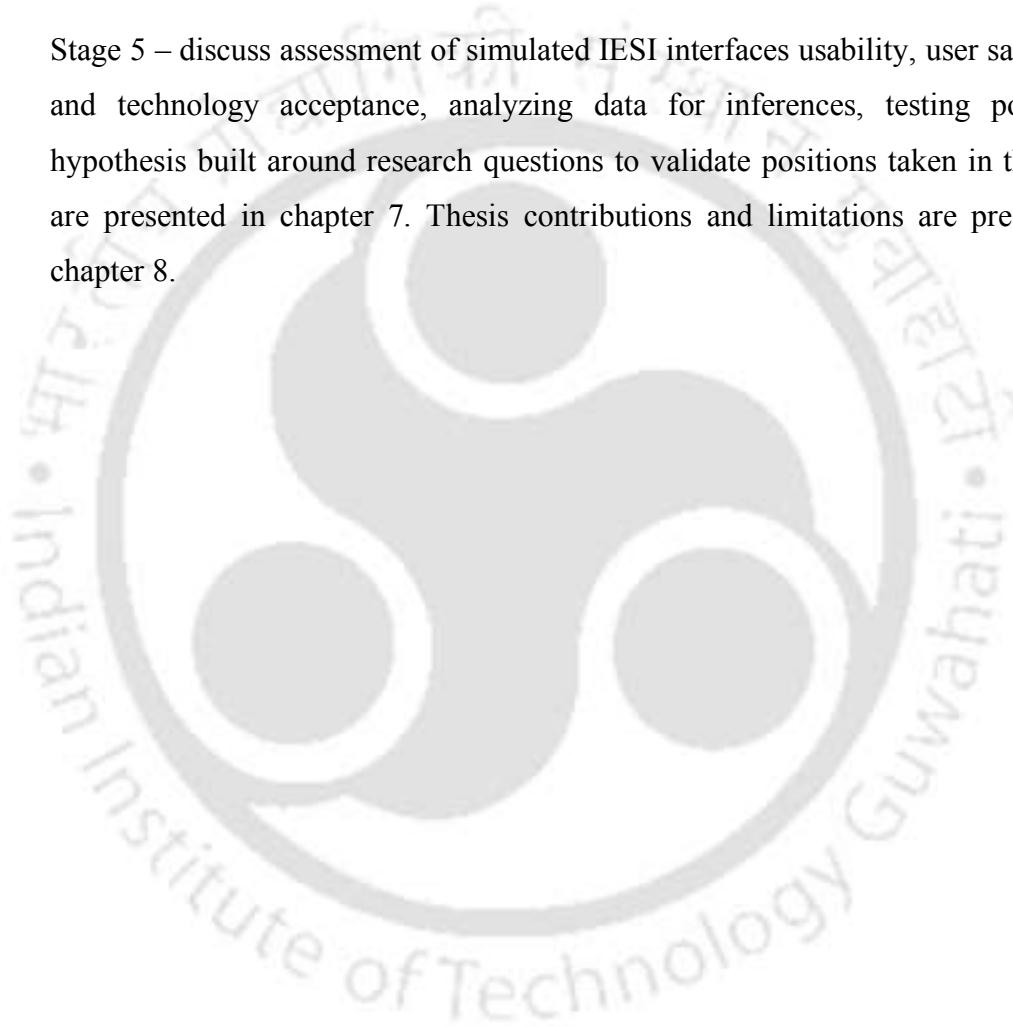
Stage 1 - understanding research problem through state of the literature presented in Chapter 2.

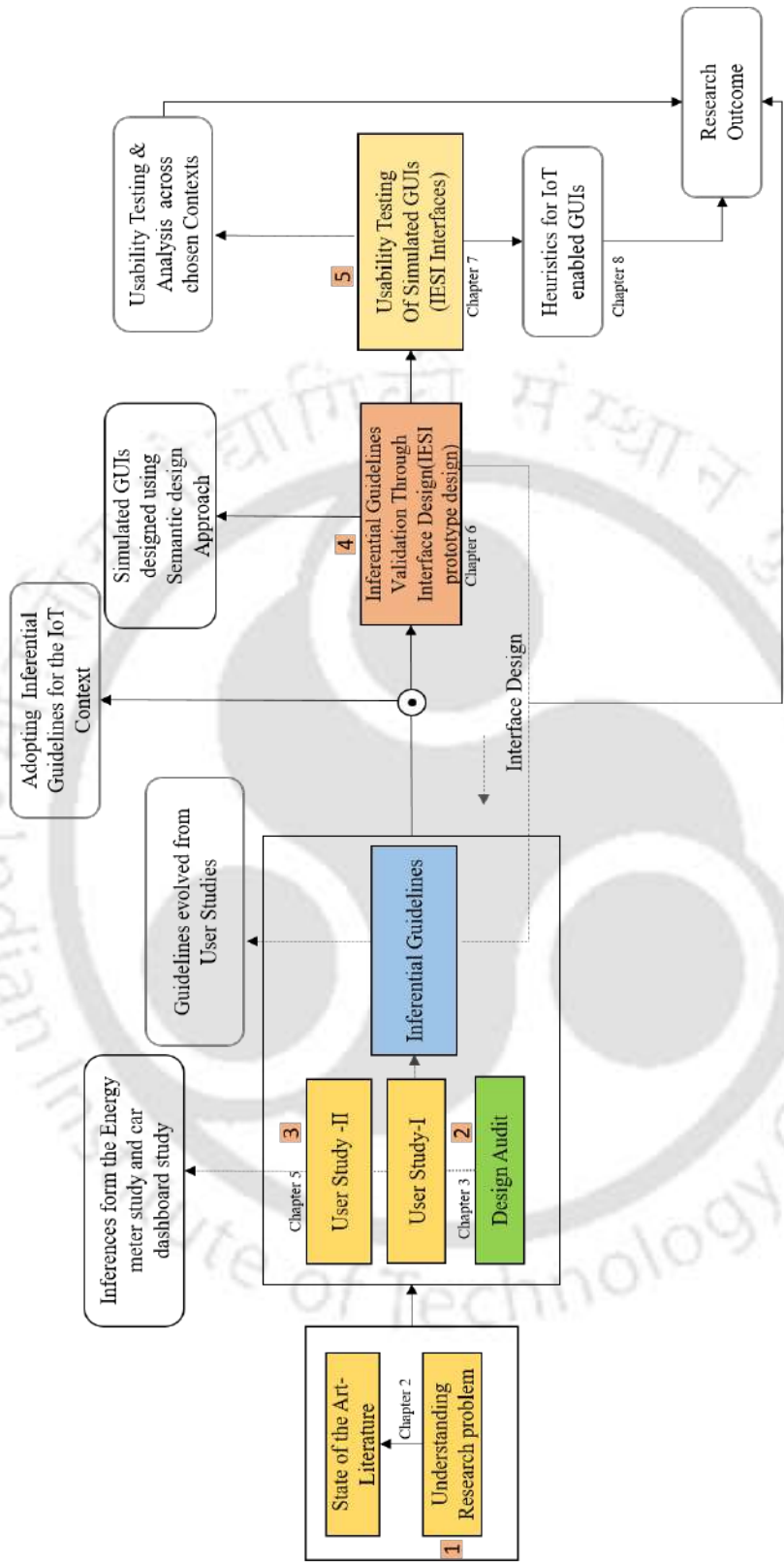
Stage 2: Discusses the user study-I conducted to understand the problem areas of interaction with respect to current GUIs present in India. Numerical dominated energy meters were used for the study. A design audit on existing GUIs of electricity energy meters to understand on what basis they are built is also presented in the Chapter 4

Stage 3. - discusses the user study-II to understand user models with respect to various information preferences of ICT GUIs. Set of GUI design guidelines are inferred from user study-I and user study –II and presented at the end of the chapter 5.

Stage 4 - discuss validation of inferred GUI design guidelines through simulated interface designs taking IoT enabled smart energy utilization interfaces (IESI) as test case is presented in chapter 6.

Stage 5 – discuss assessment of simulated IESI interfaces usability, user satisfaction and technology acceptance, analyzing data for inferences, testing posits and hypothesis built around research questions to validate positions taken in this thesis are presented in chapter 7. Thesis contributions and limitations are presented in chapter 8.





GUI= Graphical User interfaces IESI= IoT Enable Smart Energy utilization Interfaces

Figure 3. 2 User centered design process and research plan of this thesis

### 3.2 Chapter Summary

A user centric design research framework has been adopted to conduct investigations in this research. UCD is adopted in the larger DSRM frame outlines studies and experiments have been designed to answer the various research question raised.



## 4. Field-based User Study to Find out Problem Areas of Interaction

*Abstract: This chapter presents a field based user study with a purpose to understand problem areas of interaction with respect to energy meter and issues related to information communicability. Study was conducted with rural and urban energy users. Electricity energy meters used across urban and rural areas in India were used for the study. Design of the study, analysis and results are presented.*

### 4.1 Introduction

A user study was conducted with purpose to find answers for some broad questions mentioned below raised during initial stages in this thesis with respect to user perception of graphical user interfaces such as of Energy meters and problem areas of interaction. GUIs of seven Energy meters were chosen for the study. Variation and differences across the user groups, if any in perceiving them as well as existing GUI's ability to communicate information in the Indian context was intended to be gauged.

The questions that prompted this study are as follows:

- a) How do Indian users perceive and make meaning of the existing numeral dominated GUIs?
- b) Are these existing energy meter user interfaces catering to the needs of the diverse user groups in the Indian utility context?
- c) Are GUIs usable and are they communicating relevant information to target user groups?
- d) Do Users find the Information meaningful and useful?
- e) Can one design GUI suffice across various groups of users say Farmers on one hand and urban homemakers on the other?

## 4.2 Study Design:

A study was conducted to understand the perception of energy meters and their ability to communicate the intended meaning across various user groups. Contextual Inquiry was employed to conduct the user study. This method is based on a participatory design approach widely used in user interface design, where users are actively involved and observed in the field during their interaction with a user interface or system, and interviewed alongside real tasks. Contextual Inquiry, initially described by Holtzblatt and Beyer, (1997), combines observation and semi-structured interviews in the users' natural environment, which helps researchers understand not just what people say but what they actually do in practice. This approach allows gathering rich insights on work habits, tacit knowledge, and any gaps in interaction that might not be revealed through surveys or lab tests alone. The method also gives practical guidelines on how to prepare for a field study, like setting clear focus areas, choosing the right user groups, planning how the observation will be done, and then analysing the data to draw useful design insights.

For this study, GUIs of seven electricity energy meters that are currently available in the Indian and one that will be introduced in the near future were chosen. High-resolution photographs of selected seven electricity energy meters were photo printed with uniform resolution, pictures of the stimulus are shown in the Figure 4. 1. Except for the Meter 1, all the other meters are smart energy meters. Smart energy meters selected here are the type of meters that can only send the consumption details to the service provider via a mobile network. Meter 4, 5, 6 and 7 shown in Figure 4. 1 are independent in hand displays that are not yet present in the Indian market. Each one of them were selected with improvements in technological features, screen size, richness in graphics from one to another.

In our study, we used high-resolution printed photographs of meter screens as stand-ins for live devices. While this low-fidelity approach does not capture dynamic interactions, it is a well-established HCI method for evaluating semantic clarity-layout, iconography, and labels- without the distractions of implementation details

(Virzi, Sokolov, & Karis, 1996), (Snyder, 2003). Static mock-ups have also been shown to evoke realistic mental models when participants are already familiar with the products (Catani & Biers, 1998) (Gulliksen et al., 2003b). All commercially available household meters in the Indian market present every reading on a single, non-scrolling display; hence, a photograph faithfully represents the full interface. Moreover, some of the newer designs we included are not yet in production, making printed exposures the only feasible way to gather information related to user perception.

By recruiting subjects with prior meter-use experience, and the print mock-ups served as effective visual stimuli to support cognitive recall and discussion around actual usage. Empirical findings demonstrate that user expertise and familiarity with a product domain enhance the number and accuracy of issues recalled (Sauer, Seibel, & Rüttinger, 2010). Therefore, in the context of this study - where the focus is on information comprehension rather than system responsiveness- printed interfaces offer a valid approach.

Thirty users of an age group of 20 to 65 years belonging to the various backgrounds were randomly approached from the rural and urban areas of various states of India (Assam, Telangana, and Karnataka). Minimum criteria for the participants was, Indians with minimal exposure to any energy meter available in their households. Details and descriptions of the study are shown in Table 4. 1.

**Table 4. 1 User group characteristics and study details**

Type of device Interfaces	Electricity Meter GUIs
Mode Of Stimulus	Printed High Resolution Photographs (Uniform resolution)
No of GUIs	Seven
No of Participants	30 (14 Rural,16 Urban)
Participants characteristics	Users from Rural & Urban areas of Andhra, Karnataka, Assam Indian states Female -9 Male-21 Age (20 -65 Yrs.)
Study Duration	30-35 Mins /Subject Toal-950-1000 Mins



Meter 1



Meter 2



Meter 3



Meter 4



Meter 5



Meter 6



Meter 7

**Figure 4. 1 Energy meter interfaces used for the study**

### 4.3 Study Procedure:

This study employed semi-open ended interview method which is suitable for users coming from across different social stratum, language and background. Users belonging to different work backgrounds were interviewed with guided questions (Figure 4. 2). User categorization based on their work background is shown in Table 4. 2 All the interview responses were transcribed and audio recorded (See Annexure A). Guided questions were drafted based on the cognitive process of human information perception and meaning formation.



Figure 4. 2 Subject interviews

Table 4. 2 Subject categorization

Subject User group	Gender Division	Number of subjects
Technical professional	5 Male 2 Female	7
Homemakers	8 Female	8
Farmers	8 Male	8
Design professional	5 Male 2 Female	7

Guided questions are as follows

Q1. Can you identify/recognise the product? What do you think about the product in general?

Q2. Do you understand the information present on the screens?

Q3. Describe the meter's appearance.

Q4. What do you feel when you see this product?

Q5: Please read and interpret the Information on the screen (Task)?

Apart from the above questions, subjects were engaged in open conversation to describe more interpretations of the products such as their preferences like/dislikes, emotional responses, aesthetic preferences, perceived ease of use and language preferences. They were also asked to describe their experiences with the meter they have been using. Every subject was interviewed for an average time 30 minutes each. Total time taken for the study is close to 780 minutes. User responses were transcribed and audio recorded with their due consent (See Annexure A).

#### 4.4 Data Analysis and Inferences:

Analysis was carried out using content analysis technique (Krippendorff, K 2004) (Auerbach & Silverstein, 2003). Initially , relevant text from the subject responses was identified where each relevant response was coded under expert guidance. All the relevant repeated responses across the subjects were grouped and a master list of most repeated responses were prepared. Repeated responses are counted with an aim to quantify and segregated based on the user categories mentioned in the Table 4. 2. Out of 30 subject responses, 26 were considered for data analysis (see Annexure A). Table 4. 3 presents a few excerpts from subjects’ interviews and highlight some of the problems described by them.

Table 4. 3 Excerpts from a few subjects interview

Subject	Response
S1	I can recognize the meter 1 and 2.... I do not understand the reading that is shown on meter.... I rarely check the reading since I do not understand... I am scared of checking the reading from close distance especially the meter 1...The only Indicator that I check is the rotating dial....
S2	I can recognize all the meters... I understand the reading very well, as since I am a technician I am very familiar with the notations... The most important thing ...
S3	I recognize the Meters 1 ,2 and 3 ...I am a homemaker and I pay my bill based on the bill sheets at the end of the month....Meter 4 and 7 I find

	interesting due to visuals. I do not understand the numbers much and what they mean...
<b>S4</b>	I recognize meter 1 and 2 .... I am farmer I do not understand that numbers ...I only see the light blink on the meter which convey something is happening ...I sometimes do not trust these meter working ...

Inferences:

Inferences are drawn from the analysed data and categorized in to four user groups identified based on the users profession as mentioned in Table 4. 2 and discussed as below

*1. Farmers:*

From the analysis of the data it is inferred that this user group was able identify only meter 1 due to the long exposure /familiarity but none were able to identify the rest of the/remaining meters. None of the users knew the actual meaning of the reading and most of them do not read since they fear to approach it, majority of the users do not know how to read them for a correct interpretation, the graphics on the interface is not helpful in interpreting the meaning. They feel these products are not safe to approach though the modern ones are entirely safe. Many users do not trust the meters when it comes to the way they function and monthly billing due to insufficient feedback from the interface or very slow activity indicators. This user group is more concerned about the monthly bill and interested to know proper representation of the consumption in an easy way they can understand, than the engineering reading that does not make any sense to them. Some of the users in group shown interest towards the meter 7(shown in Figure 4. 1 ) that rich in graphics and have used some colourful icons.

*2. Technical professional and Engineers:*

This user group is able to identify and associate to all the meters they understood all conventions, graphics and readings, except for the aesthetic dislikes they did not find any meters ambiguous. They felt the presence of the tariff /fare is an added advantage

but not mandatory but the absence of engineering kWh (Kilo Watt Hour) reading is a complete no for them and it is less informative. All the engineers feel safe about products and trust them for their functionalities.

*3. Design University Scholars:*

This user group is more aesthetically sensitive. Designers without technical knowledge did not understand the technical conventions and graphics. More interested in suggesting the design changes that can be made to look products more safe, informative, meaningful and useful. Trust in products is variable. Due to professional instincts they were more in designers' role than a user's.

*4. Homemakers:*

All the users of homemakers group are women. Homemakers without the technical knowledge have similar response to that of farmers. More interested in knowing the household consumptions and suggestions to save the energy, interested in fare more than the just a numerical reading. Most of the users of this group rarely use/have less exposure to the household energy meters. They fear in approaching the meters.

**4.5 Summary of Findings from the User Study-I**

Table 4. 4 presents the consolidated finding from the user study-I

**Table 4. 4 Consolidated findings from user study-I**

Readability	Majority of the Users find Interfaces have poor readability
Understanding Information and making meaning	76 % of the users do not understand the Except Users with relevant technical knowledge Understand Information
Complexity	Majority of the Users Find complex to operate; And the with use of Technical terms makes it difficult.

	Design Implications: Reduce Complexity
Trust	Majority of the Users do not trust the way these products work Do not see the meters working as Watt/Hour change slowly, Design Implications: Improve least count and provide more live feedback on activity
Information Relevancy	Majority of the Users find that information has no relevance to their need Semantics of friendly safe is missing
Safety & Fear of Using	Users have fear of approaching these products though they are safe to use
Usability	23% -Find them partially Usable 77%- Do not find them Usable
Task Performance	22% of total Users were able to find and interpret the meaning of the Meter Information correctly

Findings from the study reveal some of the problem areas and investigative questions mentioned below that can be explored further in the following studies.

- What are the variables that enhance Information, communication, affect meaning, reduce the complexity of user interface and improve the information relevancy across Indian user groups.
- What are the seams that need to be incorporated to enhance the meaning and utility value considering the user social backgrounds?

#### 4.6 Design Audit of Existing Interfaces

A design audit was conducted on set of energy meter user interfaces. The design audit was conducted using feature analysis method (T. Karjalainen, 2007b). Aim of this design audit is to analyse and understand, on what basis these interfaces are built, their features, how they are suitable or not suitable to the Indian users considering the context and user group variation. In this analysis, most occurring features of the user interfaces are extracted and mentioned on the left side as shown in the Figure 4. 3. The most occurring features are circled and given weightage as shown below.

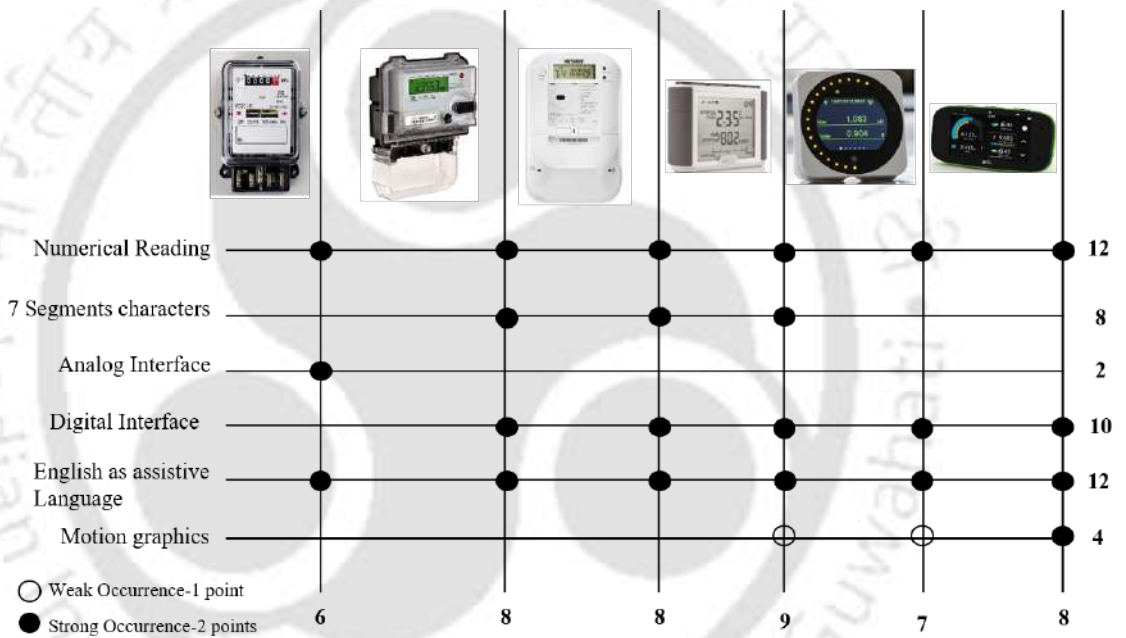


Figure 4. 3 Interface Feature Analysis Matrix

From the Figure 4. 3, the most occurring feature across interfaces are numerical readings and the English as assistive language. Semantically these numerical notations and language are symbolic in nature that can only be interpreted and understood with sufficient learning. Therefore, the existing energy meter user interfaces are suitable for users with relevant knowledge. These observations from feature analysis complements the user study-I findings discussed above.

## 4.7 Chapter Summary

The chapter discusses a field based user study conducted with purpose-to understand the existing issues with respect to energy meter GUI interaction and information communicability. Various UCD methodologies like contextual inquiry, and interviews were adopted for this investigation. The feedbacks provided further directions to user-modelling studies that is discussed in Chapter 5.



## 5 User Study-II

*Abstract: This chapter presents user studies conducted to understand the users from the two Indian context namely Urban and Rural. The studies are aimed at modelling the users and Infer GUI design guidelines for the contexts mentioned. Design of these studies, analysis and the results are presented. Set of GUI design guidelines have evolved as the synthesis of studies and design audits conducted in this research are presented.*

### **5.1 Understanding User perception of Information, needs and preferences through user studies**

As mentioned in the research process, the initial objective of this research is to understand the users while using energy meters. Two user studies were carried out across rural and urban contexts of India. User study-I with energy meters was presented in the chapter 4. User study-II, which is to be discussed in this chapter is aimed at specific objectives of understanding users with respective to their information priorities, preferences and expectations in an information system GUI context. For this study, set of automobile dashboard interfaces were chosen. These interfaces were chosen for the study due to larger user base across strata because many see them on daily basis but may not have used them. Automobile dashboard are similar to energy meter because automobile dashboards are numerically dominated and standard based and many studies report that most of the users find them difficult to use therefore it is suitable to gauge user characteristic, their utility value in day-to-day life and usage impact. The study is conducted with two categories of Indian user contexts namely Rural and Urban.

### **5.2 Aim and Objectives of the study**

This study is intended to understand Indian user's perception of interface and its (i) meaning interpretation, (ii) likes and dislikes, (iii) contextual preferences, (iv)

priorities of the information clusters across the user groups and (v) user usage patterns. As it mentioned set of automobile dashboards are chosen.

Objectives of the study

1. How utilitarian is the dashboard information?
2. Do users relate to dashboard interface personally or it is just a part of the car?
3. Do dashboard communicate what it is supposed to?
4. If not, why it is failing?
5. What is the Role of signs/symbols /graphics on the automobile dashboard in meaning making?
6. How they belong or not belong to the cultural context?
7. What are the user information preferences, likes and dislikes?

### 5.3 Study Design

User Study-II utilized three types of user-data gathering methods. Figure 5. 1 depicts the flow and different stages of the study.

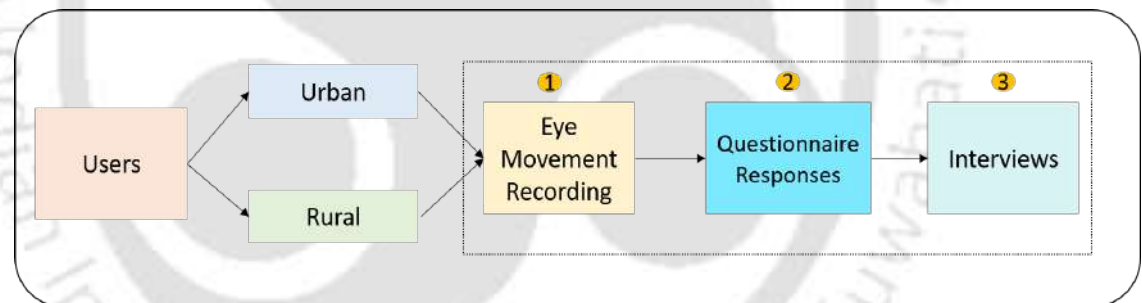


Figure 5. 1 Stages involved in user study-II

1. Eye Movement Recording (EMR)
2. Structured questionnaire
3. Semi structured Interviews

Eye Movement Record (EMR)/Eye Tracking:

EMR is widely used technique used in user interface evaluation, usability studies and various user studies employed to capture unbiased user response to a stimulus. Eye tracking technology records user's eye movements in terms of eye fixation and

saccade movements on given visual stimulus. Analysis of these two parameters are known to reveal visual and cognitive process of the users (Balkenius, Crosby, Ydewalle, & Findlay, 2003). Numerous studies (Çöltekin, Fabrikant, & Lacayo, 2010) (Bergstrom & Schall, 2014) have reported the efficacy and advantages of using the eye tracking. In this study, set of automobile dashboard stimulus prepared for uniform resolution and presented to the users on a digital display for eye tracking study. Tobii X50 Eye Movement Recorder was used for these study. Various modes of data such as Gaze Plots, gaze path and Cumulative hotspot data was recorded and utilized for analysis.

Questionnaire:

Questionnaire (See Annexure B: B1) aimed at capturing three different categories of user information as mentioned below a) Information priority and Utility value b) User likes and dislikes c) User Information Preferences d) Information Interpretation. Information interpretation was aimed at user's ability to recognize and interpret the meaning of the dashboard conventional signs. To find out how various Indian user groups can recognize graphical conventional signs and interpret the meaning, set of graphical conventional signs that are currently used on automobile dashboard are used (See Annexure B). Questionnaire information captured using multiple modes namely Likert scale (7 point), multiple choices questions and closed ended questions.

Semi structured Interviews:

Semi-structured interview was aimed on acquiring the information related to the users experience in using the dashboard information in their day-to-day experience, importance and dependency on the information while using an automobile, difficulties related to understanding information, ease of use of existing dashboards and other usage experiences.

#### **5.4 Method**

Automobile dashboards of cars that are currently used in India were chosen as stimulus for the study. Automobile dashboards are chosen as they have one of the

larger user base across the India. Stimulus was presented to the participant in two ways, one as three dimension stimuli through the smartphones based 3-Dimensional (3D) Virtual Reality (VR) headset and second stimulus as 2-Dimensional (2D) picture for Eye moment recording and open-ended question. VR was chosen mainly due to the feasibility it offered in a lab setting- bringing multiple dashboard designs into a single, controlled environment without needing physical setups. Importantly, VR-based studies by Bruno & Muzzupappa, (2010) show that, in a comparative evaluation of various product-assessment methods, VR-based studies produce results comparable to traditional approaches and yield similar outcomes. Likewise, Bordegoni, et al. (2009) applied VR to automotive design, demonstrating that it effectively supports design-assessment workflows. Together, these studies show that VR prototyping delivers valuable usability insights into layout and information presentation.

#### Stimuli preparation:

Five automobile dashboards interfaces of different makes of cars currently running on Indian roads were chosen randomly. Dashboards were photographed for 3D and 2D with a high-resolution camera and five sets of stimulus were prepared in stereoscopic 3D and 2D formats (samples shown in Figure 5. 2 & Figure 5. 3). Stimulus was presented to the participant in two mediums, one as three dimension stimuli through a smartphone based 3D virtual reality headset and second stimulus as 2D picture via a LCD (Liquid Crystal Display) monitor for EMR and open-ended question.



Figure 5. 2 Automobile dashboards used in the user study-II



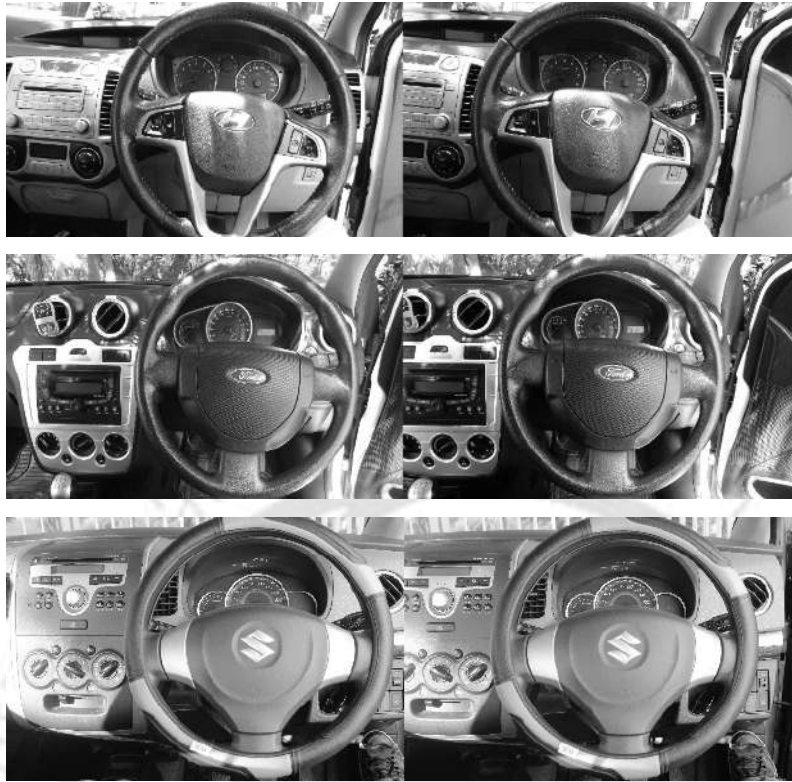


Figure 5. 3 samples of 3D stimulus used for VR immersive headset

## 5.5 Materials and Study Procedure

Study was conducted in a laboratory environment equipped with the tools required. Forty-two Participants of an age group of 20 to 60 years participated in the experiment. Subjects are from the different parts of India. The criteria for the participants are, Indians with minimal experience with GUI based products and exposure to automobile dashboard interfaces. All participants had prior experience driving and were familiar with dashboard systems. Studies shows that familiarity with a product domain enhance the number and accuracy of issues recalled (Sauer et al., 2010) . Details of the study are shown in Table 5. 1.

Step1:

Subjects were first sensitized with the 3D stimuli (Figure 5. 4) of test dashboards with the help of smartphone based 3D virtual reality headset (Merlin VR Immersive

lenses) to recreate the real-time environment. Then proceed for eye Movement recording.

Step 2:

Each subject was presented with 2D photographs of the test dashboards on a digital display monitor for the eye movement recording (EMR) (Tobii X50 Eye Movement Recorder). Each stimulus was displayed for ten seconds followed by a blank white screen for five seconds.

Step 3:

Responses for Pre designed Questionnaire were collected after EMR recordings. Users were informally enquired after the experiment and questions were asked based on their questionnaire responses and EMR hotspots. Study was conducted with forty-two subjects with an average data collection time of 5400 sec (90 Minutes) per subject.

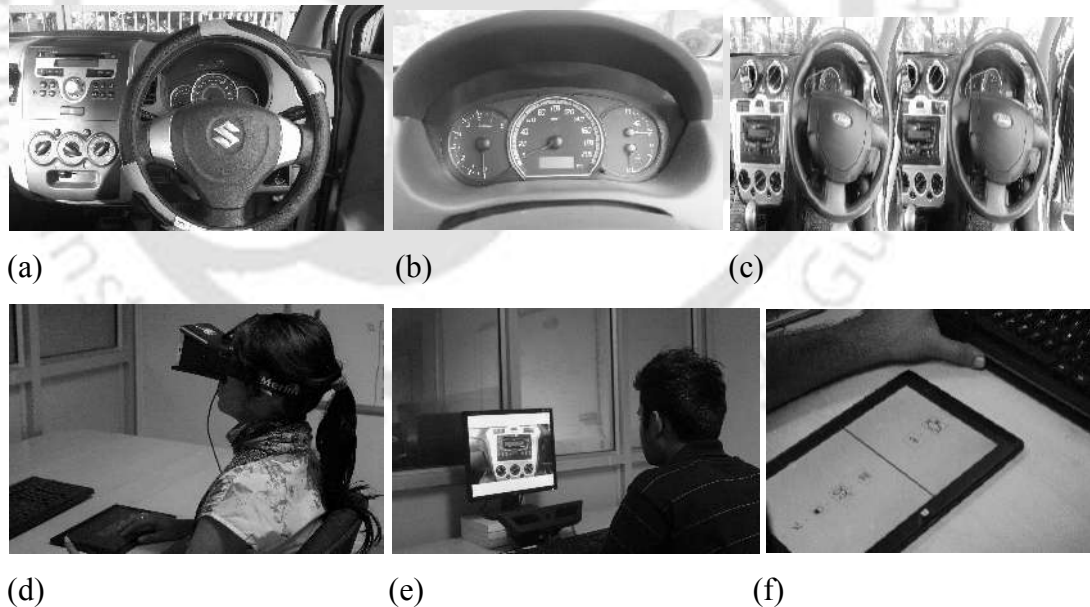


Figure 5. 4 Study stimulus, procedure in sequence. a & b sample 2D stimulus, c sample 3D stimulus, d & e 3D and 2D stimulus presentation, f dashboard graphic conventional signs

**Table 5. 1 User Study-II Characteristics**

Stimulus Used	Car Dashboards
Mode Of Stimulus	VR-3D,LCD Monitor
Stimulus Selection	On Technology basis
No of Dashboards	5 Models (14 stimulus)
No of Participants	42 ,valid 40 (23 Rural,17 Urban)
Participants characteristics	Target Users -(Rural & Urban) Female -4 Male-36 Age (20 -65 Yrs.) Urban-All over India Rural-Telangana
Data Collection Method	Questionnaire( $\alpha=0.79$ to 0.85), Interviews, Eye Movement Recording(EMR)
Analysis Methods	Descriptive stats, Content Analysis ,EMR cumulative Hotspot /Gaze plots

## **5.6 Data Analysis and Inferences**

As mentioned the user responses were collected on multiple modes, different analysis approaches (see Table 5. 1) were used. Based on nature of questionnaire and analysis used, results of the study are categorized in to five different sets as mentioned below.

Set 1: Information Importance and Utility

Set 2: Likes and Dislikes

Set 3: Language preferences –Assistive text and Voice

Set 4: Sign Comprehensibility-interpretation

Set 5: Eye Movement Recording Patterns

Set 1: Level of Importance of various Information

A car dashboard contains plethora of information in the form of display indicators, icons, knobs etc. A dashboard communicates various types information related to critical operational Features, automobile health, road and personal safety, self-comfort infotainment and other additional information. To use an automobile

efficiently, a user need to understand all this information and interact. In this question user were asked to rate level of importance that they feel of various dashboard indicators on a 7-point Likert scale. Each user was also asked for reasons for their preferences verbally. Aim of this question is to find information priority and utility value across rural and urban users. Descriptive statistical analysis method was used to find the mean values of the responses and the results were compared between rural and urban users (See Table B. 1 Annexure B).

Based on the Results (Mean Value) mentioned in Table B. 1 (Annexure B), in the rural context, the first priority is given to the features that are essential for an automobile to run. The second set of priority is given for intangible features, which are essential for safety such as indicators and headlamp. The next priority is given to the features such as health of the automobile and then priority is given for features of road safety, personal safety features such as tire pressure, airbag indicators. Lastly the priority is given to personal comfort features such as air temperature, and then to features that they consider as trivial such as current gear status, headlight intensity etc. Where as in the case of urban users the sequence of the priority is similar to the rural expect for the self-comfort and engine health. In the urban case self-comfort is important than the engine health where is in the rural it is opposite. Some Excerpt from the users verbal responses that highlight some of the priorities described by them are mention below

Rural Users:

*“The most essential information features are fuel indicators, engine health, turn indicators and the lights ,this features ensures me that my rides don’t get effected and do not lead to break downs. It is very difficult get any assistance in this village conditions”*

*“All I Need is the essential features and safety, rest all not much of important to me, I do not use anything that consumes extra of fuel”*

*“In the rural areas it is difficult to get any assistance or the repair of a breakdown eats up entire day or more, so the critical features are very important and at times I rely more on manual/physical inspection.*

Urban users:

*“Apart from the basic essential features such as fuel and engine health I need the AC since difficult to drive while there is traffic jam”*

*“I need to have all the information about the vehicle, priority goes to the comfort, entertainment and they are mostly used on a daily basis”*

From the verbal responses, it is observed that this preference sequence is attributed to the contextual driving conditions, needs and resource availability, for instance reasons mentioned in user’s verbal responses mentioned above.

Set 2: Likes Dislikes and Perceived factor responses

This set of questionnaire are aimed at capturing user’s response in four categories to the five dashboards chosen (Figure 5. 2). These categories are the users aesthetic and emotional responses (Ulrich, 1983) , perceived ease of use, perceived usefulness, most liked and disliked of the five dashboards (See Annexure B for Questions). For each question, users were asked to choose one appropriate dashboard as per their preference/perception. Each user was also asked to verbally describe their preferences. Descriptive satirical analysis was done to rank responses. The results are mentioned in the tabular form as below.

**Table 5. 2 Results showing user responses to the dashboards - Urban users**

<i>Dash Board</i>	<i>Aesthetic and Emotional</i>
Dash Board 1	2nd Most Irritating , 2nd Most Safe One
Dash Board 2	--
Dash Board 3	Less safe, Most Irritating, The Ugliest One Uncheerful one
Dash Board 4	--
Dash Board 5	Most Pleasant, 1 <sup>st</sup> Most Safe, Most Cheerful

<i>Dash Board</i>	<i>Perceived Ease of Use</i>
Dash Board 1	Most Difficult to read, Most Complex
Dash Board 2	--
Dash Board 3	Most Difficult to Read
Dash Board 4	--
Dash Board 5	Most Comfortable to read, Most Easy to Understand, Most Simple, Most Non Confusing.

<i>Dash Board</i>	<i>Perceived Usability</i>
Dash Board 1	One that has More Useless Items,
Dash Board 2	--
Dash Board 3	Most Useless
Dash Board 4	--
Dash Board 5	The most Useful, The Most Efficient

<i>Dash Board</i>	<i>Overall Preference (Most Liked and Disliked)</i>
Dash Board 1	2 <sup>nd</sup> Most Safe
Dash Board 2	--
Dash Board 3	The Less Safe, The Least Liked
Dash Board 4	--
Dash Board 5	The Most Liked ,and Safe



Figure 5. 5 Automobile dashboards

Table 5. 3 Results showing user responses to the dashboards – Rural users

<i>Dash Boards ( Figure 5. 5)</i>	<i>Aesthetic and emotional response</i>
Dash Board 1	The safest one.
Dash Board 2	
Dash Board 3	The Most Irritating, The Less Safe, Uncheerful, Ugliest
Dash Board 4	--
Dash Board 5	Most Cheerful, Most Pleasant,

<i>Dash Board</i>	<i>Ease of Use</i>
Dash Board 1	The Most Difficult to read, Most Complex
Dash Board 2	
Dash Board 3	The Most Simple
Dash Board 4	
Dash Board 5	The Most Non Confusing, Most comfortable to read, Most Simple, Most Easy to Understand

<i>Dash Board</i>	<i>Usable</i>
Dash Board 1	One That has Most Useless Items

Dash Board 2	--
Dash Board 3	--
Dash Board 4	--
Dash Board 5	The Most Useful, Most Efficient

<i>Dash Board</i>	<i>Overall Preference (Most Liked and Disliked)</i>
Dash Board 1	The Most Safe, The Most Liked
Dash Board 2	--
Dash Board 3	The Less safe, The Least Liked
Dash Board 4	--
Dash Board 5	2 <sup>nd</sup> Most liked

From the results above it is observed that that in both the rural and urban groups significant responses were given to the dashboard 1, dashboard 3 and dashboard 5 across all the categories. The responses with in a user group are similar for both Rural and Urban. A pattern of similarities and differences are observed between Rural and Urban are discussed below.

In the overall Preferences Dashboard 3 is the most disliked, least safe and not preferred across all both rural and urban groups. Dashboard 1 and Dashboard 5 are on the preference side, they are ranked differently between urban and rural .First preference in Rural is Dashboard 1 and then the dashboard 5 while in the urban case it is opposite.

In the rural user's case, it is observed that dashboard which is considered as most complex is also safest, most preferred and liked. From the rural user's verbal response it is understood that the complex appearance of the dashboard is considered as safe, complexity is perceived as an advanced technology therefore it is considered safe though it is difficult read. It also observed that the level of education seems to have effect on this preference the information understanding.

In the Urban case, dashboard that is simple to read is considered less irritating, safe, pleasant and most preferred. Urban users find the complex dashboard is distracting

therefore less safe. It is understood that in the urban user's case, the level of complexity is well understood therefore the preference for the easy to understand dashboard such as dashboard 5 (Figure 5. 5). Whereas most of the rural users do not know how to read therefore dashboard-1 information did not interest them since they did not understand most information elements.

### Set 3: Language preferences–Assistive text and Voice

This set of questions are aimed at knowing the users language preferences for assistive text/labels and voice assistance on the dashboard. Users were asked to select the language preference between their mother tongue and English. User were also asked if they have understood the labels on the dashboards indicators. Descriptive statistical analysis was used to analyse the responses. From the results (shown in Figure 5. 6 ) it is observed that language preferences are affected by the users education, there is strong relation between the subjects level of education and their language preferences (shown in Table 5. 4).

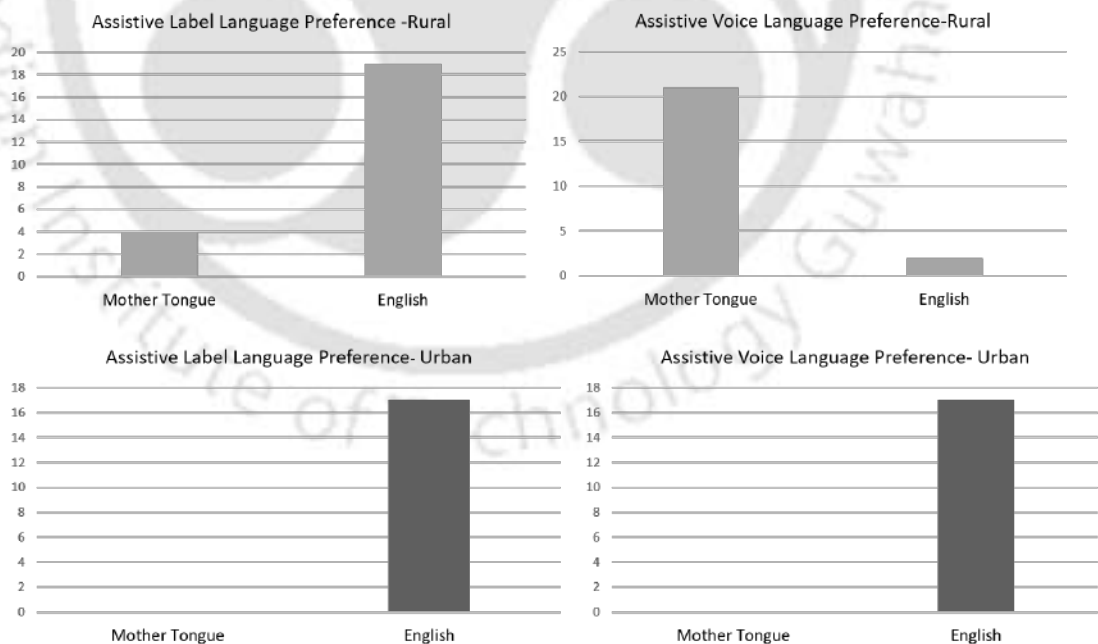


Figure 5. 6 Language preferences of urban and rural groups

**Table 5. 4 Users Language Preferences Divisions**

<b>Users Level of Education</b>	<b>Language Preference (Labels, Voice)</b>
Lower Primary-Primary	Mother Tongue , Mother Tongue
Upper Primary	English, Mother Tongue
Secondary	English, Mother Tongue
Graduation	English, English

From the content analysed data, it is observed that rural users depend very less on the dashboard utilities and they are trying to memorize few very essential indicators. It is also understood that language assistance in English is not useful across majority of the rural users.

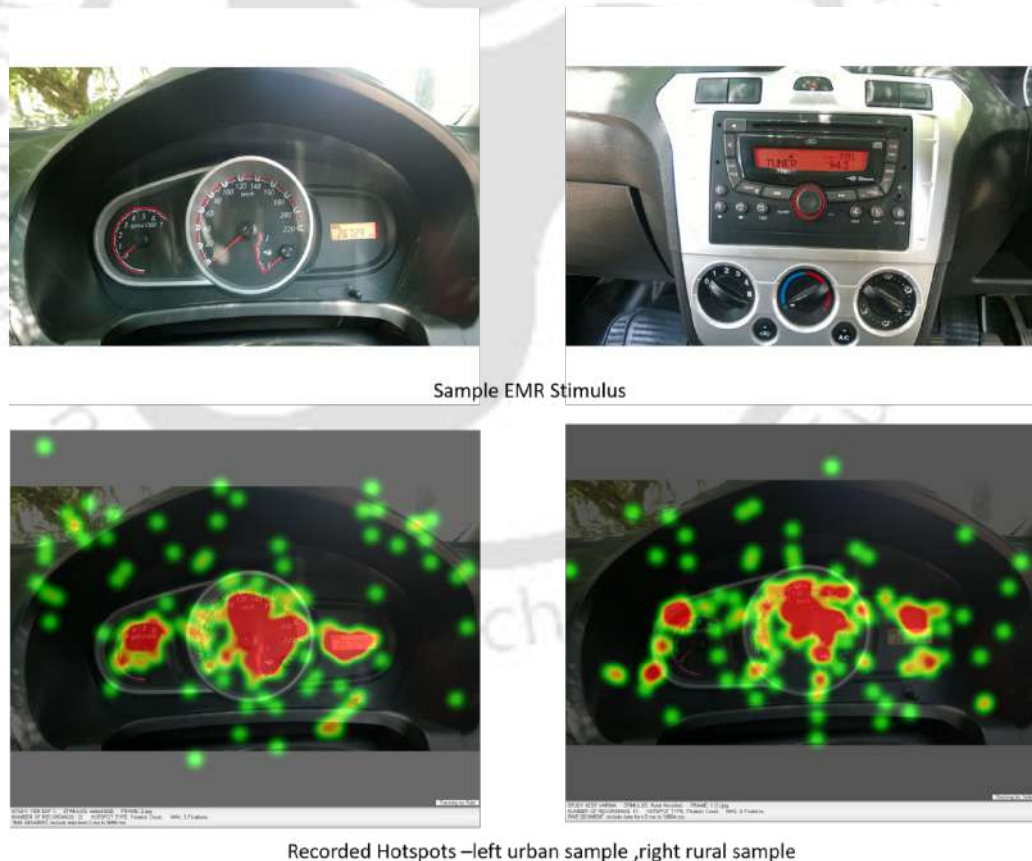
#### Set 4: Dashboard conventional signs comprehensibility

To understand user's ability to recognize and understand the meaning of various dashboard conventional signs a set of conventional signs (ISO: 2575:2010) that are currently used on automobile dashboard were chosen. In this questionnaire, users were asked to recognize the signs and their use. A descriptive method was used to analysis responses. Results shows that ninety percent of the users do not know the meaning and use of the ninety percent of the dashboard indicators. Majority of the users were able to recognize very essential indicators such as fuel level, direction indicators. Dashboard signs from ISO: 2575:2010 standard comprises a mixture of symbolic and iconic elements. Symbolic signs are conventions that need to be learned such as hazard sign and signs that are iconic in nature resembles the physical properties of thing being represented such as fuel indicator sign. Majority of the users were able to recognize the signs with iconic elements and very less on signs with symbolic elements. Users with relevant knowledge and education were able to recognize more number of signs as compared to others.

#### Set 5: Eye Movement Recording Patterns

Eye tracking technique captures two basic parameters that are eye saccades and fixation. Fixation time represented in the form of cumulative hotspots of all the subjects and eye gaze path are the two parameters/metrics used for the analysis. The time duration and path of the eye fixation on the visual stimulus reveals variety of information about the user’s visual and cognitive process. After a quick scan of any visual stimulus, a user looks at an information element or an object for a longer duration if that object is visually or mentally salient, attracting, important or distinct etc.(Goldberg ,Kotval 1999). The pattern of the fixation reveals the user’s perception of the interface, visual hierarchy, and mental floor plan of the interface.

Figure 5. 7 shows screenshots of few hotspot recordings of the study (see Annexure B for more). All the green spots on the stimuli are fixations (minimum count 3). As the fixation count on a specific object increases, spot turns red.



**Figure 5. 7 Sample stimulus and hotspots**

From the Figure 5. 8, it is evident that the gaze path and fixation patterns of the urban are different from the rural users. From the image, it is seen that the maximum spots are concentrated on information elements such as dials, icons, text, switches etc. across both the user groups. Differences are observed in terms of number of fixations on given stimulus, amount of information that is scanned (fixations) by both the user groups.

In the urban case, users were systematically scanning all the information objects and all were able to scan most or all the information objects for the given 10 second time/stimulus presentation time. In the Rural case, fixations are more scattered and were concentrated on fewer information elements. It is also observed that rural users missed to fixate on many of the information objects on the stimulus.

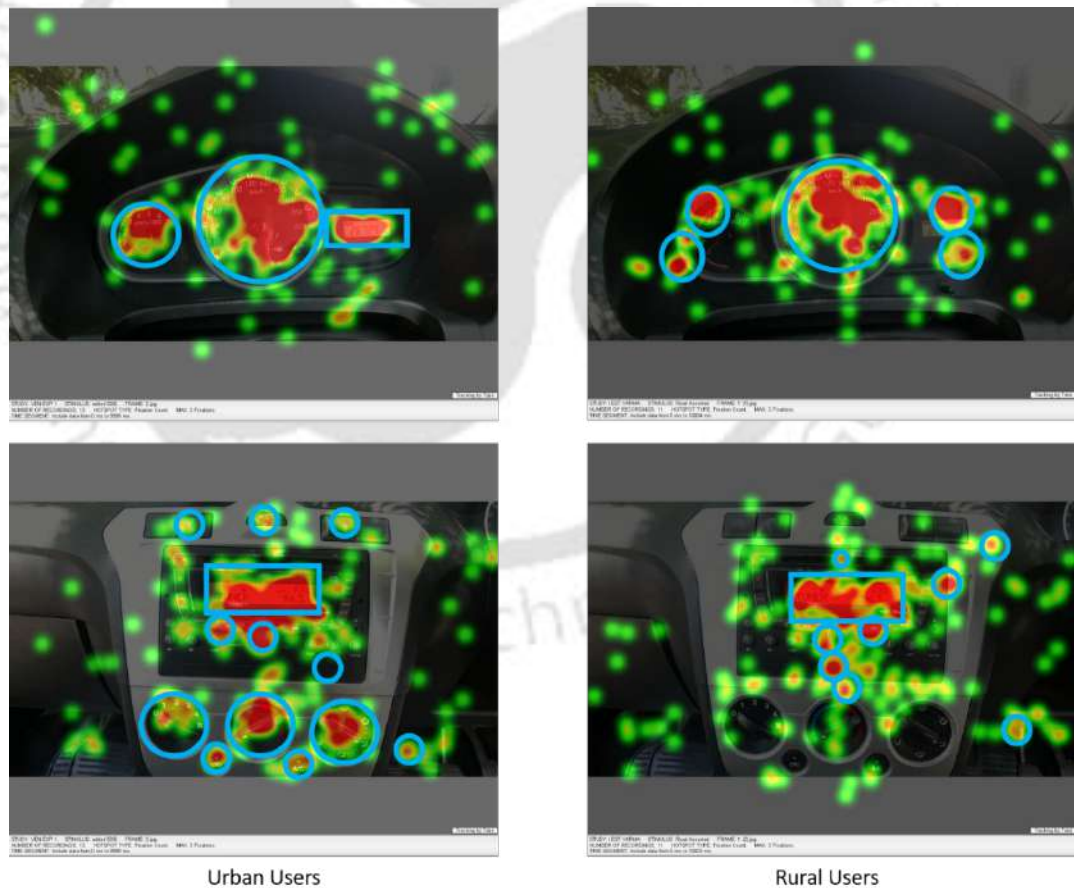
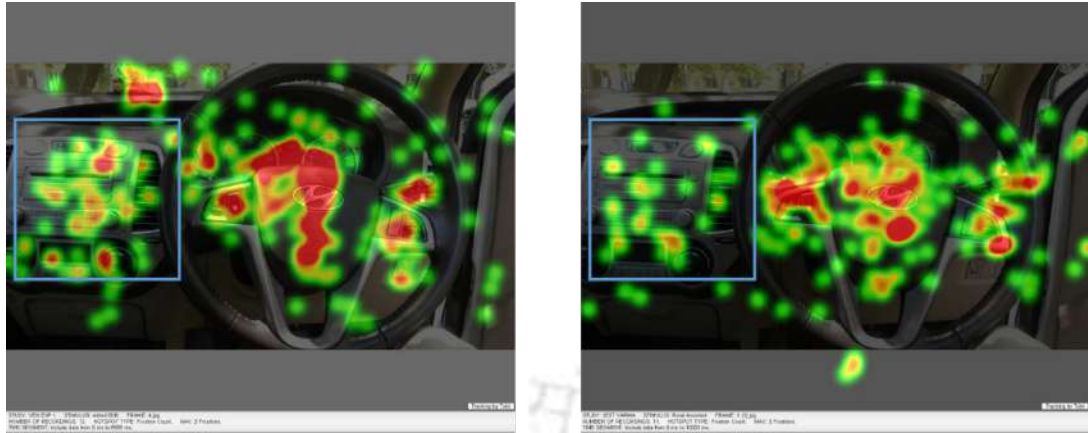


Figure 5. 8 Cumulative hotspots sample, left urban users, right Rural Users



**Figure 5. 9 Fixation patterns left urban, right rural**

For the entire stimulus presented, urban user group did not miss any textual information (see Figure 5. 9) whereas rural user group fixations were limited to the objects such as colourful dials, icons, and graphic elements and negligible on the text areas. As most of the assistive text or labels on the dashboard are in English, it is difficult for the rural user group to comprehend as majority do not know English language.

It may be inferred that load of information is high in the rural users case, as they are taking more time to understand the information elements, they were able to scan less number of information elements as compared to urban user group in given stimulus presentation time (see Figure 5. 8). It can also be inferred that they did not pay attention to these information objects as they are not useful or not of interest to the users therefore less fixations.

Rural users were comfortable with certain signs that are easy to understand and their dependency on labels is very less as labels are in English. It is observed that their preferences are dependent on the level of literacy and medium of language. A detailed language preference are presented in section 5.5 set 3

## **5.7 Summary of Findings**

User study-II is aimed at understanding Indian users in the rural and urban contexts. This study provides essential insights in to users interface information interaction patterns across contexts, how users interact with information systems interfaces, their information needs, utility value of the information and factors affecting them. It is observed that there exists differences across these two user groups and context is affecting information needs, preferences. Overall perceptual responses such as aesthetic and emotional responses, likes and dislikes of the user groups are understood. Through these observations factors affecting their preferences, likes and dislikes with respects to their overall appearance were identified. These observations are complemented by eye movement recording study findings. EMR patterns revealed user interests, amount information user groups able to conceive. Set of user segments are identified based on the literacy rate/level of education. Information Language preferences are varied across these users segments and influenced by the education level and medium of instruction. User's familiarity and ability to recognize various visual information is also understood from the dashboard conventional sign recognition test.

### **5.7 Inferred GUI design guidelines**

The research has identified user group segments, usage contexts, based on the various observations. Set of GUI design guidelines were inferred from the synthesis of user study I and II. Design guidelines that are inferred after synthesis of user study findings are mentioned below. Table 5.5 presents the empirical data and observations that support the development of these design guidelines.

Interface design guidelines:

1. Information Representation- Rural users have preference for Icon based visual representations than text-based information. A visual representation may be more sensible and informative to the user groups with low literacy. Preference of assistive

text along with icons is dependent on the education level of the user. Urban educated have preference for abstract graphical Icons along with text. Avoid using signs that are symbolic in nature.

2. Language preferences in voice assistance for navigation and Icon assistive text is dependent on users literacy/education level and medium of instruction they received therefore consider findings Table 5.4. Prefer native accent for voice and familiar

3. Interfaces such as energy meters should evoke the feeling safety since many users are scared to utilize the meters though they are very safe.

4. Provide sufficient live feedback on activity. Majority of the Users do not trust the way these products work for instance . In the energy meter use case, users do not see the meters working as Watt/Hour change slowly. May Improve least count and provide more live feedback on activity.

5. Rural users have high importance to the basic functions and critical features such as fare and monthly bill in the energy meter case. Unnecessary Complex information or axillary information can be avoided in the rural context.

6. Urban users prefer detailed information for instance in the energy meters interface a detailed energy consumption information in scientific units on time basis is preferable by urban users.

7. Pay attention to amount of information use on interface. Preference is varied across rural and urban and seem to dependent on the education, familiarity or technology literacy (See EMR observations).

**Table 5. 5 Empirical evidence for Guidelines**

S.N	Guideline	Empirical Evidence
1	<p>Information Representation- Rural users have preference for Icon based visual representations than text-based information. A visual representation may be more sensible and informative to the user groups with low literacy. Preference of assistive text along with icons is dependent on the education level of the user. Urban educated have preference for abstract graphical Icons along with text. Avoid using signs that are symbolic in nature.</p>	<p>The guideline is supported by findings from the sign comprehension (discussed under section 5.5 (Set 4) study involving 40 participants. Results showed that 90% of users could not recognize 90% of the dashboard signs from the ISO 2575:2010 standard, especially those with symbolic elements. However, signs with iconic elements such as the fuel level and direction indicators, seat belt signs were correctly identified by the majority, particularly by users with lower education levels. In contrast, urban and educated users performed better overall and preferred abstract icons when paired with assistive text. These findings empirically support the need for intuitive, icon-based designs for low-literacy users and context-specific adaptations based on education levels.</p>
2	<p>Language preferences in voice assistance for navigation and Icon assistive text is dependent on users literacy/education level and medium of instruction they received therefore consider findings Table 5.4. Prefer native accent for voice and familiar vocabulary for the assistive text</p>	<p>The Guideline is supported by the data collected on language preferences where findings from a study involving 40 participants. Users were asked to choose between their mother tongue and English for dashboard labels and voice navigation. analysis revealed a strong relation between education level and language preference ,users with lower education levels and non-English mediums of instruction showed a clear preference for native language and familiar vocabulary, both in text and voice. Conversely, more educated users were more comfortable with English. These findings validate the need to localize dashboard communication based on user profiles, including accent and vocabulary familiarity. More detailed 0language preferences are discussed in Section 5.5 (Set 3), Table.5.4 &amp; Figure 5.6</p>

3	Interfaces such as energy meters should evoke the feeling safety since many users are scared to utilize the meters though they are very safe	This Guideline is supported by the data collected from User Study 1, discussed in chapter 4 where majority of the users expressed the fear of approaching the Energy meter Interfaces, even with consumer interfaces that are away from the Hi-Voltage lines , In this study data is collected from 30 Subjects, across Urban and rural set-ups, The details of the study are discussed in chapter 4 section
4	Provide sufficient live feedback on activity. Majority of the Users do not trust the way these products work for instance . In the energy meter use case, users do not see the meters working as Watt/Hour change slowly. May Improve least count and provide more live feedback on activity	This guideline is supported by the data collected from User Study 1, discussed in Chapter 4, where the majority of users expressed a lack of trust in how energy meter interfaces function. In particular, users reported that they could not perceive any real-time activity, as the Watt/Hour readings changed too slowly, leading to skepticism about whether the device was working correctly. The study involved 30 participants from both urban and rural settings, and the responses were captured through semi-structured interviews and interface interaction sessions. As detailed in Table 4.4, users also highlighted issues such as complexity, low readability, and the presence of irrelevant technical information, all contributing to a disconnect in user trust. Therefore, the recommendation to improve the least count and provide animated or real-time feedback indicators directly stems from these observations, aiming to bridge the gap in user understanding and system transparency
5	Rural users have high importance to the basic functions and critical features such as fare and monthly bill in the energy meter case. Unnecessary Complex information or axillary information can be avoided in the rural context	This guideline is supported by the findings from User Study 1 and User Study 2, as discussed in Chapter 4 and Annexure B. In User Study 1, which involved 30 participants interacting with various energy meter interfaces, it was observed that rural users were primarily focused on

		<p>understanding their monthly bill and consumption in a simplified, recognizable format. Most users expressed difficulty interpreting technical readings and lacked trust in the meters, particularly because of insufficient feedback and the perception of unsafe or complex design. Many could not read the displays and only recognized the most familiar meter interface (Meter 1), while some showed interest in Meter 7, which used colorful and intuitive graphics. Similarly, User Study 2, which evaluated dashboard indicators in automobiles, found that rural users prioritized only essential functional and safety-related features over auxiliary or comfort-related information. As documented in Table B.1 (Annexure B), rural users consistently ranked core operational elements- such as speed, fuel, and indicator lights- higher than features related to vehicle health or user comfort. This pattern clearly reflects a strong preference for minimal, relevant, and easy-to-understand information among rural user groups, justifying the need to reduce complex or auxiliary content in smart energy interfaces for this demographic.</p>
6	<p>Urban users prefer detailed information for instance in the energy meters interface a detailed energy consumption information in scientific units on time basis is preferable by urban users</p>	<p>This guideline is supported by the findings from User Study 2, specifically from the analysis of information prioritization among urban users as discussed in Set 1 and Table B.1 (Annexure B). In this study, participants were asked to rate the importance of various dashboard indicators on a 7-point Likert scale, followed by qualitative responses. The analysis revealed that urban users, who were generally more educated and technically literate (as also reflected in User Study 1), consistently prioritized a broader spectrum of information- not just essential operational features, but also comfort, vehicle</p>

		<p>health, infotainment, and safety indicators. Verbal responses from urban users reinforced this trend, with statements such as “<i>I need to have all the information about the vehicle</i>” and “<i>priority goes to comfort, entertainment, and features used daily.</i>” Unlike rural users, urban participants valued comprehensive, detailed, and time-based data, which aligns with their familiarity with technology and higher cognitive capacity to interpret complex data. This supports the inference that urban users prefer detailed information displays, such as scientific units of energy consumption over time, in interfaces like smart energy meters- enabling deeper engagement and more informed decision-making</p>
7	<p>Pay attention to amount of information use on interface. Preference is varied across rural and urban and seems to dependent on the education, familiarity or technology literacy (See EMR observations)</p>	<p>This guideline is supported by the eye-tracking study discussed in Chapter 5, where fixation patterns and gaze paths were analyzed across rural and urban users to understand their visual processing of interface information. As shown in Figures 5.7 to 5.9, urban users systematically scanned nearly all information elements- including text, icons, and controls- within the 10-second stimulus window, indicating higher visual literacy and cognitive readiness. In contrast, rural users had scattered and limited fixations, focusing mostly on colorful, iconic elements while largely ignoring text-heavy areas, particularly those labeled in English. These differences in attention and comprehension suggest that the perceived information load is higher for rural users, often due to lower educational exposure and unfamiliarity with interface conventions. To support and validate the EMR patterns, verbal responses were also collected from participants, confirming that rural users found many elements either irrelevant or</p>

		<p>difficult to understand. Therefore, the amount and format of information should be adapted based on user literacy and technology familiarity, reinforcing the importance of iterative design that accounts for user-specific cognitive capacities (see EMR observations and Section 5.5 Set 3)</p>
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These guidelines are further evaluated thru an experiment where an experimental prototype interfaces for IoT enabled smart energy utilization interfaces (IESI) are designed using design guidelines. Guidelines were suitably adopted for IESI use cases are mentioned next chapter.

### 5.8 Chapter Summary

The chapter discusses a field based user study conducted with purpose to understand the users from the two Indian context namely Urban and Rural. Study aimed at understanding and model the users with respect to various information preference choices. Various UCD methodologies like field interviews, structured questionnaire and EMR were adopted for this investigation. Interface design guidelines for the contexts mentioned were inferred form the findings of user study I&II. Next Chapter 6 discusses the presents the adoption of inferential guidelines to design an IoT smart energy utilization scenario.

## 6. Validation of inferential Guidelines through new Interface Design

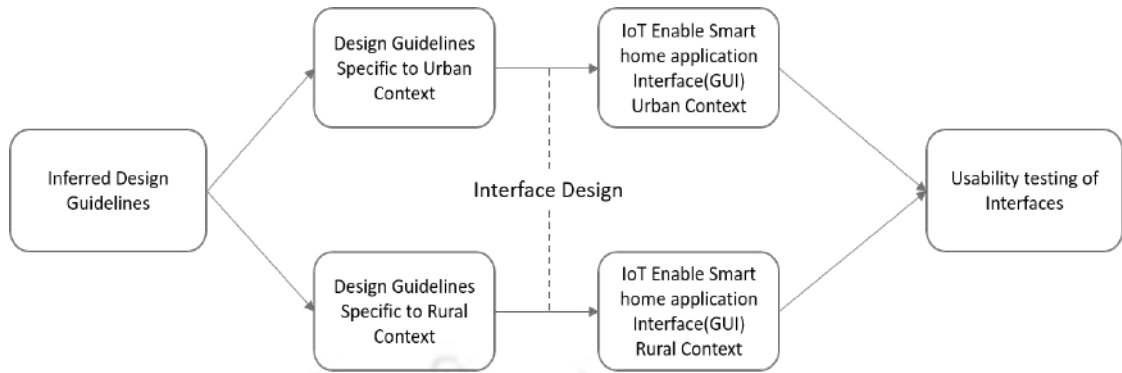
*Abstract: This chapter presents the adoption of inferential guidelines for an IoT smart energy utilization scenario. It explains design process and methods adopted for designing the IoT enabled smart home energy utilization prototype interfaces. It presents complete setup of IoT enabled working prototype design.*

### 6.1 Introduction

This chapter presents validation of inferential graphical user interface design guidelines for Indian contexts. This chapter starts with experimental model adopted to test and validate the inferential guidelines. This research has adopted a composite user-testing framework derived from usability testing methods to validate the inferential guidelines, presented in the following sections. This research is intended to design IoT enabled smart energy utilization interfaces (IESI) for the Indian contexts to test and validate the inferential guidelines. Interfaces were designed for two contexts namely rural and urban for usability testing and validation purpose. Both the version of simulated graphical user interfaces are implemented on workable IoT laboratory model using suitable electronic hardware platform (Raspberry Pi). A detailed description of the prototype design using inferential guidelines is presented in this chapter.

### 6.2 Inferential guidelines validation model

Design research framework adopted in this thesis requires a validation of inferred guidelines. A usability evaluation based method (Hartson, Andre, & Williges, 2001) is adopted to validate inferential interface design guidelines. A new validation framework is formulated as mentioned in the flow chart below (Figure 6.1), a holistic approach of design and testing was adopted where for various versions of interfaces are designed and a usability testing is conducted.



**Figure 6. 1 Inferential guidelines validation approach**

This thesis has taken household IoT enabled smart energy utilization system scenarios for validating inferential design guidelines.

### **6.3 IoT Enabled Smart Energy Utilization**

Prior to designing user interfaces it is imperative to understand the current energy utilization sector in India .This section discuss present Indian energy utilization scenario, users interaction with energy utilities and ongoing developments towards IoT policies in energy sector. The depictions of rural and urban energy-use scenarios presented in here build directly on the issues surfaced in the Chapter 4 user study. In Chapter 4, we observed that meters in both settings suffer from poor readability, mismatched semantics, and low trust, findings that stemmed from users' real-world interactions with existing devices. By mapping those issues onto the everyday routines of rural and urban households, This section explicitly explains how the current interaction context informs and motivates our IoT-enabled interface designs. In other words, the usage flows and control points identified here are not hypothetical: they are grounded in the same fieldwork that revealed users' struggles in Chapter 4, and thus serve as the foundation for crafting and validating the inferential GUI guidelines in the following chapters. By grounding our IoT-enabled prototype scenarios in these present-day energy routines, we can ensure that the interfaces we

design for tomorrow's smart meters address today's pain points and anticipate how users will interact once devices become fully networked.

Energy utilization in the IoT Context / current developments:

Energy Efficiency Services Limited (EESL), a government body of the India has started replacing existing energy meters with smart energy meters (EESL, 2015) under Smart Meter National Programme (SMNP). With the smart metering, certain services can be digitized such as existing manual billing, billing formats, availability of billing data, utilization trends that can be delivered to user via electronic medium such as mobile or electronic mail services.

With the further advancements in energy distribution such as smart grid systems , energy transaction between users and energy service providers is going to change such as every individuals can generate energy at homes and can sell the excess generated energy back to the energy companies or neighbours. Moving ahead in this direction, future energy utilization services will be IoT enabled. Globally many countries have already started their IoT policies in several sectors and India is taking steps towards the same (India Draft IoT Policy 2016 ), with the use of IoT technology many of the energy utilization services will be digitized. Figure 6. 2 depicts energy utilization in IoT scenario in general. In this IoT scenario various energy utility control and consumption metering is integrated in to a common platform for user interaction. As discussed in the chapter 2 section 4 earlier, domestic energy utilities are getting IoT enabled ,where user interaction with the various energy appliance can be done via a single user interface application across multiple platforms from anywhere on the earth.

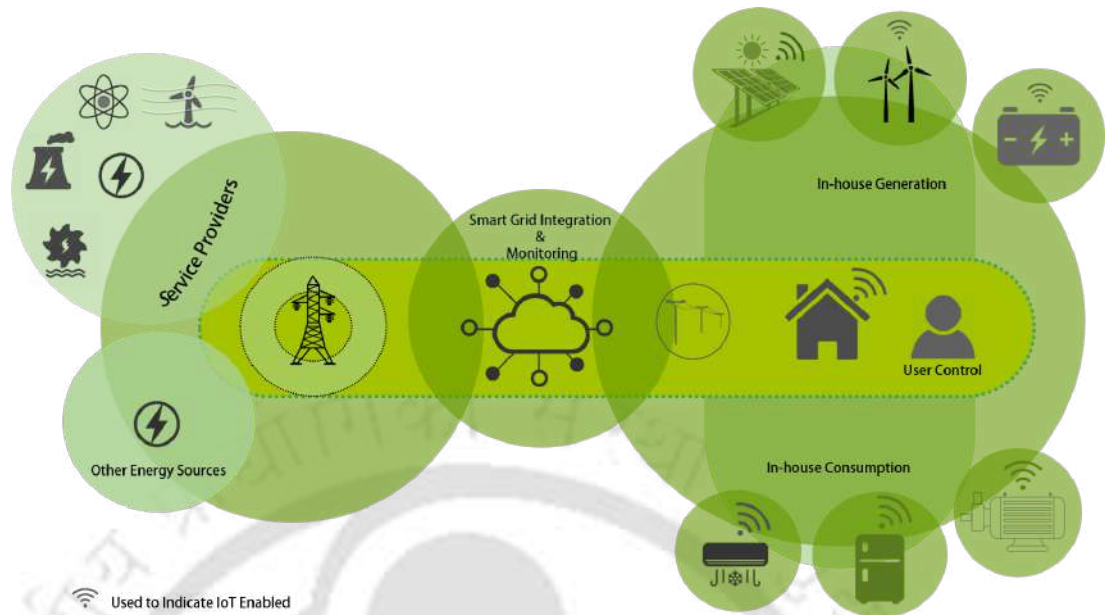
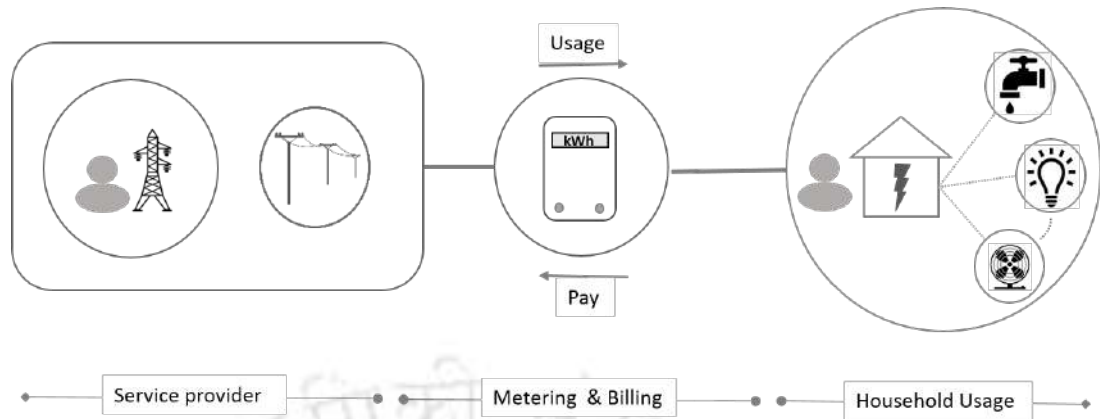


Figure 6. 2 depicting energy utilization in IoT scenario source: Author generated, Inspired from HP IoT 2013

As mentioned, the intention here is to design the IoT enabled smart energy utilization interfaces (IESI) for various Indian rural and urban application scenarios, we first tried to understand present energy utilization scenarios and user interaction across Indian rural and urban contexts.

Current Status of Energy Utilization in household domestic context:

Electricity consumption in India can be categorized in to four sectors that are industrial, domestic, agriculture and commercial (Energy statistics report 2017). Electricity generated at powerhouse is distributed to various places by a public service company. A typical energy usage activity of a household comprises of controlling appliances and paying for consumed energy to electricity service providers on monthly basis. Figure 6. 3 shows the current energy usage scenario of an Indian household



**Figure 6. 3 depicting energy usage scenario of an Indian household, Source: Author generated, Inspired form Energy census India 2011**

Currently interaction with electrical appliance such as household lighting, water pumps etc. is largely done through in-house controls or manual switches and consumption monitoring billing is done via a metering device which also known as energy meter. At present, the common interaction point between energy users and energy service providers is the meter interfaces and static billing services. These metering devices gives a cumulative sum of the consumption (kWh). At the end of every month energy billing is manually done by an billing operator at each house and the bills can be paid to the service provider manually by cash or through an online payment portal in some areas (mainly urban and semi urban areas).

According to the census (Census, 2011) , human settlements in India are categorized in to rural and urban areas. In this two areas the usage scenarios and utilities of the electricity is largely influenced by the life settings. An Individual Urban user use of electricity largely limited to domestic purposes whereas rural user use for both domestic and agricultural purposes. In the urban areas, there are certain utilities that are already digitized such as paying bills, Figure 6. 4 and Figure 6. 5 depicts Energy utilization scenarios of rural and urban users respectively.

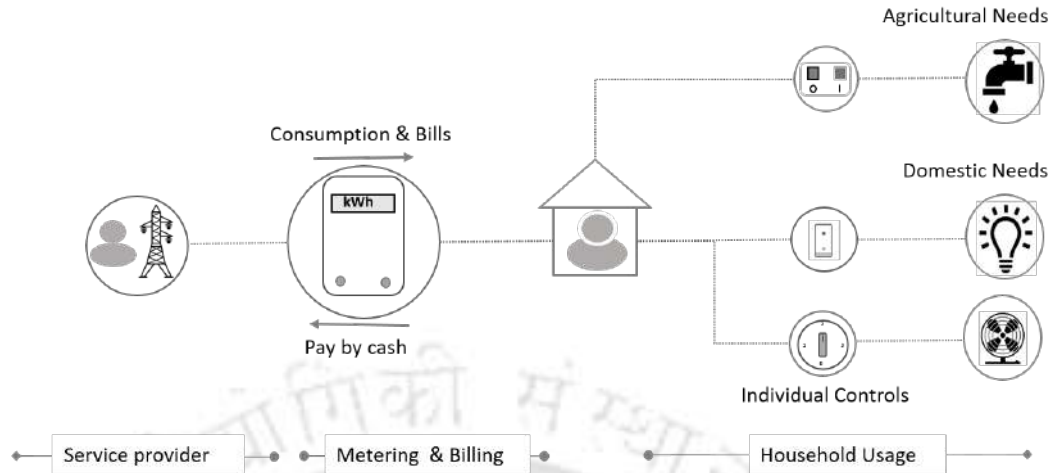


Figure 6. 4 depicting energy usage scenario of an Rural Indian household, Source: Author generated, Inspired form Energy census India 2011

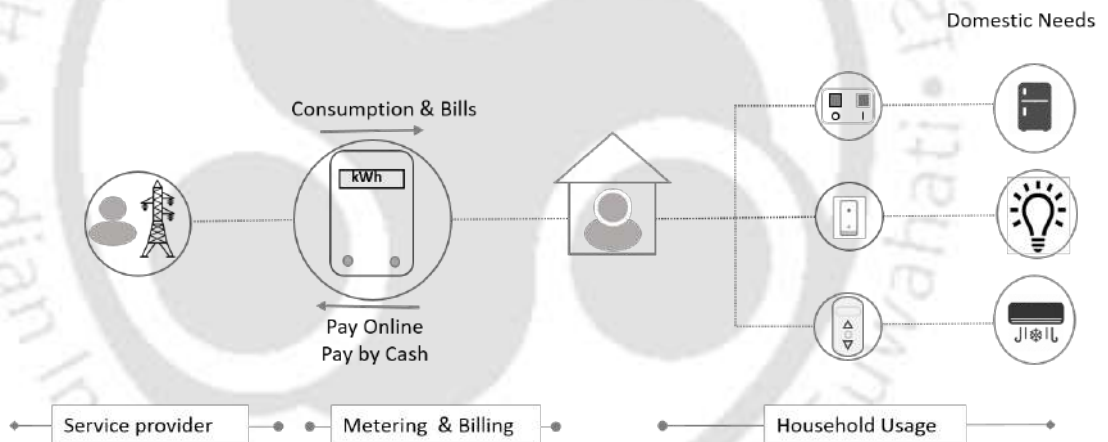


Figure 6. 5 depicting energy usage scenario of an Urban Indian household, Source: Author generated, Inspired form Energy census India 2011

Discussion above on current energy usage scenarios was taken as a basis for selecting tasks to design simulated IESI interfaces. Following sections presents the design of simulated IESI interfaces.

## 6.4 Designing simulated IoT enabled energy smart energy utilization interfaces

Designing interfaces started with feature ideation conceptualization in the IoT energy utilization context. Features of the IoT Interface system were selected based on the activities that takes place in the energy utilization scenario in general and specific to context. Table 6. 1 shows tasks and activity categories that takes place in energy utilization scenario segregated based rural and urban use contexts and the individual tasks that were considered for design.

**Table 6. 1 Task categories considered for design**

Rural	Urban
1.Device Controlling Task -Switch On/Off Lights Task-Watering Paddy Field	1.Device Controlling Switch On/Off Lights Controlling Air Conditioner
2.Energy Transactions Buy Electricity Sell Electricity Lend Electricity Borrow Electricity	2.Energy Transactions Buy Electricity Sell Electricity Lend Electricity Borrow Electricity
3.Consumption and Generation Details Checking Electricity Consumption& Generation Details	3.Consumption and Generation Details Checking Electricity Consumption& Generation Details
4.Energy Bills Checking Billing related Information(Payments ,Earnings)	4.Energy Bills Checking Billing related Information(Payments ,Earnings)

In the process of designing, each task was understood with respective to user needs, expectations, activities that takes place in a task. Inferential guidelines mention chapter 5 for adopted for the touch based IESI use case.

The 14 inferred guidelines were adopted and contextualized from the original 7 guidelines to suit the specific design requirements of IoT-enabled smart energy (smart home) interfaces. While the original 7 were derived from user studies conducted in different contexts ,namely, conventional energy meter use (User Study I) and automobile dashboard Study (User Study II) they provided foundational insights into user preferences, comprehension, and interaction behavior. However, when we move into the IoT context, additional complexities crop up, such as multi-modal controls, live feedback loops, and remote access all change how people work with interfaces. To address this, we needed to adopt our guidelines so they fit these new tasks and technical possibilities. This adaptation of design guidelines to match evolving contexts and technologies is a widely accepted practice in HCI and UX research (Holtzblatt & Beyer, 1997) (Hirsch et al., 2024) (Mohammed & Karagozlu, 2021) . Thus, the inference and re-articulation of these 14 context-specific guidelines ensure that design decisions for smart energy interfaces are both user-centered and domain-relevant. Table 6.2 Shows the how the context specific guidelines are adopted.

#### Inferential guidelines adopted for IoT GUIs

1. Information Representation- Rural users have preference for Icon based visual representations than text-based information. A visual representation may be more sensible and informative to the user groups with low literacy. Preference of assistive text along with icons is dependent on the education level of the user. Urban educated have preference for abstract graphical Icons along with text.
2. Preference of less text, Intuitive graphic interfaces is more among rural users compared to heavy text interfaces.
3. Using of heavy graphical representations has less preference among the urban users.
4. Use of Mother tongue as assistive text among rural semi educated users will have positive affect on understanding information, interface navigation and task completion.

5. Voice navigation guidance and assistance in mother tongue will have positive affect on understanding information, interface navigation, task completion among rural illiterate users.
6. Voice navigation guidance in mother tongue and assistive text in English is preferred among rural educated users.
7. Use of English for both assistive and voice assistance text will have positive affect on task completion among the urban users
8. Semantics of the Information –Avoid using signs that are symbolic in nature, prefer icons that are culturally and contextually familiar -specifically in rural context, use of cultural and contextual sentiments may affect impact on perceived meaning positively.
9. Interfaces should evoke the feeling of safety since many users are scared to use energy utility interfaces though they are safe.
10. Provide sufficient live feedback on activity. Majority of the Users do not trust the way these products work, may use animated icons and simulated activity indicators of activity.
11. Rural users have high importance to the basic functions and critical features such as fare and monthly bill in the energy meter case.
12. Unnecessary Complex information or axillary information can be avoided in the rural context.
13. Urban users prefer detailed information for instance in the energy meters interface a detailed energy consumption information in scientific units on time basis is preferable by urban users.
14. Pay attention to amount of information use on interface. Preference is varied across user groups and dependent on the education, familiarity or technology literacy. Amount of information can be reduced by avoiding use information with less utility. Proceed with an iterative approach.

Table 6.2 shows how the 14 inferred guidelines adopted from original 7 guidelines discussed in chapter 5.

Adopted Guidelines for IoT Context	Derived From Guideline	Explanation
Guideline 1	1	Directly relates Guideline 1 "Information Representation" and education-based visual preferences.
Guideline 2	1	Expands on rural users' inclination towards Icon based Signs and less text interfaces.
Guideline 3	1	Builds on urban users' preference for clean, abstract design paired with text.
Guideline 4	2	Tied to language preferences based on literacy and educational background (Table 5.4).
Guideline 5	2	From guideline 2 – speaks to oral understanding in low-literacy contexts.
Guideline 6	2	From Guideline 2 -Rural educated user preference based on bilingual literacy where the educated users are comfortable in reading assistive text signs and comfortable in mothertongue for voice instructions
Guideline 7	2	Reflects urban-educated users' English proficiency and comfort.
Guideline 8	1	Sign comprehensibility in low-literacy groups aligns with "Information Representation."
Guideline 9	3	from guideline 3 – addresses emotional design and trust in interface safety.
Guideline 10	4	From guideline 4 – emphasizes real-time responsiveness and animated feedback.

Guideline 11	5	From guideline 5 – about focusing on essential information in rural energy meter use.
Guideline 12	5	From guideline 5 – eliminating cognitive overload in rural contexts.
Guideline 13	6	From guideline 6 – urban users expect deeper, time-based technical information.
Guideline 14	7	From guideline 7 – calls for user-adaptive information density and design iteration.

Inferential design guidelines were utilized alongside the existing established design principles and knowledge in the design process. Figure 6. 6 shows the design flow used to create the IESI prototype. Grounded in User-Centered Design (UCD) principles, this generic flow follows the steps of understanding the context, designing solutions, and iterating on them. The diagram offers an overview of how the IESI prototypes were tailored to the specific use cases listed in Table 6. 1. Since this thesis aims to validate heuristics drawn from previous studies, those heuristics are applied at different phases of the design process, providing guidance for the development of the IESI prototype.

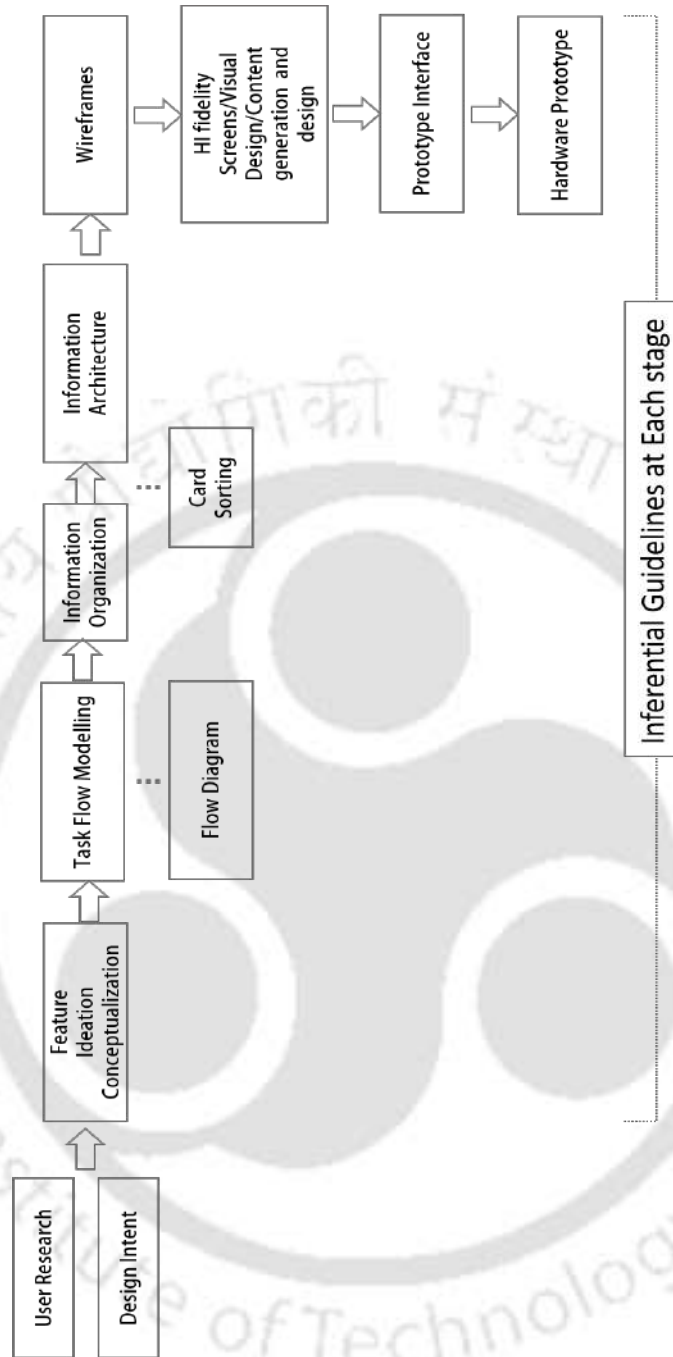


Figure 6. 6 depicting design flow of IESI prototype

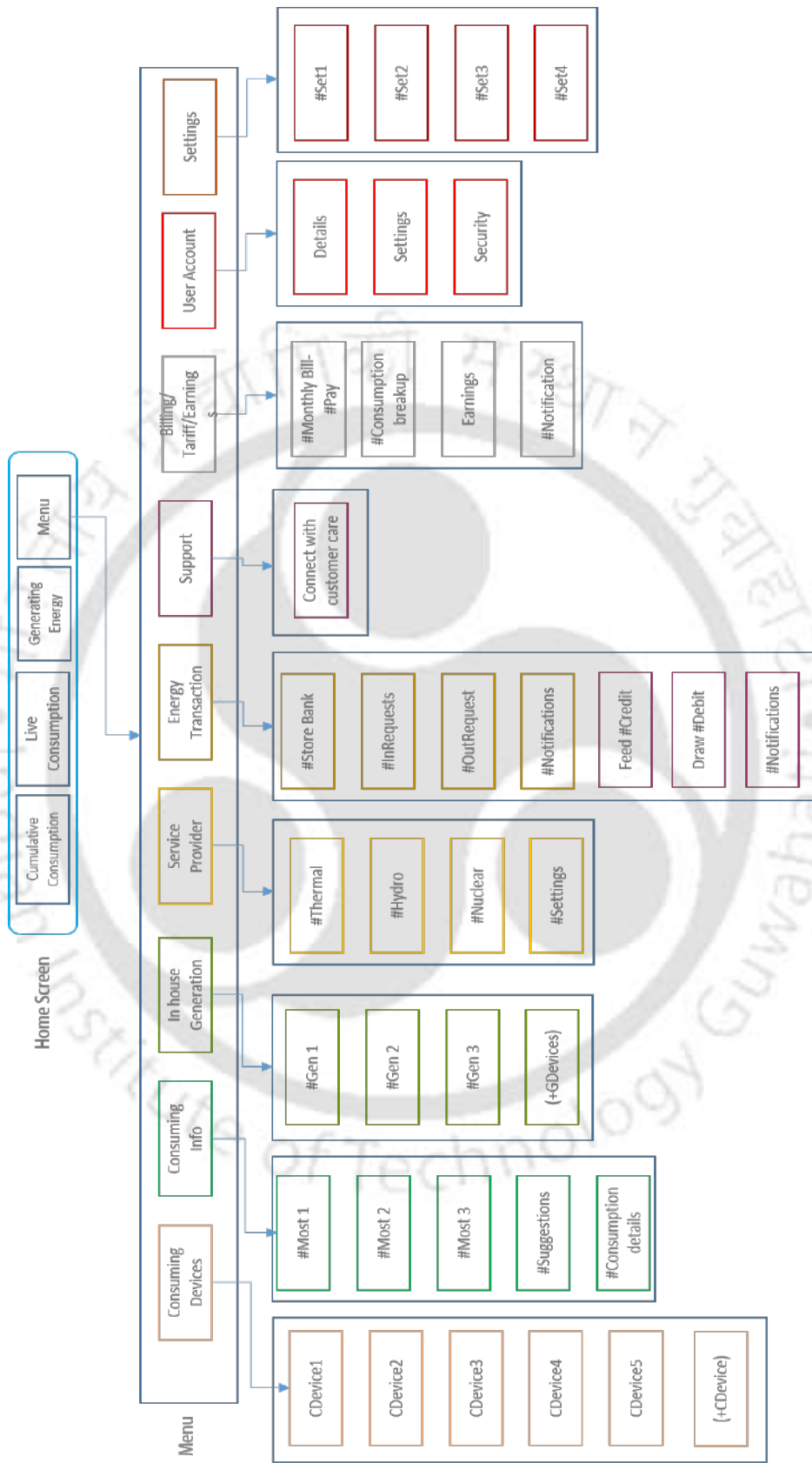


Figure 6. 7 showing information architecture of IESI prototype

Figure 6. 7 provides a comprehensive visual representation of the Information Architecture (IA) for the IESI Prototype, the levels shown are the arrangement and organization of tasks, navigation, and other key elements. Information Architecture, in this context, serves as a blueprint that outlines how users will navigate through the application and interact with its various components .The Information Architecture depicts how different tasks and functionalities are structured within the application. This includes the grouping of related tasks, defining the hierarchy of tasks, and ensuring a logical flow of actions for users. Out of the entire application design, here we are presenting two use cases that are

- 1) IoT enabled irrigation motor control for watering paddy field (Rural)
- 2) Energy Buy (Urban)

Remaining tasks can be found in the Annexure C.

Semantic Design Methodology:

Before delving into these specific use-case task designs, we first outline the semantic approach that guided every information element in our IESI prototype. As mentioned in the design flow (Figure 6. 6), Semantic Design Methodology here refers to a design approach wherein information elements are developed using methods with the primary goal of conveying intended meaning to users. To achieve the intended meaning effectively, this methodology advocates for or implies expansive design methods, not confined but fundamentally, user-centred methods principles such as Product semantics (Klaus Krippendorff, 1989)((T. M. Karjalainen, 2005) and semiotic theories (Atkin. A, 2010). The initial stages of this process entail gaining an understanding of the meaning intended for communication to the user. This understanding encompasses factors such as context, user group culture, demographics, and other pertinent considerations. The second stage is designing information elements. Stage 3 is evaluation and iteration of the designed information elements.

## Stage 1:

### Understanding User:

Understand users, their preferences, and cultural contexts. This step involves gathering data on user behaviours, expectations, and communication preferences.

### Understanding Context:

Analyse the context in which the design will be experienced. Consider the environment, user goals, and any specific circumstances that might influence how information is perceived. Methods such as contextual inquiry, field observations can be used.

### Cultural Considerations:

Take into account cultural nuances and sensitivities. Design elements should resonate with the cultural background of the users to ensure meaningful and relatable communication.

### Demographic Understanding:

Understand the demographics of the user base. Different age groups, educational backgrounds, and professional experiences can influence how information is processed and interpreted.

## Stage 2: Design

Design in regards to a GUI has to consider all the elements that makes it up, that means individual information elements that are icons, colour, assistive text and the composition of all these elements following an Information hierarchy and navigation of a whole task or between GUI screens. A semantic approach recommends to Utilize culturally, contextually, and demographically based cues to meaningfully design information elements and integrate information hierarchy, UI layout, and navigation elements, with visual breadcrumbs enhancing user guidance and cohesion.

### Stage 3: Evaluate and Iterate Design

#### Meaning Validation

A subject-matter expert first conducts a formal semantic analysis- deconstructing each sign into its basic cues (shape, color, form, context) and evaluating, with the target user in mind, whether those cues align with the intended message. If further confirmation is required, present the same prototypes to representative users and ask them to describe what each icon, label, or visual cue conveys. Note any mismatches between intended, expert-validated, and user-perceived meaning, then iterate accordingly.

Designing each specific task followed this same pattern: first understanding the usage scenario and context, deriving the design problem, and then designing according to the user's needs derived from present energy utility applications and inferential guidelines. Informal interactions were conducted with the users as and when required. For instance, an interaction with farmers to understand the agricultural field-watering task in general and to fill in any gaps in real-world detail.

#### 6.4.1 Use case task designs

The use cases have been chosen not as speculative scenarios but as natural extensions of the tasks that users across rural and urban contexts already perform. In Chapter 4, we saw farmers manually switch irrigation motors -activities that surfaced in our field interviews. By transplanting these very same routines into an IoT framework, we ensure that our IESI interfaces remain firmly rooted in users' lived experiences. Thus, our scenario grows naturally from the present-day practices users described.

- 1) Task design for use case: IoT enabled irrigation motor control for watering paddy field

Task category: Agricultural device controlling - Consuming devices-Rural context

Scenario: Watering paddy field in IoT scenario

Understanding scenario:

In rural Indian farming, irrigation motors are widely used to water paddy fields or any other crops. Farmers use electric irrigation motors daily depending on the stage of crop growth. In the process of watering a field in current farming scenario, a farmer needs to personally inspect various factors such as moisture content of soil, weather conditions, availability of electricity or electricity timing in some areas. Moreover, they need to be at the field until the watering task is finished. In the present condition, irrigation motors are manually operated from a switching panel present at the field.

For the use case discussed above, we intend to design an IoT enabled irrigation motor control interface to cater needs of a rural farmer in a way he/she can understand and operate efficiently.

Figure 6. 10 show the task flow of the IoT enabled irrigation motor control. Due to IoT technology, information required to make decision on watering paddy field such as weather information, soil moisture content etc. can be presented on user interface in real time without a need for user to be present at the paddy field.

Based on understanding of the scenario, user preferences task modelling was done. Figure 6. 10 depicts the task modelling for water paddy scenario. Understandings of the use case and inferred design guidelines from user studies were utilized in the design process. For instance, as per the inferred design guidelines (chapter 5), number of information elements are reduced for rural users as compared to the urban user interfaces. Assistive text language in mother tongue and voice navigation assistance in local accent was used. Emphasis was given to semantics of information, context while designing and organizing the interface screens. For instance, (see screen 1.4 below) to convey soil moisture information to an Indian rural farmer showing cracks in the field conveys the moisture content effectively than showing moisture numerical data. Therefore, a graphical representation that simulates the moisture content /cracks

in the soil in real time is used in the design. Likewise, the weather information without numbers was also simulated in real time, which is a primary decision maker for watering paddy. Iteration was done for each information element and screens until each element reaching intended meaning (see Figure 6. 8 Figure 6. 9). For instance, for the icon shown below



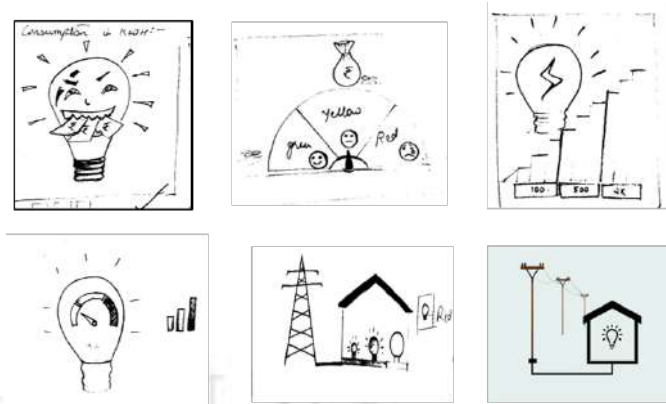
Intended meaning of the Icon: Energy Bill

Semantic Cues:

- a) In Indian culture right hand is used pay money to someone
- b) Most of the domestic chores such as paying bills is handled by women
- c) Suite Sleeve on the left represents the service provider and someone who is collecting



Figure 6. 8 Icon design iterations for Bill pay



**Figure 6. 9 Icon design iterations for live energy consumption**

Figure 6. 11 depicts information architecture of the task. Techniques such as flow diagrams, card sorting was used to finalize the task modelling and to organize information architecture. Wire frames shown in Figure 6. 12 were used before iterating for the final screen design. A design audit was conducted under expert guidance for overall design and communicability. Screen 1.1 to Screen 1.6 shows final screens of the paddy field task, screens are presented in the interaction flow model starting from the main home screen of the IESI application.

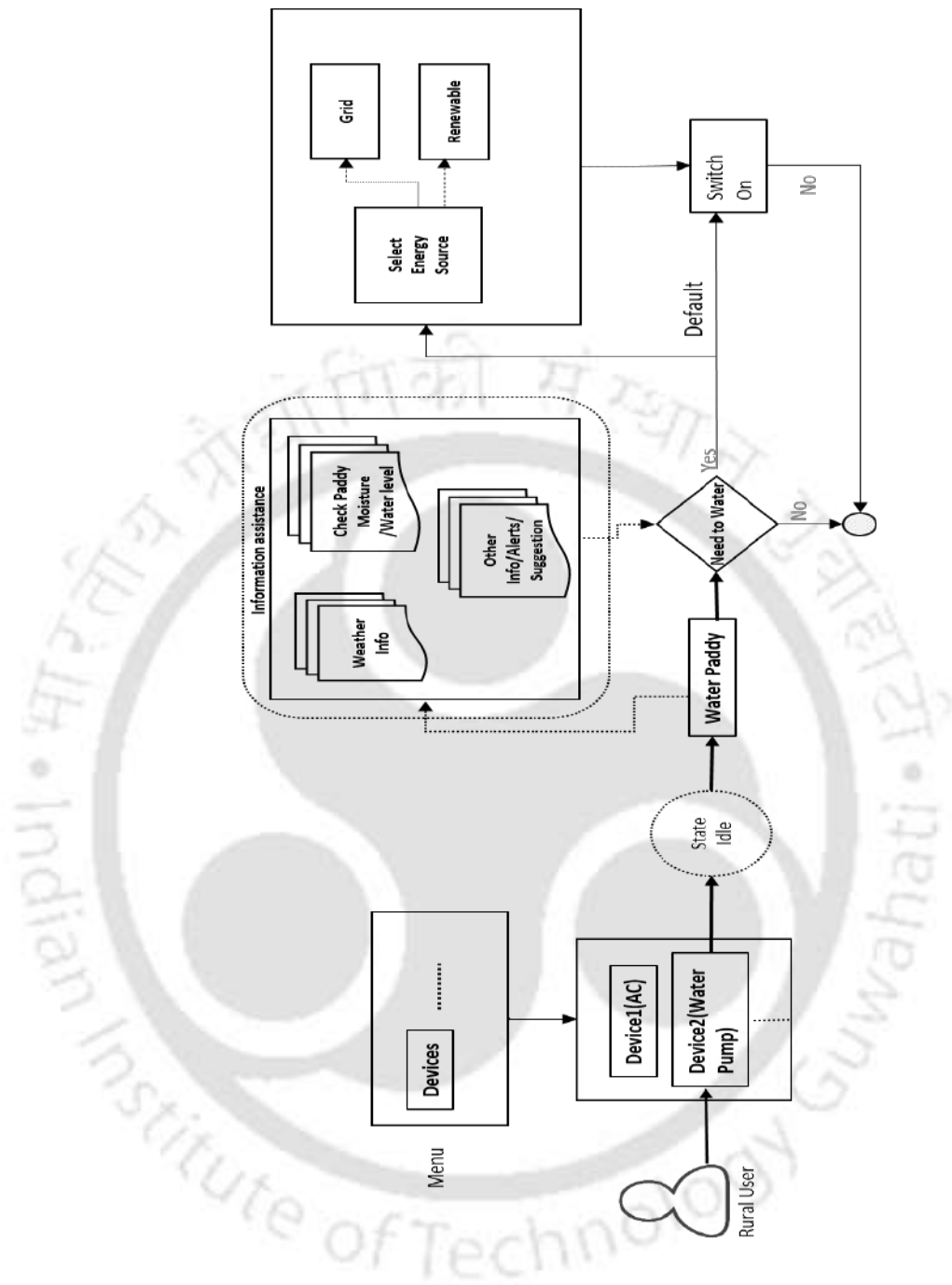
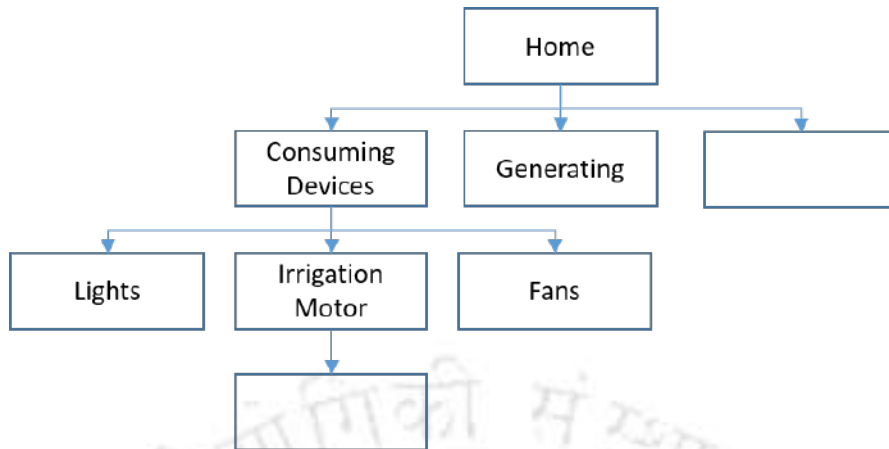
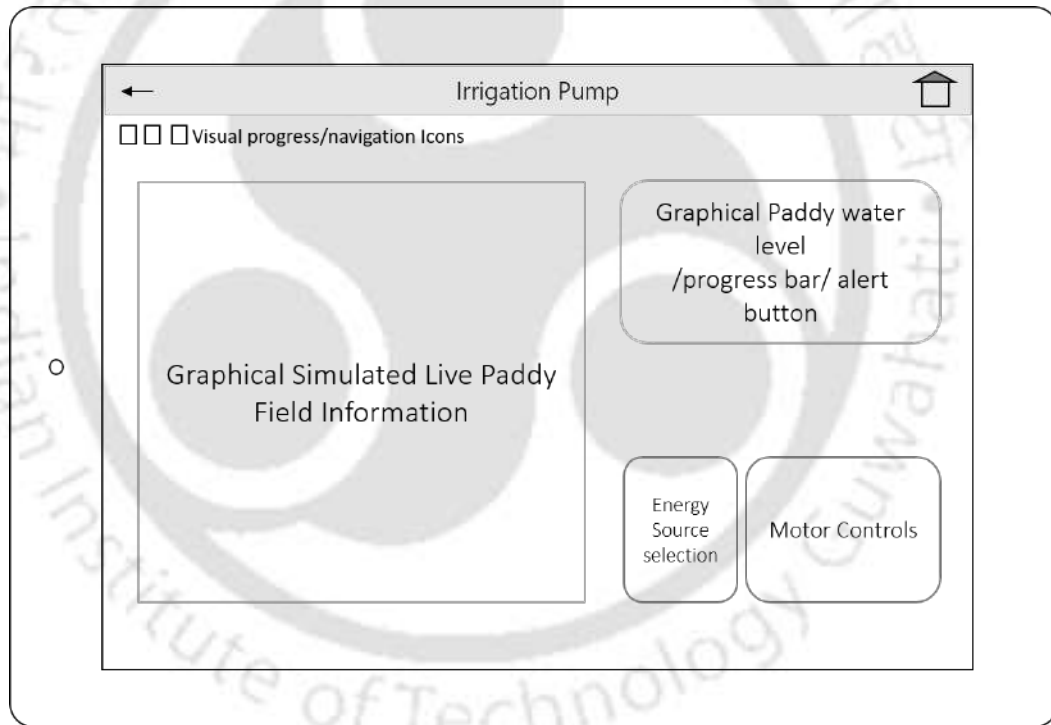


Figure 6. 10 Task flow of the IoT enabled rural irrigation motor control

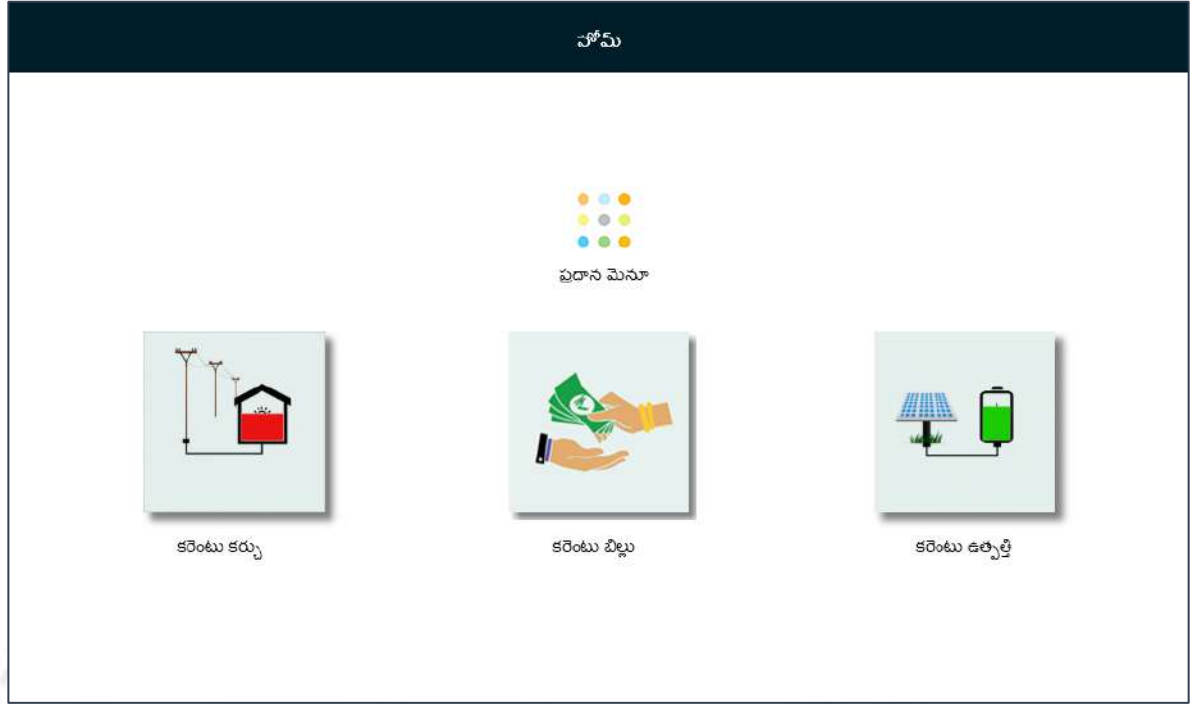


**Figure 6. 11 Information architecture of IoT enabled rural irrigation motor control task**

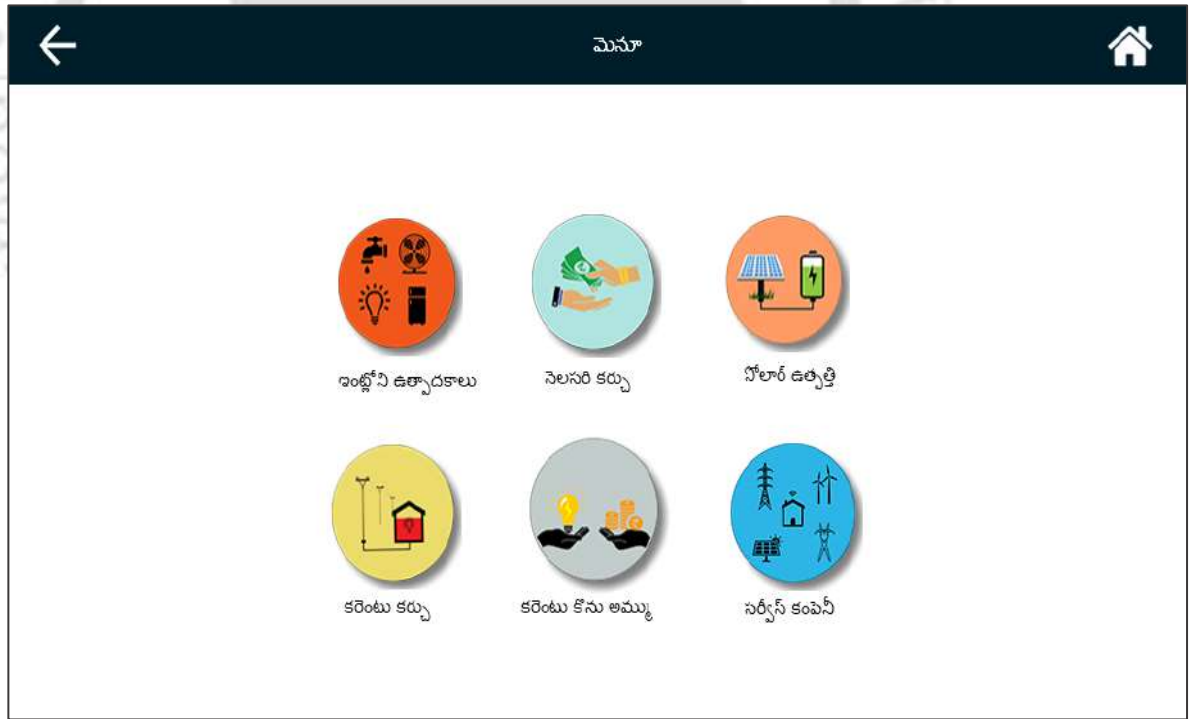


**Figure 6. 12 Wireframe design of IoT enabled rural irrigation motor control task**

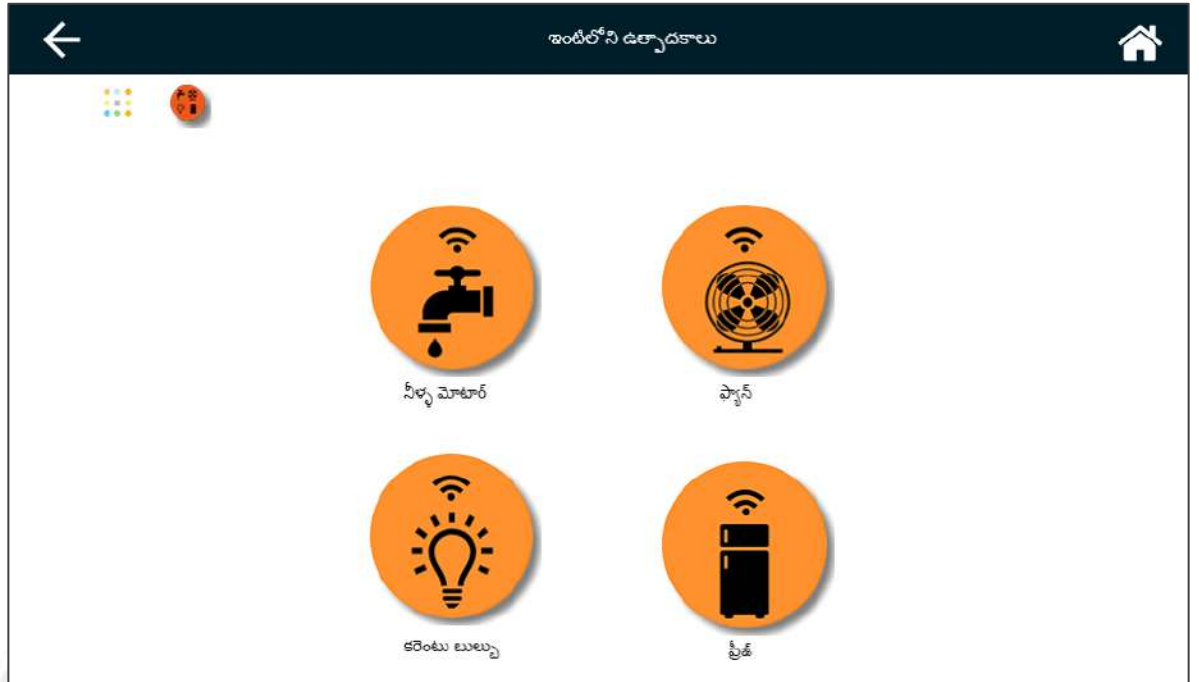
Interaction flow screens of IoT enabled rural irrigation motor use case: Screen 1.1 to 1.6 shows interaction flow for rural IoT enabled irrigation motor use case. User starts task



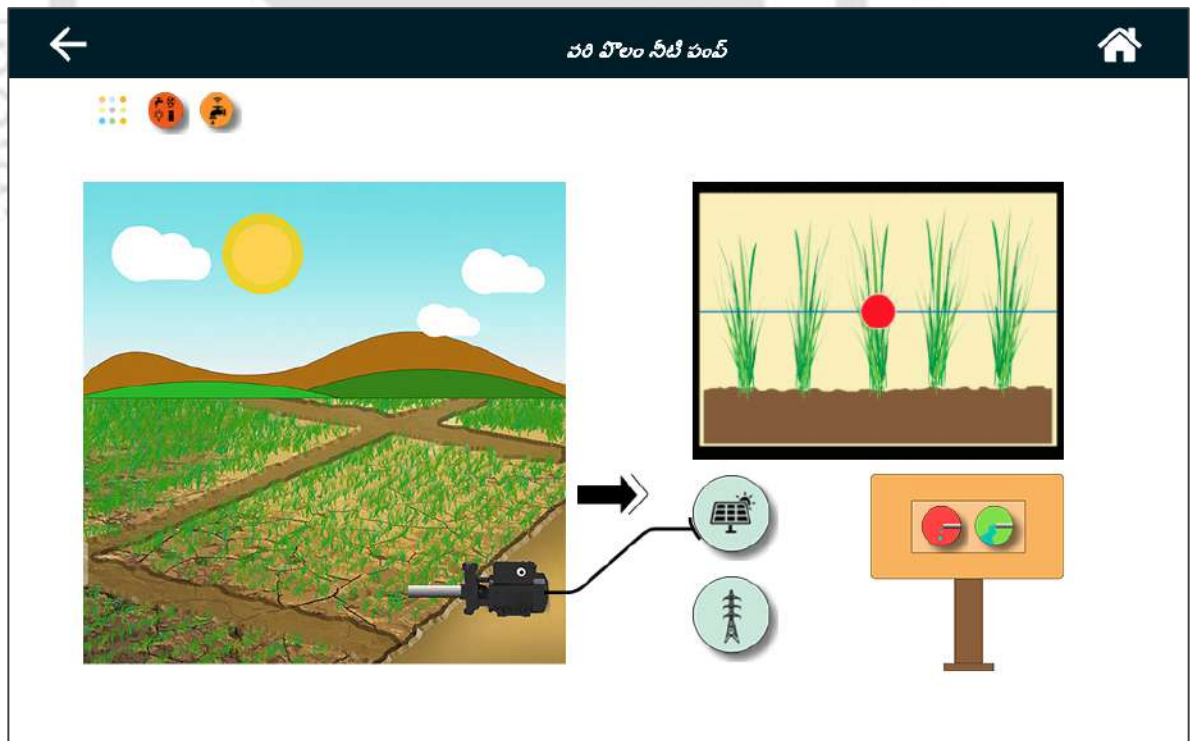
Screen 1.1 Home screen –screen shows the home screen of the rural context interaction flow



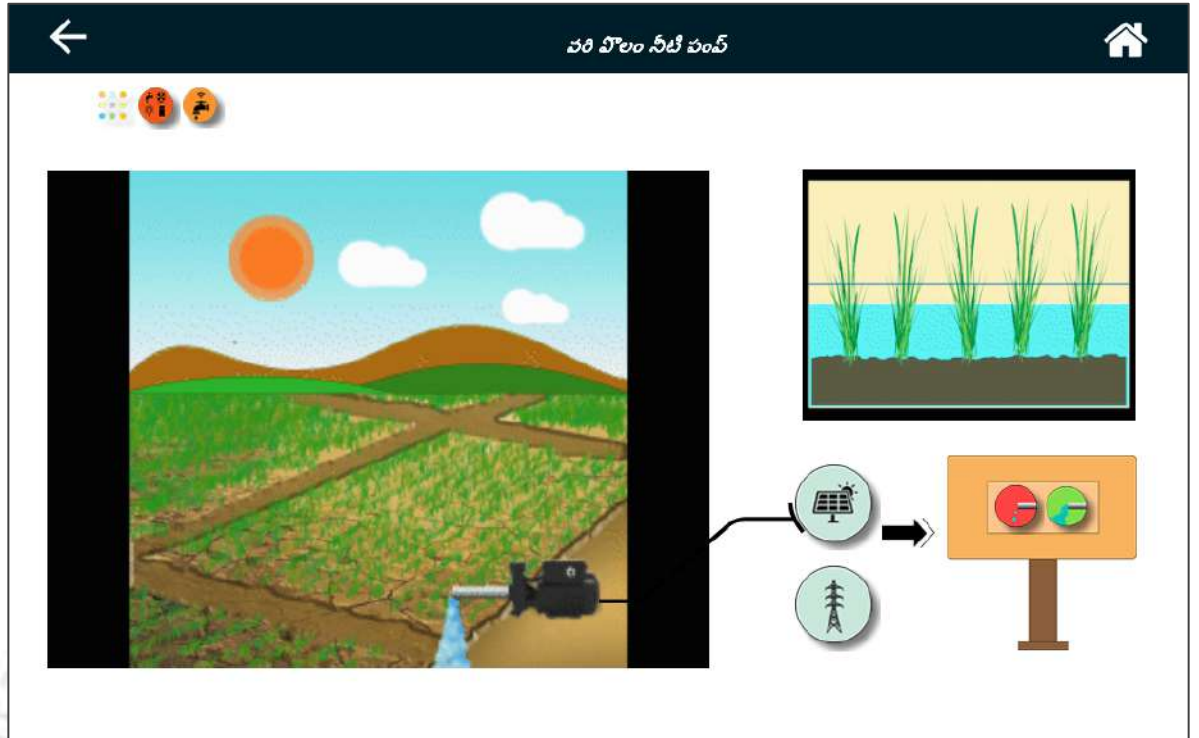
Screen 1.2 Menu screen user - screen shows the main menu screen of the rural context interaction flow



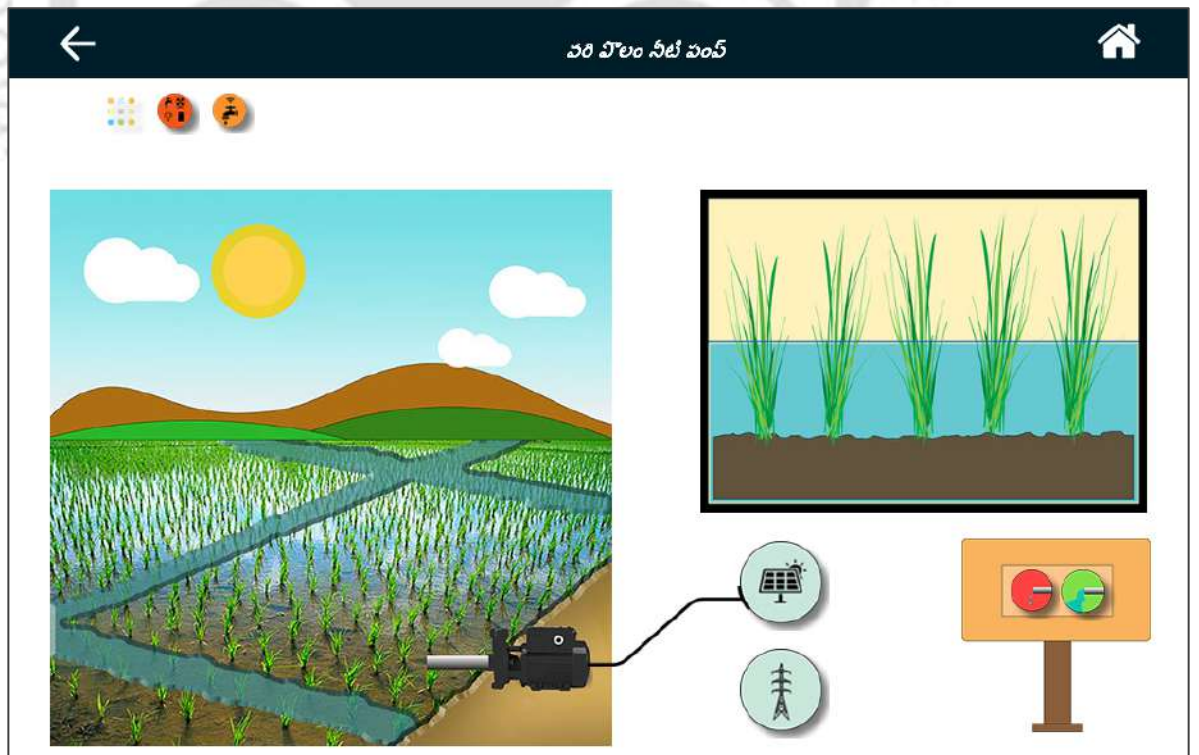
Screen 1.3 Consuming devices screen –screen shows the Consuming devices screen of the rural context interaction flow



Screen 1.4 Paddy field irrigation pump control screen-screen shows the Irrigation motor option and status of the water level in a paddy field is visible



Screen 1.5 live screen - screen shows the IoT enabled Irrigation motor status (On currently) and the water level in a paddy field is visible on right top corner



Screen 1.6 live screen – screen shows the status of a fully watered paddy field and switched off motor

2) Task design for use case : Buy Energy (Urban)

Energy transaction is a use case where the electrical energy generated at household can be bought and sold to neighbour communities via smart grids. This future scenario was designed considering the inferred guidelines and urban user model in terms of their information priorities, likes dislikes, amount of information etc. Differences with rural use case design discussed above can be seen with respect to language, amount of information and use of numerical notations (Screen 2.1 to screen 2.7). Figure 6. 13 Figure 6. 14 depicts task flow and information architecture of energy sell use case for urban. Screen 2.1 to screen 2.7 presents task interaction flow.

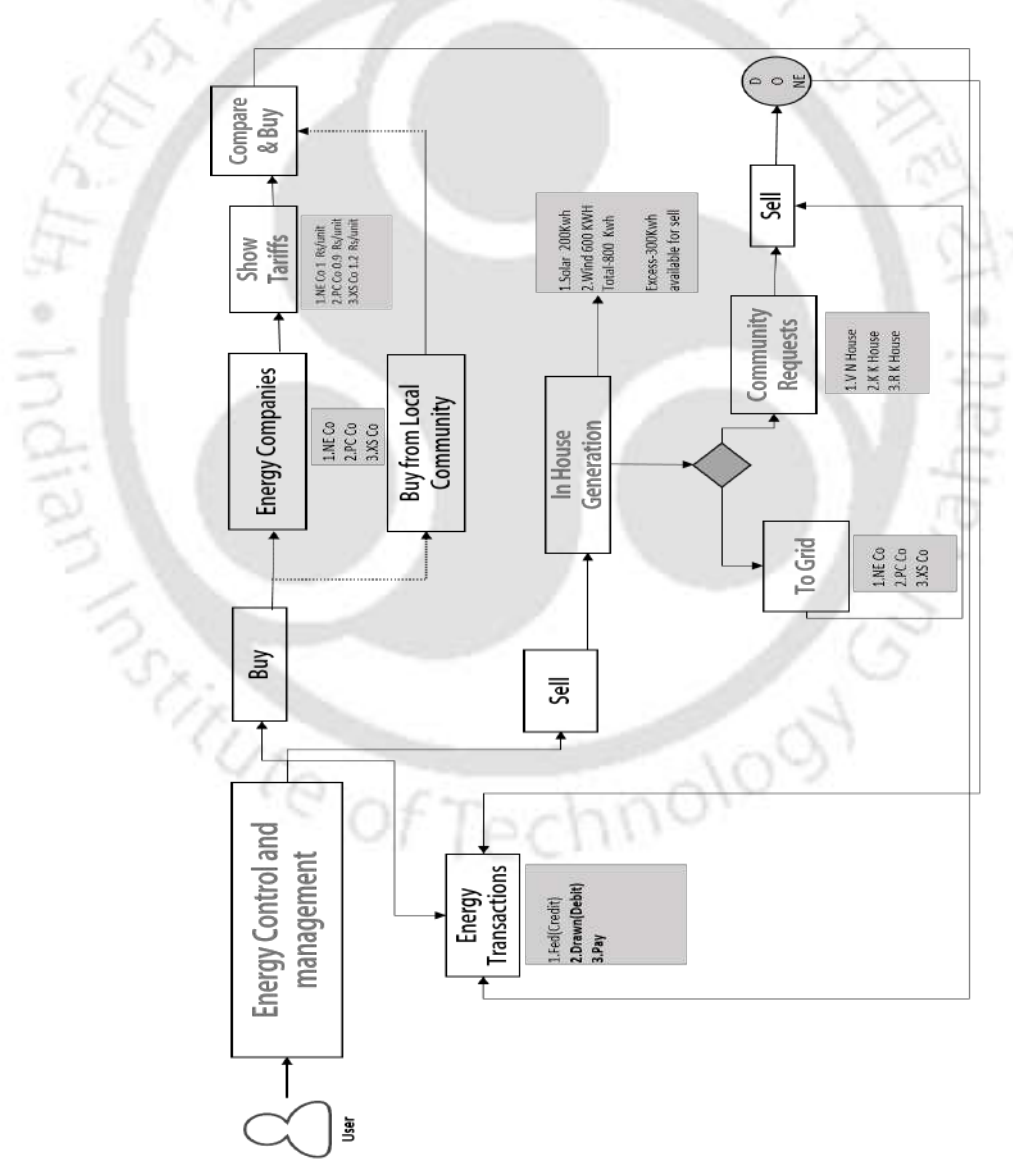
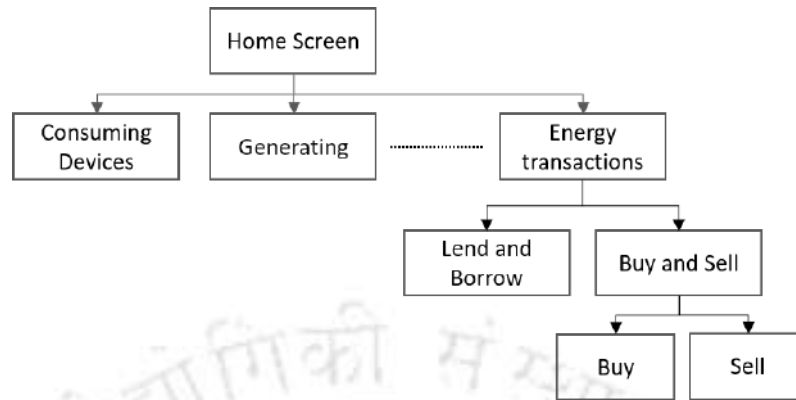
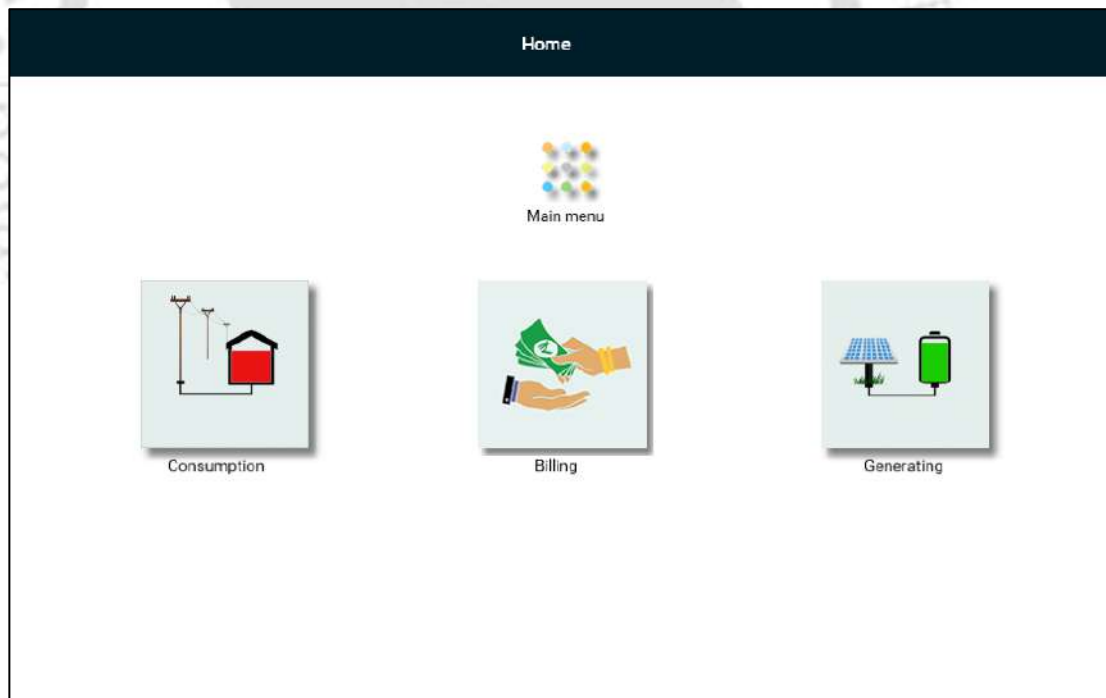


Figure 6. 13 Task flow of IoT enabled urban energy transactions task

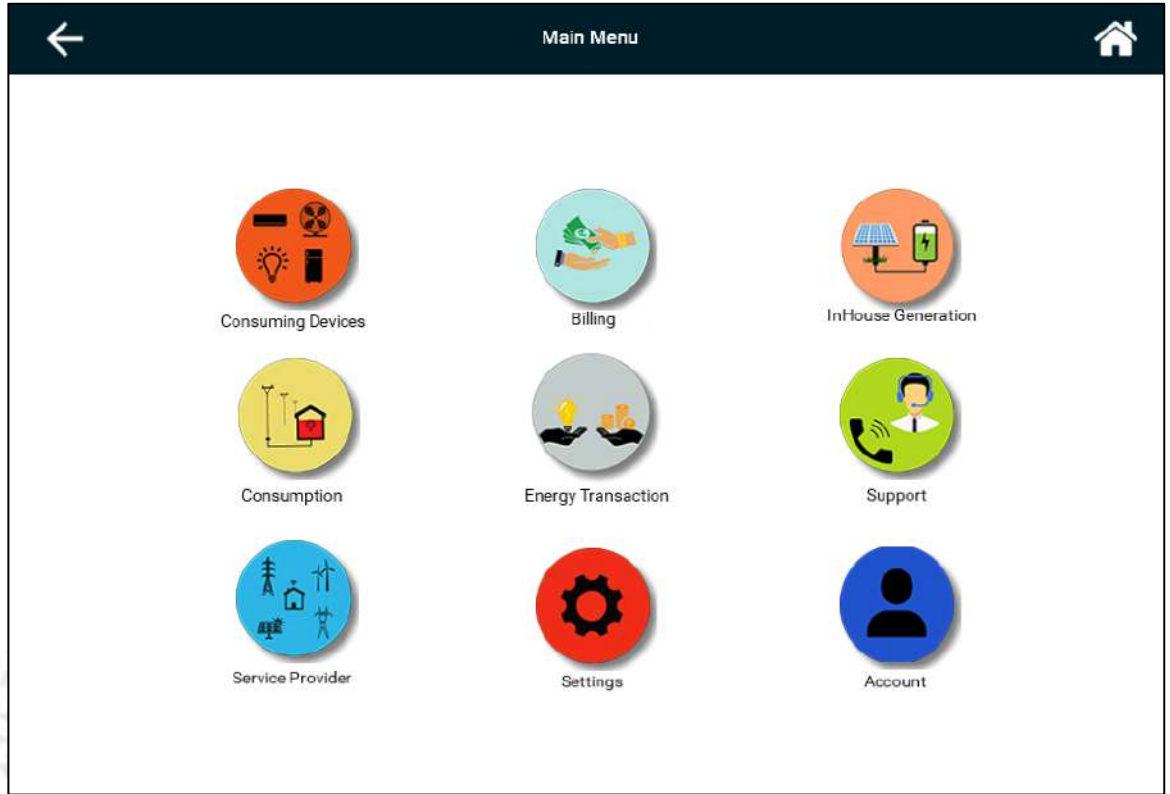


**Figure 6. 14 Information architecture of IoT enabled urban energy transactions**

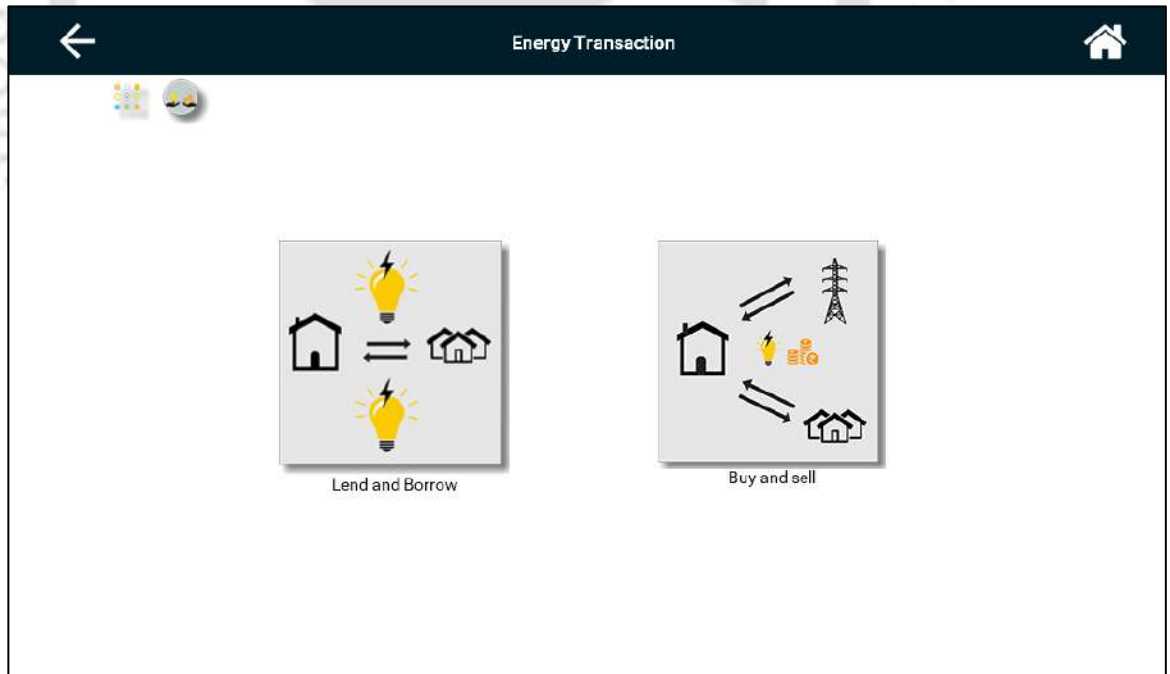
Interaction flow final screens of Energy sell use case (Urban): Following set of screens from Screen 2.1 to screen 2.7 shows the interaction flow of selling energy use case in urban context.



Screen 2.1 Home Screen (Urban- English): screen shows the home screen of the Urban context interaction



Screen 2.2 Menu: screen shows the Main Menu screen of the urban context interaction flow



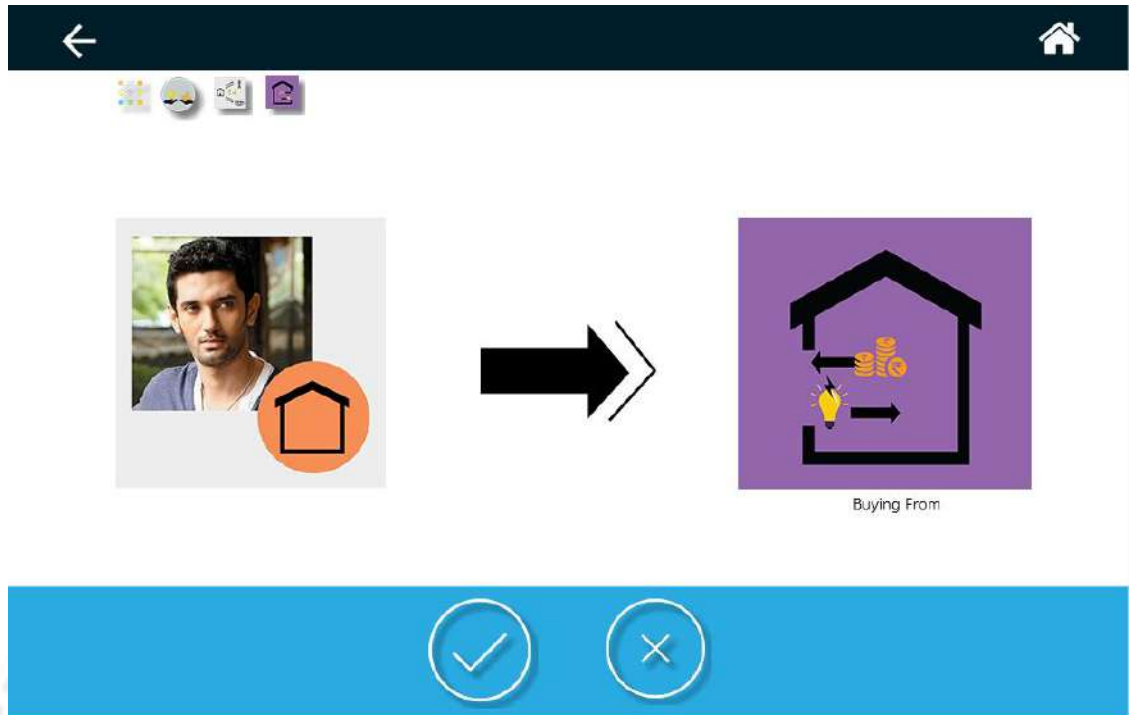
Screen 2.3 Energy Transactions: screen shows the flow from Main Menu screen to the energy transaction options of the urban context Interaction flow; two options that are Lend & Borrow, Buy and Sell are visible.



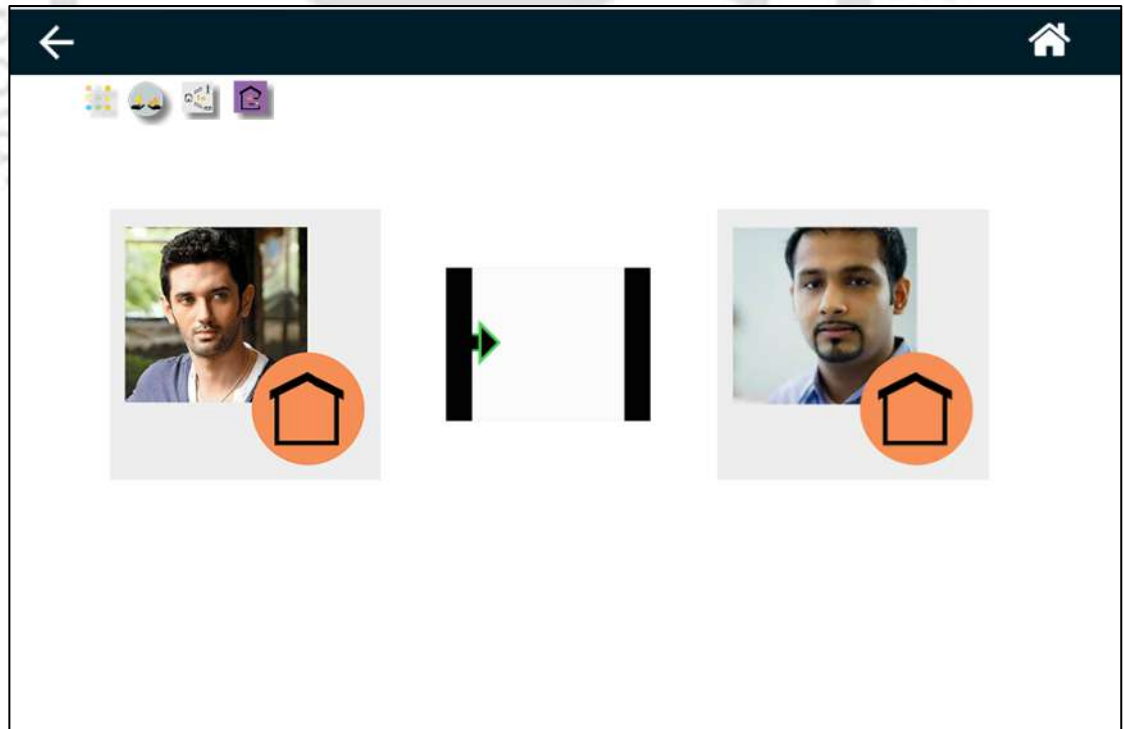
Screen 2.4 Buy and Sell: screen shows the buy and sell options of energy



Screen 2.5 Buy Energy: screen shows the next screen in buy option, in this screen a comparison scale of different buy options is visible, in this interaction flow user get to select the best buy option.



Screen 2.6 Buy confirmation Select: screen shows an energy seller available in the neighbourhood and an option to confirm the transaction



Screen 2.7 Buy Confirmed: screen shows confirmed energy transaction between buyer and seller.

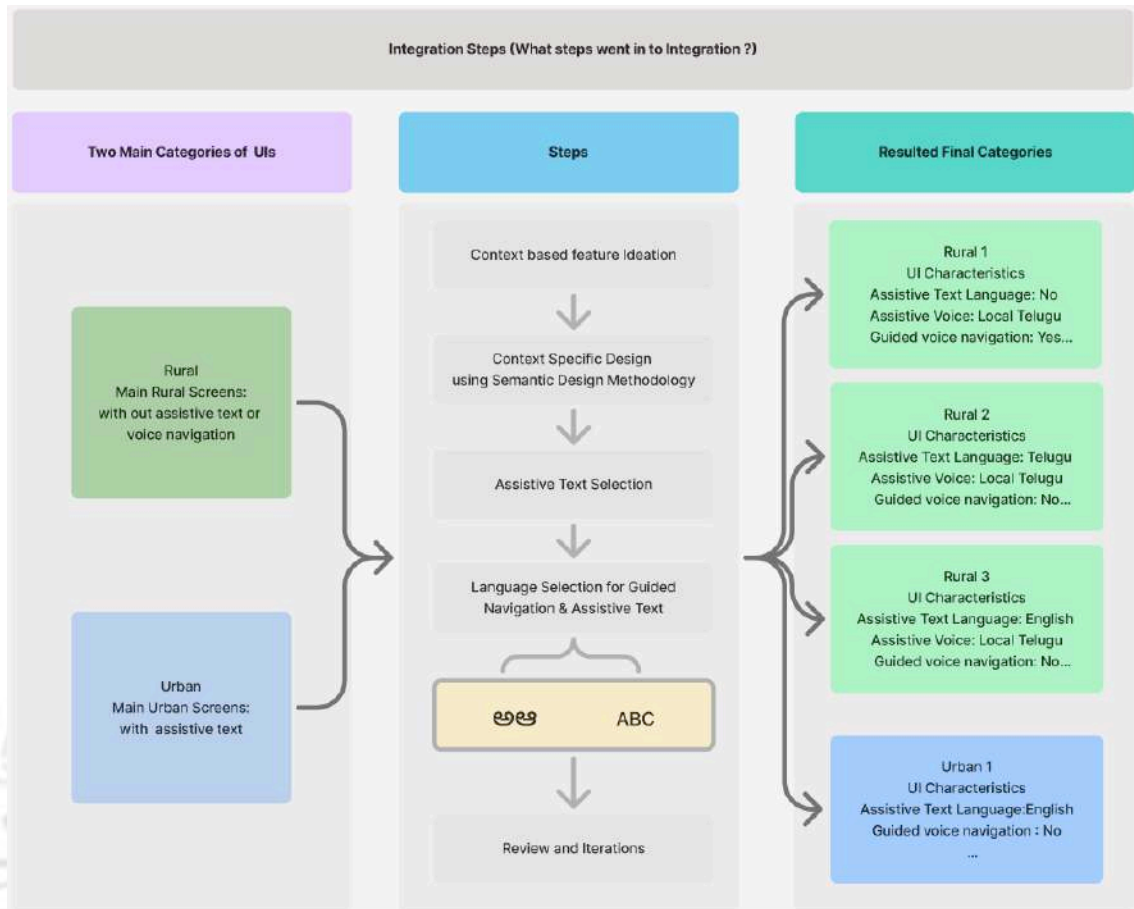


Figure 6. 15 GUI Design Integration Process

Two hundred fifty GUI screens were designed and five different versions of interfaces are integrated for the final study, Figure 6. 15 illustrates the integration process. Number of iteration were done until every GUI was tested backwards for its communicability and semantic efficiency. A prototype was built with an integration of both software and the hardware capabilities, task 1 that is ‘Switch on/off lights’ mentioned in the Table 6.2 was implemented on hardware model for demonstration purpose. A voice navigation assistant was implemented in Telugu language in native accent; a voice synthesis program developed by Technology Development for Indian Languages (TDIL) was used to generate phrases in Telugu native accent female voice. Prototype hardware is built on Raspberry Pi IOT enabled Server (shown in Figure 6.16). User Interfaces were integrated using a HTML based user interface design tool

(Adobe Muse). Interfaces are designed and customized for two Indian context namely rural and urban.

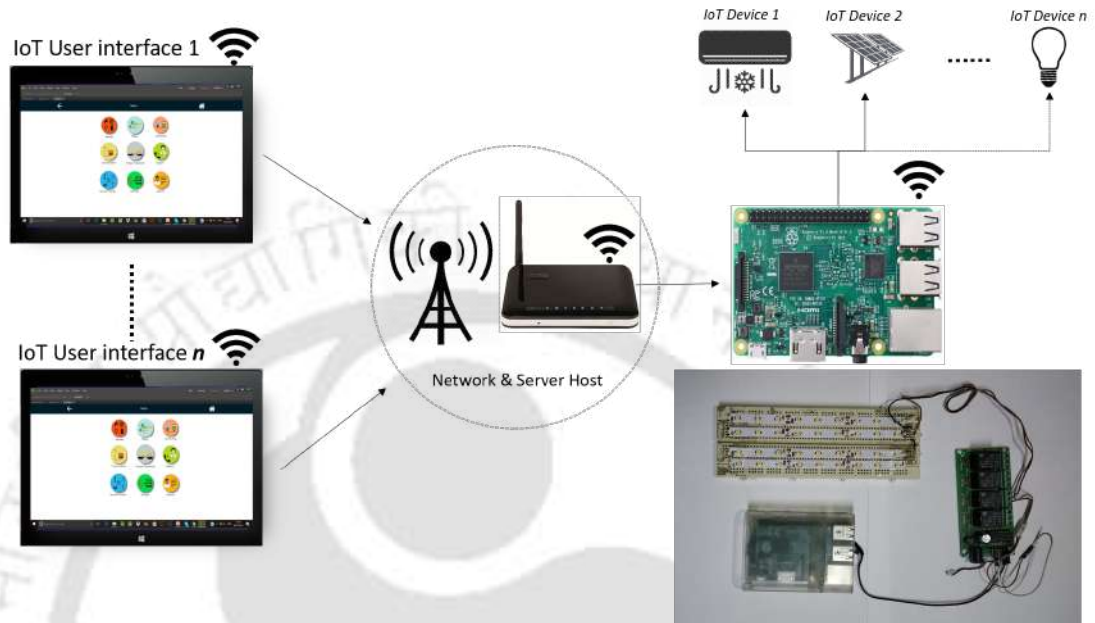


Figure 6. 16 Hardware simulation setup of IESI prototype

Table 6. 2 shows the details regarding the interface versions for respective user groups. These user groups were sub categorized based on literacy level.

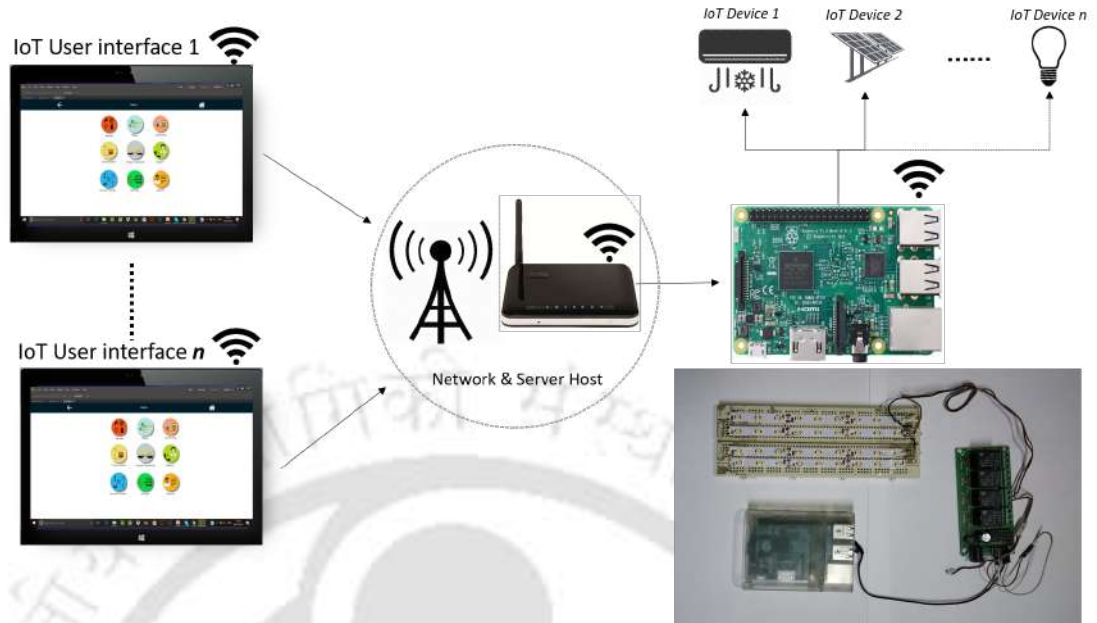


Figure 6. 16 Hardware simulation setup of IESI prototype

Table 6. 2 Details of IESI interface versions

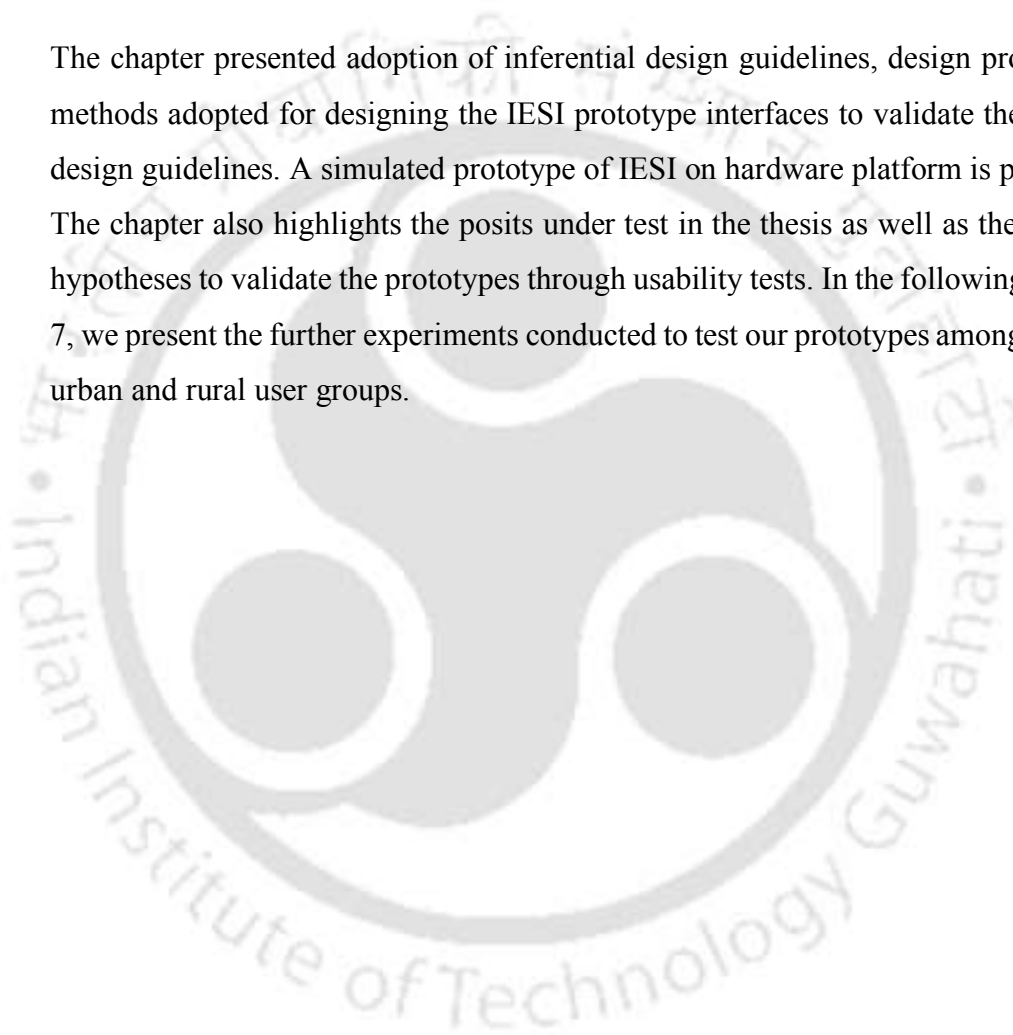
Context	IESI Application for Rural Context					IESI Application for Urban Context
	Rural User 1	Rural User 2	Rural User 3	Rural User 4	Rural User 5	
<b>Prominent User Groups</b> (on the basis of education)	Rural User 1 Education : Nil	Rural User 2 Education : Primary	Rural User 3 Education : Upper Primary	Rural User 4 Education : High school	Rural User 5 Education : College and above	Urban User Education :College and above
<b>Interface features</b>	IESI Application for Rural Context  Assistive Text : No  User Options : personal voice ( Telugu native accent) assistance for navigation	IESI Application for Rural Context  Assistive Text language : Telugu	IESI Application for Rural Context  Assistive Text language : Telugu	IESI Application for Rural Context  Assistive Text language : Telugu	IESI Application for Rural Context  Assistive Text language : Telugu & English	IESI Application for Urban Context  Assistive Text language : English
<b>Number of Tasks for User Testing</b>	16	16	16	16	16	16

We posited that the IESI interface screen designed using the inferential guidelines and the semantic design methodology will enhance the communicability and influence the user performance, user satisfaction. A usability based design experiment

was planned to test the simulated IESI across the rural and urban user groups and validate posits and hypotheses mentioned in Chapter 7. Next Chapter describes these studies in detail. Posits and Hypothesis are stated and formulated to asses usability of the IESI prototype Interfaces across the Urban and Rural User groups.

### **6.5 Chapter Summary**

The chapter presented adoption of inferential design guidelines, design process and methods adopted for designing the IESI prototype interfaces to validate the inferred design guidelines. A simulated prototype of IESI on hardware platform is presented. The chapter also highlights the posits under test in the thesis as well as the working hypotheses to validate the prototypes through usability tests. In the following Chapter 7, we present the further experiments conducted to test our prototypes amongst Indian urban and rural user groups.



## 7. Evaluation of Simulated IoT Enabled Smart energy utilization Interfaces

*Abstract: This Chapter presents experiment plan for evaluating and validating simulated IoT Enabled Smart energy utilization Interfaces that are designed using inferential design guidelines. It gives the description of validation model, questionnaire tools adopted and instruments used for user validation study and data collection. It presents analysis of the data collected on user-based usability testing of interfaces. It summarizes all the results and proceeds on to the inferences made. Chapter concludes with hypothesis testing and discussion.*

### 7.1 Introduction

To assess the inferential GUI design guidelines developed for the Indian context and to validate the design methodology outlined in this thesis, we needed to test the simulated IoT-enabled smart energy utilisation interfaces introduced in Chapter 6. By evaluating these IESI prototypes, each crafted according to our guidelines, we could directly measure how well the guidelines improved interface effectiveness. We therefore adopted a structured evaluation framework to determine the real-world impact of our design recommendations. Recognising that directly testing the guidelines in their entirety would be too broad and complex, we began by formulating overarching posits. These posits served as foundational statements that encapsulated our assumptions. We then distilled these overarching posits into testable hypotheses, each examined through focused, usability experiment-driven validation. This method made it possible to assess, in an iterative fashion, exactly how our guidelines affected usability outcomes.

Set of posits and hypothesis are formulated to test and evaluate simulated interfaces through a usability study with target users. Usability validation framework for the interfaces was built on ISO 9241:11 standard (Bevan, Carter, & Harker, 2015) where three key parameters that are, efficiency, effectiveness and user satisfaction are measured in the study after performing set of tasks. These three parameters will define

or give a measure of ‘quality of usage’ of the interfaces. As defined by the ISO 9001(Abran, Khelifi, Suryn, & Seffah, 2003) , the quality of usage encompasses all the parameters, which influence the products use in the practical usage scenarios.

Chapter presents analysis and results focused on extracting various aspects of user performance across all the user groups, intragroup performance differences, factors affecting the user performance parameters, user satisfaction and their intention to use.

## 7.2 Validation model

To asses and infer the usability of the IESI prototype interfaces, a framework was formulated based on the usability testing(Bevan & Macleod, 1994) (Figure 7. 1). Usability investigations involves measuring three key parameters that are efficiency, effectiveness and user satisfaction. An extensive usability testing review by (Frøkjær, Hertzum, & Hornbæk, 2000) suggests investigating all three mentioned parameters critical for defining the usability of information systems. Therefore, all three parameters are investigated in this study. These three parameters fall into two categories: efficiency and effectiveness are task-performance measures, whereas user satisfaction is a post-task subjective response.

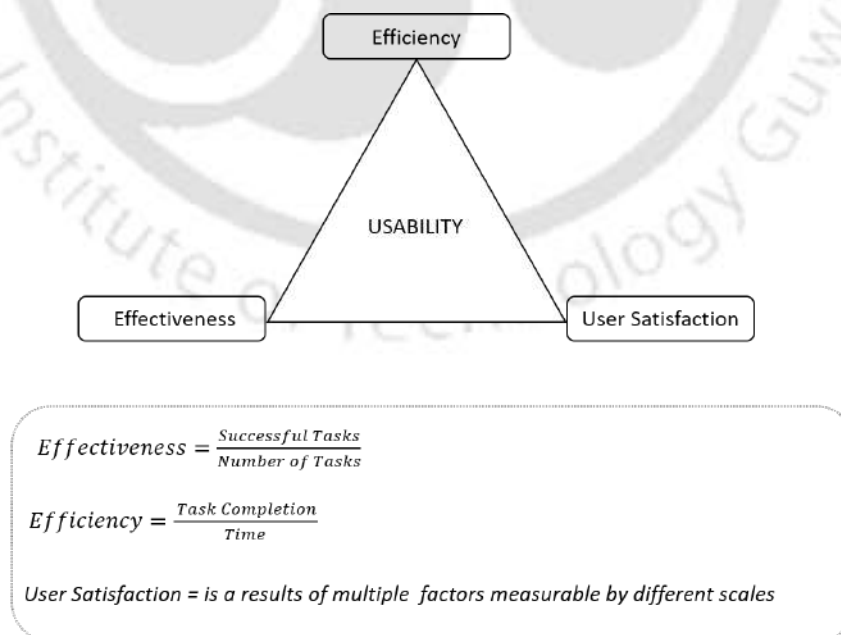


Figure 7. 1 Usability testing metrics

Before detailing our validation model, we first state the core posits and hypotheses that guide our evaluation.

Following posits and hypothesis were under test in the Experiment:

Posit 1: IESI Interface designed using the Inferential guidelines will achieve the good task effectiveness across all the Rural and Urban User groups.

Posit 2: IESI Interface designed using the inferential guidelines evolved will achieve the good satisfaction /usability across all the Rural and Urban User groups.

As identified from the initial field studies conducted in this research we observed that there are large variations with in user groups in the rural areas with respective to education and age. It was posited that the level of education and the age would be a factor that affects the task completion times therefore the temporal efficiency. Based on this observation hypothesis 1 and hypothesis 2 were formulated.

Hypothesis 1: A positive relationship exists between Task time and Age across all the user groups

Hypothesis 2: A positive relationship exists between level of education and Task efficiency across all the user groups

Efficiency:

Efficiency by definition is successfully completing a task at an expense of resources required (Bevan et al., 2015). In this study, we considered/measured task completion time as primary indicator to determine the temporal /time based task efficiency

$$\text{Temporal Efficiency} = \frac{\sum_{j=1}^R \sum_{i=1}^N (n_{ij}/t_{ij})}{NR}$$

N = The total number of tasks

R = The number of users

$n_{ij}$  = The result of task i by user j

$t_{ij}$  = The time spent by user j to complete task i.

Effectiveness:

Indicators of efficiency parameter are successful completion of a task and time taken to complete whereas the indicator of effectiveness is successful achievement of task goals. In this study, we have taken task completion time and successful task completion as indicators for efficiency and effectiveness respectively.

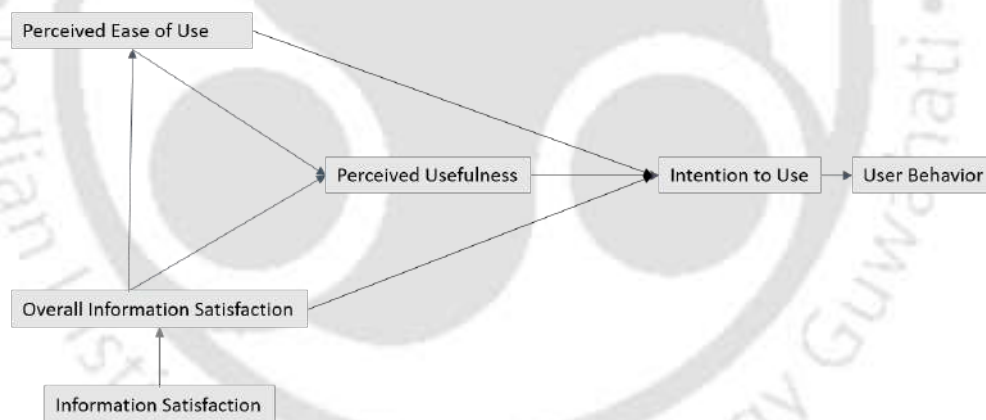
User satisfaction:

The other category of parameter that is User satisfaction is investigated using multiple questionnaire (see Annexure D) comprising of the following items

- i) System Usability Scale (SUS) (Brooke, 2013)
- ii) Perceived Usefulness (PU) (Venkatesh & Davis, 2000)
- iii) Perceived Ease of Use (PEOU) (Venkatesh & Davis, 2000)
- iv) Intention to Use (IU) (Venkatesh & Davis, 2000)
- v) Information Quality (IS) (Petter, DeLone, & McLean, 2013)
- vi) Over all Information Satisfaction (OIS)

System Usability Scales (SUS) (Brooke, 1996) is one of the widely used user subjective assessment tool of a system usability. Many studies of reported (Bangor, Kortum, & Miller, 2008) (Lewis & Sauro, 2009) the robustness and ease of using SUS. It gives a single usability scores that is based on overall users experience of a system and satisfaction. Questionnaire from (ii-v) mentioned above are based on two different technology adoption models that are Technology Acceptance Model (TAM) (Davis, 1993) and Information System Success Model (DeLone & McLean, 1992). Technology adoption models measures aspects that are indicators of user intentions to adopt and use a technology or a system. In the case of TAM, it emphasizes on behavioural beliefs such as perceived usefulness and ease of use whereas IS

emphasises on object based beliefs such as influence of system or information quality on use intentions (Wixom & Todd, 2005). Questionnaire PEOU, PU, IU are adopted from the Technology Acceptance Model (Venkatesh & Davis, 2000) and IS,OIS are adopted from the (Nelson, Todd, & Wixom, 2005). Here in this research work, we are interested in measuring both behavioural and object based intentions of the user. This integrated approach is adopted from (Wixom & Todd, 2005) . Figure 7. 2 shows the adopted technology acceptance model. In this approach, we frame our hypotheses within a Structural Equation Modelling (SEM) as followed in TAM, testing each proposed path for statistical significance. The model asserts that Overall Information Satisfaction positively influences Perceived Ease of Use (PEOU), which in turn drives Perceived Usefulness (PU); these two beliefs together shape users' attitudes and behavioral intentions, ultimately determining actual system acceptance. Figure 7.2 illustrates these interrelationships.



**Figure 7. 2 Adopted Technology acceptance model**

The following model specific hypotheses were formulated under user satisfaction and technology adoption model (as shown in Figure 7.2 )and tested during Experiment

Working Hypothesis on Technology Acceptance Model (TAM): A positive relationship exists between perceived user beliefs and use intention of IESI interfaces

Hypothesis 3: A positive relationship exists between perceived ease of use and use intention of IESI interfaces

Hypothesis 4: A positive relationship exists between perceived usefulness and use intention of IESI interfaces

Hypothesis 5: A positive relationship exists between Information Satisfaction and use intention of IESI interfaces

Hypothesis 6: A positive relationship exists between Information Satisfaction and ease of use IESI interfaces

Hypothesis 7: A positive relationship exists between Information Satisfaction and Perceived Usefulness IESI interfaces

Hypothesis 8: A positive relationship exists between perceived ease of use and perceived usefulness of IESI interfaces

Table 7. 1 shows the reliability scores of the questionnaire used and all the scores are well above the minimum Cronbach alpha value of 0.7. Questionnaire were administered post task performance ,subjects were asked to rate their opinions on a Likert scale where the questionnaire items from (ii-v) were on a 7 point Likert scale(1= Strongly disagree, 7= Strongly agree) and SUS on 5 point Likert scale (1= Strongly disagree, 5= Strongly agree).

**Table 7. 1 Reliability Scores of the instruments used**

Instrument	Reliability Scores	
	Cronbach's Alpha	N of Items
Perceived Usefulness(PU)	.878	4
Perceived Ease of Use(PEOU)	.833	4
Over all Information Satisfaction(OIS)	.967	2
Intention to Use(IU)	.928	2
Information Satisfaction	.931	11
System Usability Scale (SUS)	.825	10

Set of sixteen tasks(see Annexure D )based on the IESI features targeting task navigation, information readability, comprehensibility and discoverability (Jakob Nielsen et al., 1994) (Reinecke & Bernstein, 2011) were given to each subject to perform followed by questionnaire mentioned above. A post task open-ended interview with informal queries was conducted to capture user responses regarding individual task experiences while using the Interfaces. These investigations helped in capturing users experience, inductively derive relations between various complex subjective parameters experienced by users in interacting with the GUIs.

Figure 7. shows represents independent and dependent variables measures of the experimental study conducted.

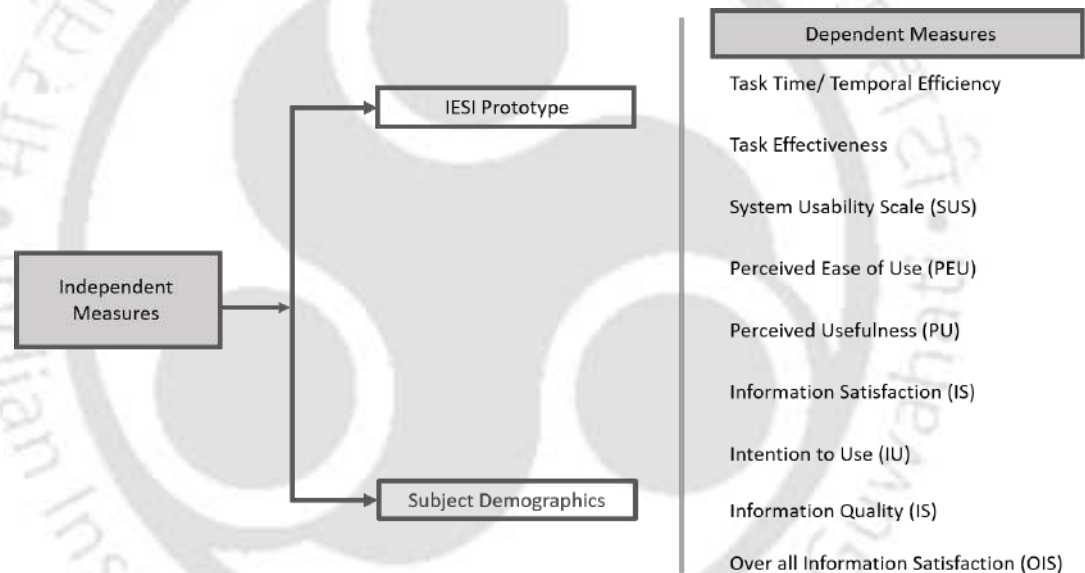
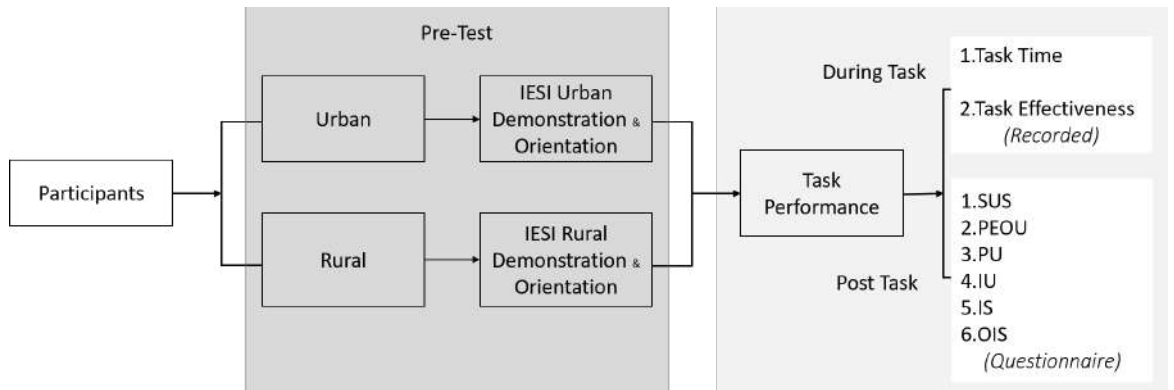


Figure 7. 3 Independent and dependent variables of the study

### 7.3 Experiment Procedure

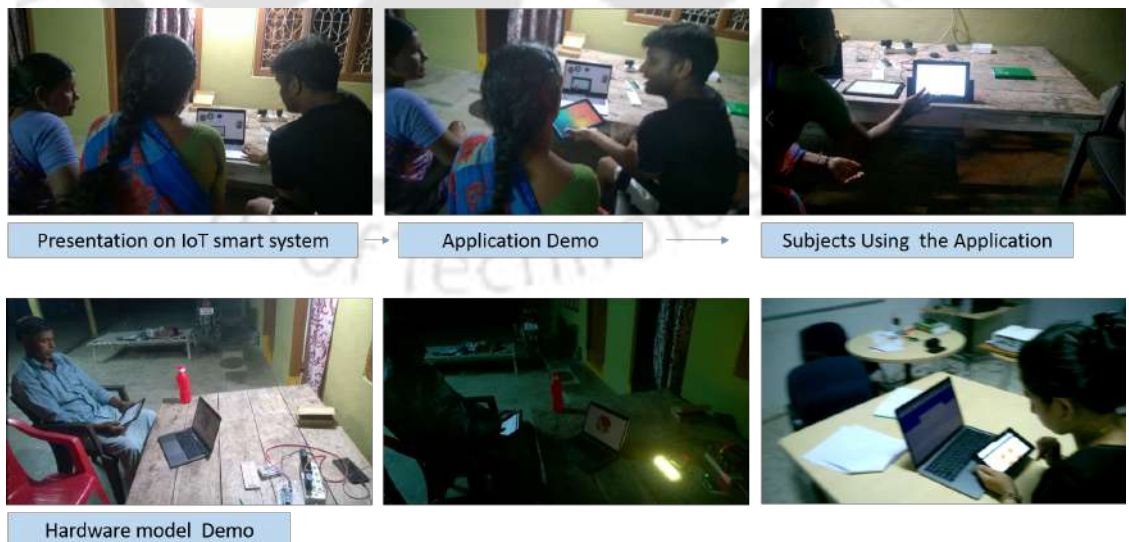
A within group experiment was conducted to investigate the variables mentioned across user groups from urban and rural areas in India.

Figure 7. depicts the stages involved in the experiment.



**Figure 7. 4 Experiment stages involved in the validation study**

Demographic information was collected before proceeding on to demonstration sessions. As the IoT enabled energy utilization technology is not familiar for the majority of the users, a technology demonstration with help of tablet based IESI Raspberry-Pi prototype (Figure 7. ) was presented to all the participants. Another quick feature demonstration session of tablet based simulated IESI interfaces was presented to all the participants. Figure 7. and Figure 7. shows the demonstration sessions and experimental setup respectively. Screenshots of user interacting with simulated IESI interfaces and Hardware prototype are shown in Annexure D. After the demonstration, participants were allowed to use the interfaces for one day and called for the task performance sessions on the following day



**Figure 7. 5 IESI user demonstrations**



Figure 7. 6 User interactions with IESI

Table 7. 2 shows the details of user-groups, interface versions used and study details.

Table 7. 2 IESI validation study details

Context	IESI Application for Rural Context		IESI Application for Urban Context
<b>User Groups</b>	Rural User (State-Telangana-Villages around Peddapalli )		Urban User (State-Multiple States-India)
<b>Subjects</b>	Participated-120(Random Sample) :Valid Size-90	76 Rural	14 Urban
<b>Interface features</b>	IESI Application for Rural Context  Assistive Text language options: Telugu and English  Voice assistance option: Voice assistance for navigation (Telugu native accent)		IESI Application for Urban Context  Assistive Text language : English
<b>Tasks</b>	16 Tasks per Every User		
	Experiment Duration : 276478 Minutes	Experiment Completion Time per user: 24 to 48 Hours	

### Participants:

By selective convenient sampling (Etikan, 2016), participant selectively recruited from rural and urban areas of India for the study. Male and female participants in the age group of 18-65 yrs. were drawn from rural and urban areas from different parts of India, Table 7. 3 shows the characteristics of the subjects. In the rural cohort, we specifically recruited Telugu speakers from Telangana, where regional-language familiarity was essential for our tasks, while urban participants were those most readily accessible. While convenience sampling does sacrifice statistical representativeness, it remains a common method in HCI research (Prastawa et al. 2019). Subject demographic information and other information related to the mobile device usage (Annexure D) was collected prior to the demonstration sessions. One hundred twenty (120) subjects were participated in the initial demonstration and orientation sessions where ninety-six (96) participants were turned up for final experiment. Experiment was conducted with ninety-six (96) users (81 Rural, 15 Urban) with total experiment time of ( $\approx 276480$  Minutes) average time for each participant 48 hours.

**Table 7. 3 Subjects characteristics**

Measure	Item	Frequency	Percentage%
Gender	Female	40	44.4
	Male	50	55.6
Age	21-30	27	30.1
	31-40	30	26.7
	41-50	12	14.4
	51-60	14	16.6
	61-70	10	12.2
Education Qualification	Nil	32	35.6
	Primary	16	17.8
	Upper Primary	11	12.2
	Higher Secondary	11	12.2
	Graduates	20	22.2
Context	Rural	76	84.4
	Urban	14	15.6

Sixteen tasks (see Annexure D) were given to each subject to perform followed by questionnaire (Annexure D) and informal interviews. All experiment sessions were video recorded, transcribed and photographed with the due consent from the subjects.

#### 7.4 Data Analysis

Prior to analysis, collected data was checked for reliability and normality. As it mentioned, the study reported here is aimed at validating the IESI Interfaces with target user groups. For this purpose, sixteen (16) tasks were given to participants to perform and then the data required for the validation is collected. In present study two types of data are collected, that are objective and subjective in nature. The objective measured data that is task completion and time taken were analysed in view of the efficiency of task performance, effectiveness in completing the task using descriptive methods. Inferential methods were used to observe intergroup differences in terms of task efficiency, effectiveness and factors affecting the performance.

User post task subjective data collected on multiple instruments analysed using multiple statistical techniques, the hypotheses framed on user satisfaction and intra group performances were tested using t-test and non-parametric hypothesis testing techniques. Table 7. 4 shows the details of the data collected and the statistical techniques used to analyse the data.

**Table 7. 4 Details of the parameters measured and analysis techniques**

s.no	Parameter Name-Data Type	Analysis Technique
1	Efficiency – (Performance measure) Task completion time recorded	Standard descriptive and Inferential ,observing variations on Time Limitations
2	Effectiveness (Performance measure) Task Success recorded	Standard descriptive and Inferential ,observing variations on Time Limitations
3	User satisfaction Parameters (Preference measure)	Various Analysis Techniques: Standard descriptive and Inferential, correlations, t-tests

#### 7.4.1 Results

This section presents result of the usability parameters of the IESI interfaces presented to the target user groups, validation of posits and hypotheses formulated to evaluate the interfaces.

##### Effectiveness:

Effectiveness in this study measured in terms successful task completion or achieving the task goals successfully without time being a restriction. Table 7. 5 presents the results of the task effectiveness measured across both user groups. Results shows that all the users from both the user groups were able complete all the tasks successfully.

**Table 7. 5 Results of task effectiveness across rural & urban**

<b>User group</b>	<b>Effectiveness (Task Success Rate)</b>
Rural	100%
Urban	100%

Effectiveness results shown in the table upholds our Posit 1

Posit 1: IESI Interface designed using the inferential GUI design guidelines will achieve the maximum task effectiveness across all the Rural and Urban User groups.

##### Efficiency:

Efficiency in this study was measured in terms of time taken to complete a task. Therefore, it is temporal or time-based efficiency (see section 7.2). Results shows that from a descriptive comparison there is difference between the urban and rural groups which is basis for hypothesis 1 and hypothesis 2 as discussed earlier.

**Table 7. 6 Results of time based task efficiency across rural & urban**

<b>User group</b>	<b>Time Based Efficiency</b>
Rural User	0.16 tasks/sec
Urban User	0.53 tasks/sec

Urban users are relatively faster in completing the tasks compared to the rural user groups. Table 7. 6 presents the results of time-based efficiency of rural and urban user groups.

Table 7. 7, Table 7. 8 shows the descriptive results of the based on users group identified on the level of education and age. Figure 7. , Figure 7. represents the results shown in the table.

**Table 7. 7 Task efficiency results based on education across rural & urban**

<b>User group</b>	<b>Time Based Efficiency</b>
RI 1	0.10 tasks/sec
RI 2	0.11 tasks/sec
RLP	0.12 tasks/sec
RLUP	0.13 tasks/sec
RLHS	0.25 tasks/sec
RLBHS	0.30 tasks/sec
UH	0.53 tasks/sec

**Table 7. 8 Task efficiency results based on age across rural & urban**

<b>Age group</b>	<b>Time Based Efficiency</b>
18-35	0.33 tasks/sec
36-45	0.1 task/sec
46-65	0.069 tasks/sec
Above 65	0.016 tasks/sec

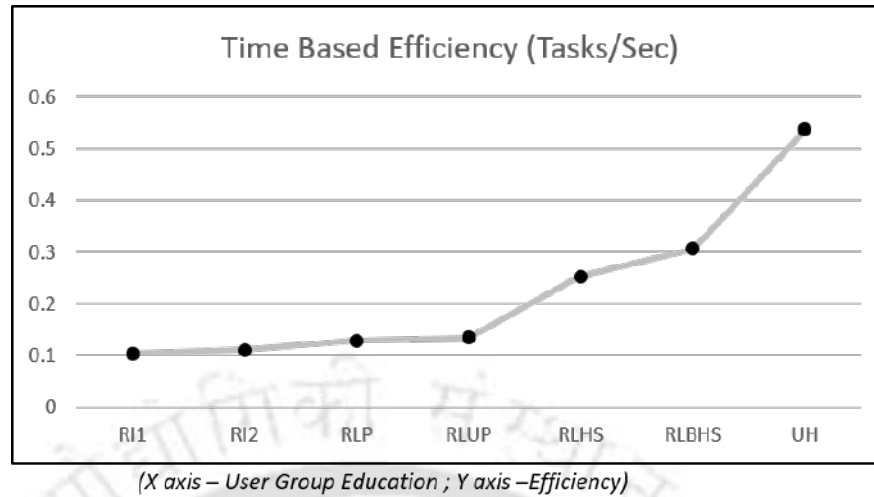


Figure 7. 7 Effect of user education on task efficiency (time based) across rural and urban user groups

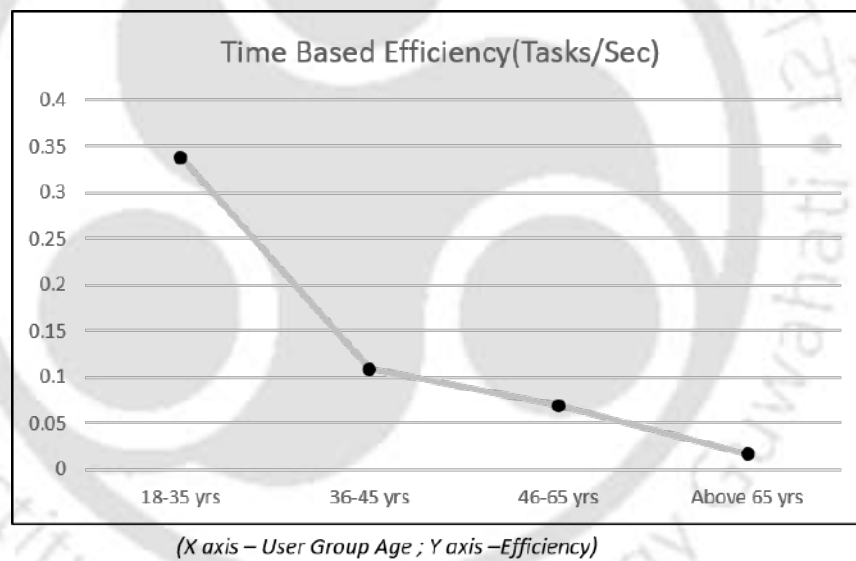


Figure 7. 8 Effect of user age on task efficiency (time based) across rural and urban user groups

For the sample-size taken in the urban user groups, there was no significant variation in the level of education and age. All the users are at least bachelor degree holders with average age of 30 years therefore one single grouping.

Hypothesis 1: A positive relationship exists between Task time and Age across all the user groups

**Table 7.9 Results of correlation between task time and age across rural & urban user groups**

			AGE	TASK1	TASK2	TASK3	TASK4	TASK5	TASK6
<b>Kendall's tau_b</b>	<b>AGE</b>	<b>Correlation Coefficient</b>	1.000	.468**	.508**	.536**	.496**	.512**	.451**
		<b>Sig. (2-tailed)</b>	.000	.000	.000	.000	.000	.000	.000
		<b>N</b>	90	90	90	90	90	90	90
<b>TASK7</b>	<b>TASK8</b>	<b>TASK9</b>	<b>TASK10</b>	<b>TASK11</b>	<b>TASK12</b>	<b>TASK13</b>	<b>TASK14</b>	<b>TASK15</b>	<b>TASK16</b>
.502**	.518**	.549**	.390**	.401**	.429**	.583**	.533**	.486**	.455**
.000	.000	.000	.000	.000	.000	.000	.000	.000	.000
90	90	90	90	90	90	90	90	90	90

A Kendall's tau-b correlation was run to determine the relationship between task time and age amongst 90 participants. There was a strong, positive correlation (for all the 16 tasks  $\tau_b = .390$  to  $.583$ ,  $p = .000$ ) between time taken to complete tasks and age i.e. as age is increasing the time taken to complete a task is increasing. Therefore Hypothesis 1 is accepted.

Hypothesis 2: A positive relationship exists between level of education and Task efficiency across all the user groups

**Table 7.10 Results of correlation between task efficiency and education across rural & urban user groups**

			EDUCATION	TASK1	TASK2	TASK4	TASK5	TASK6
<b>Kendall's tau_b</b>	<b>EDUCATION</b>	<b>Correlation Coefficient</b>	1.000	.529**	.601**	.595**	.610**	.575**
		<b>Sig. (2-tailed)</b>	.	.000	.000	.000	.000	.000
		<b>N</b>	90	90	90	90	90	90
<b>TASK7</b>	<b>TASK8</b>	<b>TASK10</b>	<b>TASK11</b>	<b>TASK12</b>	<b>TASK13</b>	<b>TASK14</b>	<b>TASK15</b>	<b>TASK16</b>
.508**	.550**	.424**	.452**	.488**	.697**	.612**	.611**	.616**
.000	.000	.000	.000	.000	.000	.000	.000	.000
90	90	90	90	90	90	90	90	90

A Kendall's tau-b correlation was run to determine the relationship between task efficiency and Education amongst 90 participants. There was a strong, positive

correlation (for all the 16 tasks  $\tau_b = .424$  to  $.583$ ,  $p = .000$ ) between time taken to complete tasks and education i.e. as level of education is increasing the time taken to complete a task is decreasing or task efficiency increasing. Therefore Hypothesis 2 is accepted.

#### User Satisfaction:

This section presents the user satisfaction scores measured using multiple instruments mentioned in the section 7.2

#### SUS scores:

Systems Usability Scale (SUS) user responses collected on 5-point Likert scale were used to calculate a unified single score on a scale of 100 (see Figure 7. ) that defines user satisfaction. Table 7. 11 presents the SUS scores of urban and rural user groups and Table 7. 12 presents the segregated SUS score based on literacy level.

**Table 7. 11 SUS results across rural & urban user groups**

<b>System Usability Scores (SUS)</b>		
<b>User Group</b>	<b>Mean</b>	<b>SD</b>
Rural	95.6	5.4
Urban	93	6.9

**Table 7. 12 Segregated SUS results across based on education literacy**

<b>System Usability Scores (SUS)</b>		
<b>User Group</b>	<b>Mean</b>	<b>SD</b>
Rural Illiterate	94.6	5.7
Rural Literate	97.7	5.3
Urban	93	6.9

Descriptive results presented in the Table 7. 12 shows that all the SUS scores are in the acceptable range (shown in Figure 7. ). To see if there is any significant variance of the user satisfaction on SUS scale across the user groups ANOVA test was run.

**Table 7. 13 ANOVA results of SUS across all the user groups**

ANOVA						
		Sum of Squares	df	Mean Square	F	Sig.
SUS	Between Groups	134.963	1	134.963	4.140	.045
	Within Groups	2868.926	88	32.601		
	Total	3003.889	89			

Results (shown in Table 7. 13) shows that there is a statistically significant difference between groups as determined by one-way ANOVA ( $F(1, 88) = 4.140, p = .045$ ). Though ANOVA results shows that there is a significant difference between groups, a one-sample test was run to obtain the range of this variance.

**Table 7. 14 One-sample t-test descriptive results of SUS scores**

One-Sample Statistics				
	N	Mean	Std. Deviation	Std. Error Mean
<b>SUS</b>	90	95.88888	5.8096093	.6123866

**Table 7. 15 One-sample t-test results of SUS scores**

One-Sample Test						
SUS	Test Value = 95					
	t	df	Sig. (2-tailed)	Mean Difference	95% Confidence Interval of the Difference	
					Lower	Upper
	1.452	89	.150	.8888889	-.327910	2.105688

A one-sample t-test was run to determine whether depression score across user groups was different to normal, defined as a depression score of 95 that falls in the SUS

acceptance ranges depicted in the Figure 7. . Mean depression score (**M=95.8**, **SD=5.8**) was higher than the normal depression score of 95, and statistically Insignificant (**p=.150**). Table 7. 14, Table 7. 15 presents the results of one sample t-test. Results shows that though there is variations in the satisfaction score, one-sample t test results shows that these variances are within the top acceptance range therefore the results upholds our Posit 2.

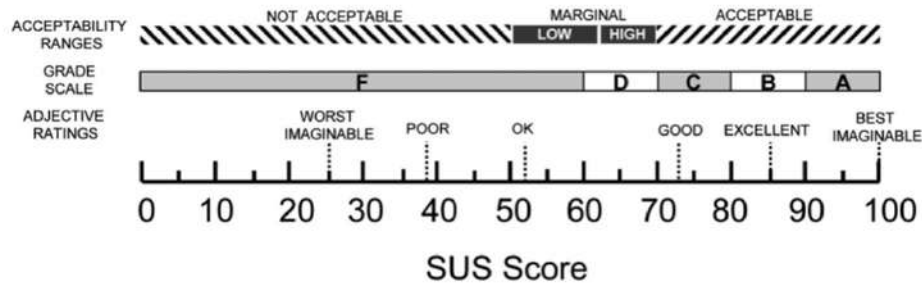


Figure 7.9 System usability scale acceptance ranges Source: Brook 1986

Posit 2: IESI Interface designed using the inferential GUI design guidelines will achieve the higher satisfaction /usability across all the Rural and Urban User groups.

Technology Acceptance:

All the technology acceptance model instrument items data was collected on 7 point Likert scale. Table 7. 16 , Table 7.17 and Table 7. 18 presents the combined and individual descriptive results of the technology adoption variables of rural and urban user groups respectively.

Table 7. 16 Consolidated TAM descriptive results

	Descriptive Statistics (Valid N=90)				
	N	Minimum	Maximum	Mean	Std. Deviation
Perceived Usability	90	21	28	27.23	1.46
Perceived Ease Of Use	90	21	28	26.37	1.83
Intention to Use	90	12	14	13.80	.58
Information satisfaction	90	55	71	68.73	3.38
Overall Information satisfaction	90	10	14	13.688	0.788

**Table 7. 17 TAM descriptive results of rural user group**

Descriptive Statistics (Valid N=76)					
	N	Minimum	Maximum	Mean	Std. Deviation
PU	76	24	28	27.57	.98
PEOU	76	21	28	26.34	1.83
IU	76	12	14	13.96	.25
IS	76	63	71	69.64	2.01
OIS	76	10	14	13.907	0.37157

**Table 7. 18 TAM descriptive results of urban user group**

Descriptive Statistics (Valid N=14)					
	N	Minimum	Maximum	Mean	Std. Deviation
PU	14	21	28	25.35	2.169
PEOU	14	23	28	26.57	1.91
IU	14	12	14	12.92	.99
IS	14	55	71	63.78	4.88
OIS	14	10	14	12.5	1.286

Results shows that all the variables PU,PEOU ,IS,OIS and IU are rated high across all the user groups showing the user intentions of satisfaction ,use and acceptance of the interfaces.

TAM Specific Hypotheses testing results:

Hypotheses are formulated on technology acceptance model (shown in Figure 7. ) to see the variables affecting the user acceptance of the technology and relation between variables affecting the user use intentions.

A Spearman's correlation was run to assess the relationship between perceived user beliefs and use intentions using sample of 90 participants. Model shown in Figure 7.

presents the correlation results. Results shows that there was a strong, positive correlation between perceived ease of use and perceived usefulness, which was statistically significant at ( $r_s = .243^*$ ,  $p = .021$ ), overall information satisfaction and perceived usefulness significant at ( $r_s = .430^{**}$ ,  $p = .000$ ). (Detailed results in Annexure D). The results of the Technology Acceptance Model–specific hypotheses(H<sub>3</sub> to H<sub>8</sub>) illustrated in Figure 7.10 and are summarized in Table 7.19

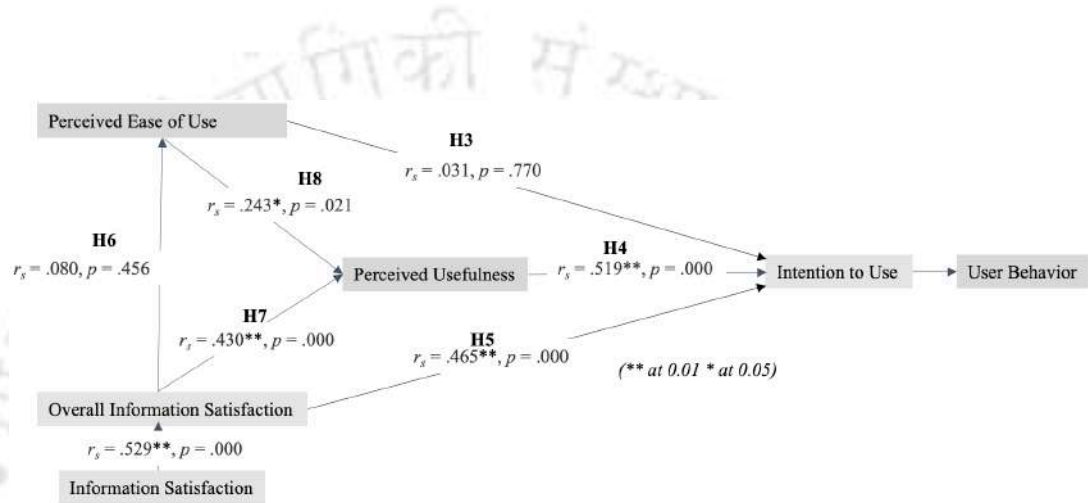


Figure 7. 10 Correlation results of IESI technology acceptance model across rural and urban users

## 7.5 Summary of the results:

Table 7. 19 shows the summary of the results of posits and hypotheses tests

Posit/Hypothesis	Result
Posit 1: IESI Interface designed using the Inferential guidelines will achieve the good task effectiveness across all the Rural and Urban User groups.	Upheld
Posit 2: IESI Interface designed using the inferential guidelines evolved will achieve the good satisfaction	Upheld

/usability across all the Rural and Urban User groups.	
Hypothesis 1: A positive relationship exists between Task time and Age across all the user groups	Accepted
Hypothesis 2: A positive relationship exists between level of education and Task efficiency across all the user groups	Accepted
Prototype Specific Hypothesis for Validating TAM	
Hypothesis 3	Rejected
Hypothesis 4	Accepted
Hypothesis 5	Accepted
Hypothesis 6	Rejected
Hypothesis 7	Accepted
Hypothesis 8	Accepted

It is observed that Users from all the user groups were able to perform IESI Interface tasks effectively. It is observed that there are differences in task performance across Individual user groups influenced by the user group characteristics such as age and education but within the higher user satisfaction levels. It is Evident from the validation test results that the IESI interfaces designed with inferential guidelines positively influencing the usability and user satisfaction across all the user groups Improvement in subjects' task effectiveness and User satisfactions over the existing Interfaces were found.

## 7.6 Chapter Summary

The chapter presents the results of user based usability tests of simulated IoT Enabled smart home interfaces conducted across India. Results shows that all the variables PU,PEOU ,IS,OIS and IU are rated high across all the user groups showing the user intentions of satisfaction ,use and acceptance of the interfaces. The results indicate

that the IESI interfaces designed using inferential guidelines found to be accepted and satisfied the rural and urban users.



## 8. Discussion ,Contribution and Limitations

*Abstract: This chapter presents the significant contributions of the thesis, its limitations and directions for future work in this area.*

### 8.1 Discussion

This thesis began with an enquiry to understand the status of graphical user interfaces (GUIs) currently available across India, focusing primarily on energy meters and status of emerging technologies- namely the Internet of Things (IoT) enable product interfaces. The initial step was a comprehensive literature survey covering the usability and design practices of existing interfaces across various domains. As established in Chapter 2, the literature survey identified a clear gap: existing interfaces often fail to effectively communicate meanings to their intended users, particularly in emerging countries like India.

This gap became more evident through empirical insights from the initial field studies described in Chapter 4. User study-I revealed significant shortcomings, such as poor readability, low understanding of information (77% users found interfaces hard to understand without technical knowledge), and substantial complexity due to technical terminology. Further, many users expressed distrust towards these interfaces due to limited feedback mechanisms and difficulty comprehending provided information. The design audit of existing meter interfaces further validated these findings, showing that interfaces relied heavily on numerical and English-language information, restricting usability to only those users with relevant knowledge.

To systematically bridge this gap, Insights form Chapter 4&5 developed inferential guidelines based directly on user studies and user modelling. Unlike existing heuristic frameworks such as those by Jakob Nielsen (1993), which are broad, generic, and mostly applicable to traditional desktop environments- the guidelines developed in this thesis explicitly address context-specific aspects like language preferences, literacy, cultural familiarity, and user trust specific to Indian rural and urban user

groups. For instance, Nielsen's generic guideline of providing help and documentation contrasts distinctly with the more context-sensitive guideline developed here, which emphasizes voice navigation guidance in users' mother tongues or bilingual formats, significantly enhancing usability for diverse literacy levels.

The validation of these guidelines (Chapter 6 and Chapter 7) provided evidence confirming their effectiveness in the Indian context. Simulated IoT-enabled smart home interfaces (IESI prototypes) designed using these guidelines achieved significant improvements in task effectiveness and user satisfaction across both rural and urban user groups, as initially posited. Hypothesis testing (Chapter 7) further revealed meaningful relationships between demographic factors such as age, education levels, and user efficiency, substantiating that demographic considerations are critical when designing user interfaces in the Indian context.

The contribution of this thesis lies clearly in contextualizing generic GUI design principles into a set of inferential guidelines suitable specifically for India's diverse user groups and IoT contexts. While the guidelines appear somewhat aligned with general principles such as Nielsen's heuristics, the critical difference- and hence the real contribution- is their precise adaptation to Indian user conditions derived from empirical, context-specific user studies. Thus, unlike generic heuristics, these guidelines significantly enhance usability by addressing cultural, educational, and linguistic realities unique to Indian users.

Below is a comparison of Jakob Nielsen's GUI heuristics versus empirically inferred, India-focused guidelines from this thesis. This highlights where the inferred guidelines aligns with, diverges from, or extends the generic principles, making the thesis's unique contributions clear for designers familiar with existing heuristics.

#### 1. Help & Documentation

Nielsen (10): “It may be necessary to provide help and documentation.”

This Thesis: Embeds voice-guided assistance in users’ mother tongues or bilingual prompts (Guideline 2).

-Instead of generic, static manuals, the interface delivers spoken, in-situ instructions tailored to low-literacy contexts.

## 2. Match Between System & Real World

Nielsen (2): “The system should speak the users’ language...”

This Thesis: Proposes two distinct visual vocabularies- purely icon-based for rural users and icon + text combinations for urban users (Guideline 1).

-Rural iconography draws on familiar, concrete metaphors; urban icon + text embeds technical labels where literacy and exposure allow.

## 3. Aesthetic & Minimalist Design

Nielsen (8): “Dialogs should not contain irrelevant or rarely needed information.”

This Thesis: Prescribes stripping out auxiliary or complex data entirely from rural screens (Guideline 5).

- Rather than “remove clutter,” it identifies exactly which readings (e.g. cumulative kWh only) meet rural users’ needs, slashing cognitive load.

## 4. Flexibility & Efficiency of Use

Nielsen (7): “Provide accelerators unseen by novices for expert users.”

This Thesis: Recommends exposing advanced, time-series consumption data prominently for urban, technically literate users (Guideline 6).

-Instead of hidden shortcuts, the design surfaces detailed readings for those who require them, while keeping the entry barrier low for novices.

## 5. Error Prevention & Trust

Nielsen (5): “Prevent problems from occurring in the first place.”

This Thesis: Introduces reassuring labels and clear iconography that evoke a sense of safety (Guideline 3).

-Beyond preventing mistakes, it addresses the emotional barrier- many Indian users fear “breaking” metering equipment- by visually reinforcing reliability.

## 6. Recognition Rather Than Recall

Nielsen (6): “Make objects and actions visible; minimize memory load.”

This Thesis: Combines culturally resonant icons with voice cues in rural and semi-literate contexts (Guideline 2).

-Users no longer must memorise abstract symbols; the interface announces each function aloud in their own language.

## 7. Visibility of System Status

Nielsen (1): “Keep users informed about what is going on.”

This Thesis: Integrates simple animations and live activity indicators (Guideline 4).

-Dynamic feedback- such as a spinning meter graphic- builds confidence where a static readout might seem unresponsive or outdated.

### Why These Add Value

Contextual Precision: Every guideline distinguishes rural vs. urban, local tongue vs. English, and even emotional trust- rather than one-size-fits-all advice.

Multimodal Delivery: Help is no longer a hidden manual but a spoken, embedded companion.

Emotional & Cultural Fit: This thesis directly confronts the fear and unfamiliarity that generic heuristics overlook.

By reframing Nielsen's heuristics through the lens of India's diversity, these guidelines become both specific and immediately actionable for designers. From a practical viewpoint, designers working in India or similarly emerging contexts can leverage these guidelines directly. Rather than relying on broad and generic principles, designers can access empirically grounded heuristics that precisely match the usability needs of Indian user groups, enhancing the effectiveness and adoption of IoT-enabled products and interfaces.

This thesis demonstrates a structured design approach-semantic design methodology, that begins with understanding users' meanings, contexts, and cultural nuances. The iterative evaluation process emphasized both expert-driven semantic evaluations and direct user validation, ensuring that designed interfaces resonate meaningfully with users' lived experiences. Such an approach not only validates the design outcome but significantly enhances communicability, usability, and user satisfaction.

#### Revisiting Research Questions:

The research questions in this thesis were shaped by a number of theoretical gaps identified in the literature -such as poor cultural contextualisation in GUI design, missing user models for diverse Indian segments, and limited incorporation of localised semantics in interface heuristics. Each of these gaps is addressed through findings from user studies, semantic analysis, and validation testing.

RQ1-aimed to identify variables that affect GUI semantics. Findings from user interviews and field observations confirm that variables such as literacy (both digital and textual), symbolic familiarity, colour and icon interpretations, and visual hierarchy are key determinants in the success or failure of interface comprehension. These variables strongly support cognitive theory observations (Ware, 2004; Nisbett & Miyamoto, 2005) that perception is influenced by memory and lived experience, which are deeply rooted in cultural and contextual exposure.

RQ2- examined whether common sentiments influence interpretation of GUI elements. The findings show clear evidence of shared symbolic memory among rural and urban users - for example, use of paddy field and soil cracks in the rural contexts, preference for familiar visual metaphors (e.g., use of right hand to pay the bills). This reinforces prior semantic studies (Krippendorff, 2006; Karjalainen, 2007) that meaning is not inherent in symbols but attributed through usage and context.

RQ3- asked whether these perceptions and sentiments can be modelled. Results from usability and acceptance testing suggest clear clustering of preference patterns based on user segment (rural/urban). These user behaviour models support the idea of developing interaction frameworks based on demographic and experiential factors - consistent with arguments made in the literature (Fischer, 2001; Allen, 1997).

RQ4- focused on whether a design method or heuristics could be developed for use in Indian IoT GUI systems. Based on synthesis of user modelling studies, usability testing, and design audits, a semantic design approach and a set of heuristics were derived. These heuristics incorporate both cultural/contextual factors and interface-level parameters. Their validation, particularly in the rural context, showed measurable improvement in comprehension and satisfaction. This confirms that theory-driven heuristics - rooted in UCD, semantics, and cultural cognition - can offer practical benefits in diverse contexts.

### **8.3 Theoretical Contributions of the Thesis**

This thesis contributes to theory in the following ways:

It extends the existing user-centred design (UCD) framework by adding a semantic layer informed by symbolic meaning, cultural cues, and sentiment interpretation. While ISO 9241-210 defines HCD as user-focused, the framework does not explicitly account for symbolic and culturally rooted meaning transfer. This study fills that gap.

It contributes to design semantics by validating the role of culturally shared meaning-making in interaction success, specifically for GUI-based IoT products. The study reaffirms Krippendorff's (2006) position that users interpret artefacts based on past experiences, but advances it by identifying GUI-specific patterns among Indian users.

It offers an empirically supported user model framework for Indian rural and urban user groups - a gap identified by Devanuj & Joshi (2013), Gollakota & Doshi (2014), and Yammiyavar (2006). These models reflect real-world diversity, usage patterns, and symbolic preferences that can guide future interface design.

Finally, it proposes a semantic design methodology for touch-based GUIs in IoT-enabled systems, rooted in both user-centred and meaning-centred design traditions.

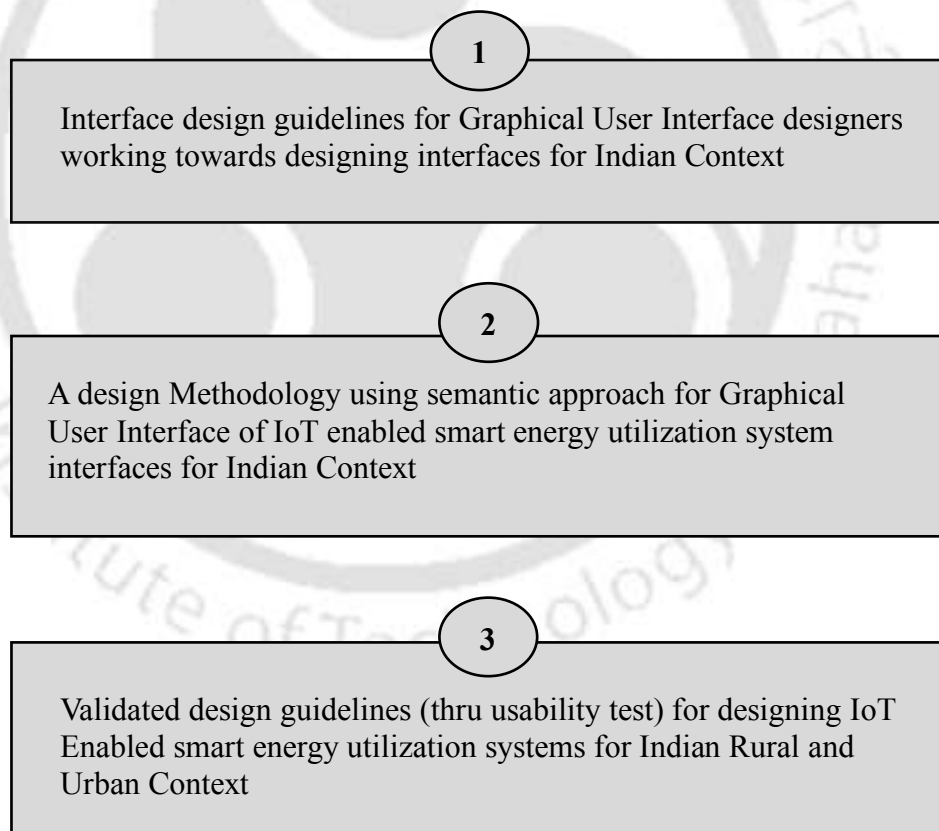


Figure 8. 1 Major thesis contributions

## **8.4 On Contextual Generalizability – India as a Technology-Receiving Economy**

As reviewed in Chapter 2, India falls into the category of digitally emergent or technology-receiving economies (Brewer et al., 2005; Fonseca, 2004), where digital products are often imported or transplanted from Global North contexts without adequate localization. The findings of this thesis are not limited to India alone -they have relevance to other economies such as Brazil, Indonesia where similar patterns of user diversity, low digital literacy, and symbolic dissonance exist. Hence, the heuristics and semantic methodology developed in this work may be generalized - with appropriate cultural calibration -to other emerging markets with heterogeneous user bases.

## **8.5 Limitations and future scope of this research:**

As with any qualitative and design-based research, certain limitations exist in this work:

Validation of inferred design guidelines in the rural context was done only on the rural user group from Telangana using Telugu and English language assistance hence it does not verify with other Indian languages. However, rural settings in India have a fair degree of similarity (Desai, 2006) such as farm activities thereby Telangana farmers are assumed to be representation of farmers.

Simulated GUIs and hardware setup used in this thesis is not a full-scale product model hence the thesis does not verify the full-scale IoT technology acceptance model. Such as in recent times, security (Ericsson 2018) in IoT enabled services which is related to technology layer has become a major concern that may affect the user acceptance of the technology.

Design method followed and the guidelines were applied for IoT enabled smart energy utilization interfaces only. Guidelines can be applied on other test cases in future to find further conclusive results on reliability.

Design guidelines and methods in this thesis are applied on touch enabled GUI only, future modalities such as VR and mixed reality interfaces can be explored in future.

## **8.6 Role of design guidelines in AI Era**

In the era of AI, the classical paradigm of graphical user interfaces (GUIs) may evolve or even fade in many contexts -but that does not render design guidelines obsolete. On the contrary, the guidelines derived in this thesis can serve a new and critical role: as priors or constraints for training AI models (LLMs or other machine learning systems) such that the AI “speaks” to the user in a way adapted to their cognitive, linguistic, and cultural profile. As pointed out by several authors (Xu et al., 2025) (Fang et al., 2024) (Xiao, Yuan, Zhu, Li, & Honavar, 2024), the use of human preference data and human feedback is crucial in the training of large language models, and frameworks for incorporating such alignment signals are continuously evolving in this direction.

In other words, in an IoT ecosystem mediated by conversational agents or AI assistants, the user-facing “interface” is often natural language or multimodal interaction. But that interaction still needs to adhere to usability, comprehensibility, and accessibility norms (Dhinakaran et al., 2022). Suppose, for example, the AI is communicating with a farmer about energy transactions (meter readings, tariff updates, load schedules, subsidy information). If the AI uses technical jargon, numeric complexity, or non-intuitive phrasing, it defeats the purpose (Wang et al., 2022). What we need instead is an “AI interface” that respects the same constraints we studied for GUIs targeted at the Indian population: clarity, minimal cognitive load, local idioms, error-tolerance, fallback explanations, predictable patterns, etc.

Thus, the design guidelines from this thesis can be recast as training objectives, constraints, or reward functions in AI model development. When fine-tuning or prompting an LLM for domain tasks (e.g. energy management, IoT status reporting, alert notifications), one can encode constraints or biases so that the outputs avoid violating the design heuristics (e.g. no overly long sentences, avoid advanced technical metaphors, use familiar units, prefer local language where needed). Over time, the model learns to “speak the user’s language” effectively.







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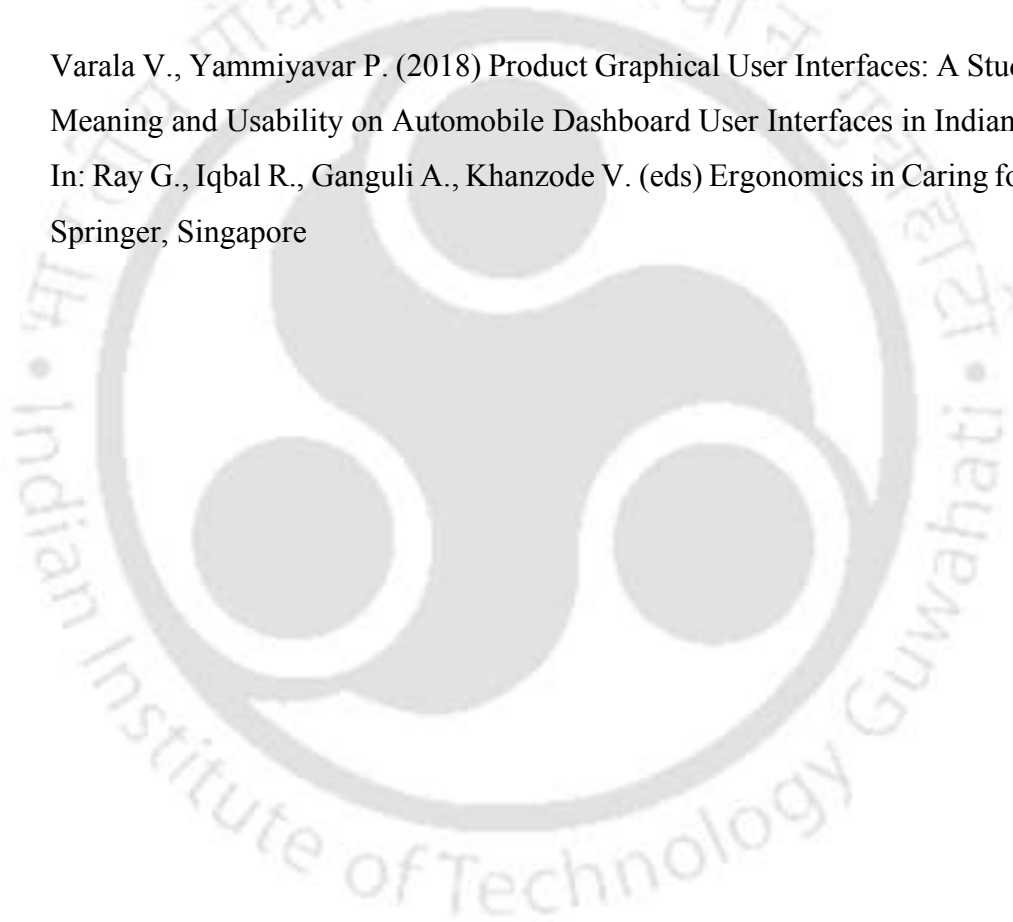
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*Annexure A*

# Sample Transcribed responses of Energy meter User Study-I:

S.No. Name: [REDACTED] Date: 03/06/14

Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
<ul style="list-style-type: none"> <li>→ could study easily</li> <li>→ look old</li> <li>→ needs to effort to ride the reading of consumption</li> <li>→ need some sign to indicate it is reading</li> <li>→ feels fearful to interact</li> <li>→ metal parts</li> <li>→ Unnecessary information</li> <li>→ Analog</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ Digital</li> <li>→ form is good</li> <li>→ Not scary because of ease of metal parts</li> <li>→ feels more safe</li> <li>→ ordinary form old meter</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ quite informative for expert user</li> <li>→ good design</li> <li>→ feels safe as encase in plastic</li> <li>→ display size can be increase</li> <li>→ LED signature Communicative</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ very nice</li> <li>→ Sticking on the information required</li> <li>→ amazing</li> <li>→ can't take a close</li> <li>→ more comfortable also for only</li> <li>→ informative</li> <li>→ light indicators should be used</li> <li>→ needs to be audio support</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ To many LEDs on front</li> <li>→ distinguishing</li> <li>→ Less interactive</li> <li>→ Compact &amp; good</li> <li>→ Comfort</li> <li>→ Font is better in EU</li> <li>→ screen size can be increase</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ nice</li> <li>→ All the info is provided</li> <li>→ more option for interaction</li> <li>→ amazing</li> <li>→ good</li> <li>→ user interface is good</li> <li>→ All the space on the screen is utilized properly</li> <li>→ calling icons</li> </ul>	<ul style="list-style-type: none"> <li>→ looks not interactive</li> <li>→ NO digital indicators</li> <li>→ less info</li> <li>→ not clear font not attractive</li> <li>→ wastes space or not clearly utilized</li> <li>→</li> </ul>

\* more content about info

S.No. Name: [REDACTED] Date: 01/07/14

Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
<ul style="list-style-type: none"> <li>→ flow of energy is clear by ripple</li> <li>→ looks clean &amp; neat</li> <li>→ Analogic</li> <li>→ Readability is good</li> <li>→ amount of work can be seen clearly</li> <li>→ nice design</li> <li>→ Transparency gives an image of transparent &amp; functional</li> <li>→ unlike because metal parts</li> <li>→ gives me a feeling of Don't mix hands</li> <li>→</li> <li>→ Too close demonstration</li> <li>→</li> </ul>	<ul style="list-style-type: none"> <li>→ E4 is more open than E3</li> <li>→ lacks interaction because there is no mobile sig</li> <li>→ Readability is good</li> <li>→ Affordability in noting down reading</li> <li>→ looks like a satellite cap</li> <li>→ speedometer</li> <li>→ more safe but inaccurate because window not seen</li> <li>→ gives a feeling of don't mix hands</li> <li>→</li> <li>→ can't distinguish because don't know works happening</li> <li>→ (Lacks LEDs)</li> </ul>	<ul style="list-style-type: none"> <li>→ looks Advanced</li> <li>→ complex &amp;</li> <li>→ may be i need a demo about how it works</li> <li>→ many parameters</li> <li>→ looks huge</li> <li>→ Reading is too small</li> <li>→ looks too rigid</li> <li>→ Not very appealing</li> <li>→ Advanced mission</li> <li>→ It looks too interaction</li> <li>→ Boring</li> </ul>	<ul style="list-style-type: none"> <li>→ Very interesting see</li> <li>→ can't take a watch (Alarm)</li> <li>→ much more handy</li> <li>→ Quite interactive</li> <li>→ out of information</li> <li>→ No confusion</li> <li>→ even the information is clustered</li> <li>→ Appealing</li> <li>→ easy to teach others</li> <li>→ safe (more) because someone</li> <li>→ softly as it is wireless</li> </ul>	<ul style="list-style-type: none"> <li>→ Interesting</li> <li>→ looks like a car</li> <li>→ Speedometer</li> <li>→ Similiar compare to E4</li> <li>→ stylish with extra information</li> <li>→ Not interested because getting more information is sight fear</li> <li>→ less</li> <li>→ Light</li> <li>→</li> <li>→ reminds me of zone violation</li> </ul>	<ul style="list-style-type: none"> <li>→ more graphically</li> <li>→ Improved version of E4 with on extra graphic content</li> <li>→ appealing because of graphic</li> <li>→ looks like more function</li> <li>→ somewhat more smarter</li> <li>→ No confusion gives me the informed and i want in a single form</li> <li>→</li> <li>→ reminds me of zone violation</li> </ul>	<ul style="list-style-type: none"> <li>→ reminds me of Lift</li> <li>→ Complexity from be cause of steel</li> <li>→ Rigid feeling</li> <li>→ Boring;</li> <li>→ looks boring though it is providing necessary info</li> <li>→ can't compare to E3</li> <li>→ looks heavy feel</li> </ul>

S.No. Name: [redacted] Date: 1/07/14

Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
<ul style="list-style-type: none"> <li>→ could recognize</li> <li>→ good ring gives less info about working conceals</li> <li>→ Information</li> <li>→ Not very consistent</li> <li>→ can user maintain</li> <li>→ transparent</li> <li>→ No diagnostic info</li> <li>→ need to put effort to remember safety</li> <li>→ No idea why</li> <li>→ No option for color</li> <li>→ Demand can be can of</li> </ul>	<ul style="list-style-type: none"> <li>→ Locks Interaction</li> <li>→ Safety is better than E1</li> <li>→ metallic mesh ring gives</li> <li>→ unnecessary info on the front face</li> <li>→ mysterious</li> <li>→ No color option</li> <li>→ mysterious in functional</li> </ul>	<ul style="list-style-type: none"> <li>→ No clear Readability</li> <li>→ pretty safe because of plastic</li> <li>→ unnecessary info</li> <li>→ LED</li> <li>→ Display is not balanced to the rest</li> <li>→ form is simple</li> <li>→ looks adequate because of the form</li> </ul>	<ul style="list-style-type: none"> <li>→ Alarm clock</li> <li>→ could not associate to electricity meter in the first look</li> <li>→ No confusion about information</li> <li>→ looks interactive</li> <li>→ Safety (snake warning)</li> <li>→ E2 is done to E1</li> </ul>	<ul style="list-style-type: none"> <li>→ Alarm clock at first look</li> <li>→ look info on the display</li> <li>→ No idea why the light are for</li> <li>→ E1 is better than E2</li> <li>→ E1 still can advance to E2</li> </ul>	<ul style="list-style-type: none"> <li>→ looks like a smart mobile</li> <li>→ interesting</li> <li>→ interesting</li> <li>→ Icons are not represented the info</li> <li>→ Not fully the icons</li> <li>→ color represents can be changed</li> </ul>	<ul style="list-style-type: none"> <li>→ Look like some meter</li> <li>→ can not associate with meter</li> <li>→ <del>Steel</del> steel is not safe</li> <li>→ need more info</li> </ul>

more parts  
 → Absolute Reality is not available  
 → Purley function  
 → Obd.  
 → more sophisticated

S.No. Name: [redacted] Date: 4/7/14

Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
<ul style="list-style-type: none"> <li>→ can't orient</li> <li>→ good design</li> <li>→ good readability</li> <li>→ Bit of unnecessary information</li> <li>→ But essential</li> <li>→ no safety issue</li> <li>→ need only expect on touch it</li> </ul>	<ul style="list-style-type: none"> <li>→ circular design is not good</li> <li>→ Locks mechanism because it looks like a wall clock</li> <li>→ good readability</li> <li>→ safe compare to E1</li> <li>→ LED is a good option</li> <li>→ needs backlight</li> </ul>	<ul style="list-style-type: none"> <li>→ Does not look like a electricity meter</li> <li>→ looks advanced</li> <li>→ needs backlight</li> <li>→ need to increase display size</li> <li>→ unnecessary info printed on the display</li> <li>→ full safe</li> </ul>	<ul style="list-style-type: none"> <li>→ looks like an alarm (no mechanism)</li> <li>→ Don't like it</li> <li>→ Information is bit cluttered</li> <li>→ can't not differentiate between two readings</li> <li>→ needs backlight &amp; indicators</li> </ul>	<ul style="list-style-type: none"> <li>→ looks good because of less info &amp; bleed backlight</li> <li>→ portable</li> <li>→ concerned about more LED (not recognized)</li> <li>→ Don't recognize interaction button</li> </ul>	<ul style="list-style-type: none"> <li>→ looks like mobile</li> <li>→ Difficult to understand</li> <li>→ Locks Interaction</li> <li>→ critical to understand start</li> </ul>	<ul style="list-style-type: none"> <li>→ Not clear Readability</li> <li>→ unnecessary info can be decreased</li> <li>→ needs clear demarcation between two Readability</li> <li>→ Simple readings are good to read</li> <li>→ steel is not good gives danger feeling</li> </ul>

\* more concern about (readability)  
 v an important part can be made smaller.

S.No. Name: [redacted] Date: 4/7/19

Element 1	Element 2	Element 3	Element 4	Element 5	Element 6	Element 7
<p>Scenes to</p> <p>→ could attach to meter</p> <p>→ could attach identity wire</p> <p>→ could not coded status as per the text printed</p> <p>→ No fear as current stuck</p> <p>→ can't identify meter wiring</p> <p>→ No issues with extra info printed might be read for some professional etc.</p>	<p>→ doesn't look a meter</p> <p>→ can't expensive</p> <p>→ no access to meter wires so maybe difficult to break</p> <p>→ concern as meter health, weather it is sunny or not need a indication (LED)</p>	<p>→ looks safe</p> <p>→ can't suggest &amp; water proof</p> <p>→ concern as weather condition → rain, etc.</p> <p>→ look advanced</p> <p>→ don't get the info printed below but don't mind it being there.</p> <p>→ Informant that printer below is not disturbing</p>	<p>→ doesn't look like a meter</p> <p>→ safe</p> <p>→ can't read the info in first signal</p> <p>→ But excited about it</p> <p>→ not usable bits is good</p>	<p>→ looks good</p> <p>→ portability is good</p> <p>→ No safety issues</p> <p>→ No issues as per LED</p> <p>→ reading is clear</p>	<p>Doesn't look like meter in the first glance</p> <p>→ but surprised weather in finding it</p> <p>→ worried by ES it gives a choice</p> <p>→ Because it is interactive</p> <p>→ concern as maintenance</p> <p>→ need better to learn it</p>	<p>→ look like a meter</p> <p>→ can't identify button</p> <p>→ clear info</p> <p>→ unnecessary info</p> <p>→ would prefer ES over ES because there are indications as device</p> <p>→ not health &amp; no fear</p>

## Content Analysis of Participant Responses (User Study I)

### 1. Data Description

A total of **27 participants** were involved in the seven-meter evaluation. Their demographic breakdown was as follows:

Demographic	Category	Count
<b>Gender</b>	Male	18
	Female	9
<b>Age</b>	Range: 22–58 years	–
	Average: 37 years	–
<b>Occupation</b>	Farmers	8
	Designers	7
	Engineers/Experts	7
<b>Education</b>	Housewives	5
	Non-literate	4
	Primary–High School	5
	University Graduates	18

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## 2. Analysis Method: Inductive Thematic (Content) Analysis

We followed a standard inductive thematic coding approach, as described by Krippendorff (2004) and Auerbach & Silverstein (2003):

1. **Familiarization**
  - Read all participant responses for each of the seven meter displays (Elements 1–7).
2. **Open Coding**
  - Extracted meaningful text segments and assigned preliminary code labels (e.g. “Recognized as meter,” “Couldn’t read numbers,” “Fearful of approach,” etc.).
3. **Codebook Development**
  - Grouped all repeated labels into a master list per element:
    - Element 1 codes E1C0–E1C5
    - Element 2 codes E2C0–E2C7
    - ...
    - Element 7 codes E7C0–E7C6
4. **Application (Axial Coding)**
  - Marked each participant’s transcript as “Yes” or “No” for each code.
5. **Tabulation & Quantification**
  - Counted how many of the 27 participants endorsed each code.

---

## 3. Coding & Tabulation Steps

1. **Define Codes**
  - Pulled code definitions from the original “Analysis 4-Coding gp.docx” file.
2. **Apply Codes**
  - Reviewed each participant’s response row by row, marking “Yes” if the comment matched the code.
3. **Count Occurrences**
  - Summarized total “Yes” counts per code across all 27 participants.
4. **Note Data Gaps**
  - Identified any codes with zero endorsements or elements with missing feedback.

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## 4. Outcomes

### 4.1 Element 1 (Meter 1) – Detailed Table

<b>Code Definition</b>	<b>n (27)</b>
E1C0 Could tell this was an electricity meter	27
E1C1 Could identify the numerical reading	21
E1C2 Noticed status indicators (dials, LEDs, icons)	18
E1C3 Complained about unnecessary or cluttered information	20
E1C4 Mentioned emotional responses (fear, safety, aesthetics)	22
E1C5 Prior exposure/experience with this meter type	24

---

### Element 2 (Meter 2) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E2C0 Could <i>not</i> associate this display to an electricity meter	3
E2C1 Described it as “safer” than Meter 1	25
E2C2 Noted lack of interactive elements	14

<b>Code Definition</b>		<b>n (27)</b>
E2C3	Praised readability	22
E2C4	Liked clear separation of information	18
E2C5	Preferred display shape	20
E2C6	Could <i>not</i> understand numerical reading	21
E2C7	Described it as “mysterious” or confusing	5

**Data Gap:** 2 participants offered no usable feedback for Element 2.

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Element 3 (Meter 3) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E3C0 Could associate it to an electricity meter	27
E3C1 Described it as “safe” or trustworthy	21
E3C2 Found it interactive (buttons/dials/LEDs)	19
E3C3 Commented on text size/display clarity	24
E3C4 Could understand the displayed information fully	20
E3C5 Mentioned the meter’s bulky/industrial form factor	16

**No Data Gaps**—all participants responded.

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Element 4 (Meter 4) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E4C0 Mistook it for another device (e.g. clock)	6
E4C1 Found it interactive/“advanced”	23
E4C2 Noted missing interactive features	12
E4C3 Praised its high information density/readability	15
E4C4 Prioritized “fare” or billing over technical readouts	19
E4C5 Could <i>not</i> understand any of the metrics	19

**Data Gaps:** Codes E4C6–E4C7 unused; no matching comments.

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Element 5 (Meter 5) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E5C0 Recognized it as an electricity meter	27
E5C1 Found it informative (technical & billing details)	8
E5C2 Noted it lacked interactive elements	13
E5C3 Complained about flashing LEDs/visual “noise”	18
E5C4 Praised text/display legibility	24
E5C5 Called it “classy” or liked its circular, compact design	20

**No Data Gaps**—full coverage.

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Element 6 (Meter 6) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E7C0 Recognized it as an electricity meter	19
E7C1 Found it non-interactive; static	10
E7C2 Noted it was informational but unengaging	18
E7C3 Described it as “dull” or industrial (metallic)	22
E7C4 Criticized font/display for being boring/unbalanced	20
E7C5 Complained data not well organized; unbalanced layout	19
E7C6 Felt unsafe due to exposed metal finish	11

**Data Gap:** Code E7C7 unused.

Element 7 (Meter 7) – Summary Table

<b>Code Definition</b>	<b>n (27)</b>
E6C0 Mistook it for another household device	8
E6C1 Called it “smart”/highly interactive	10
E6C2 Found it very information-rich	10
E6C3 Described it as complex or cluttered; hard to follow	17
E6C4 Liked the use of icons/graphics to aid understanding	23

**Data Gaps:** Codes E6C5–E6C7 unused.

<b>Theme</b>	<b>Finding</b>
<b>Readability</b>	Across all seven meters, <b>24 / 27</b> participants (89 %) complained of poor readability on at least one display.
<b>Understanding</b>	Only <b>6–7 / 27</b> (24–25 %) correctly understood the numbers on Meters 2–7.
<b>Complexity</b>	<b>20 / 27</b> (74 %) flagged “unnecessary/cluttered” info on Meter 1; across Meters 2–7, <b>17–20 / 27</b> (63–74 %) called one or more displays “confusing.”
<b>Trust &amp; Feedback</b>	<b>22 / 27</b> (81 %) mentioned fear or safety concerns on Meter 1; across all meters <b>24 / 27</b> (89 %) noted slow or missing live feedback (blinking LEDs, dials).
<b>Information Relevance</b>	On Meters 4–6, <b>19–25 / 27</b> (70–93 %) said billing/fare info mattered more than technical kWh readings.
<b>Aesthetics &amp; Semantics</b>	<b>22 / 27</b> (81 %) responded emotionally (fear, “industrial look,” lack of friendliness) to at least one interface; these affect perceived usability.
<b>Usability &amp; Performance</b>	Only <b>6–10 / 27</b> (22–37 %) felt each meter was “usable” at first glance; <b>17–21 / 27</b> (63–78 %) required assistance or found it non-intuitive.



***Annexure B***

B1

## Questionnaire-Automobile Dashboard Study

All the Questions with Likert Scale are to be answered on a 7 point scale ;Where 1 = strongly disagree, 2 = moderately disagree, 3 = somewhat disagree, 4 = neutral (neither disagree nor agree), 5 somewhat agree, 6 = moderately agree, and 7 = strongly agree

\* Required

1. Name: \*

---

2. Gender \*

*Mark only one oval.*

Male

Female

3. Age: \*

---

4. Occupation: \*

---

5. Ethnicity \*

---

6. Education \*

*Mark only one oval.*

School

Univercity & Higher

Nil

7. Do you drive a car and hold a official driving licence \*

*Mark only one oval.*

Yes

No

8. Do you Own a Car if so Please mention the Make and Model \*

---

9. A car dashboard gives information of the car. In your opinion give relative importance on 1-7 scale to each one of these in terms of their importance to the driver.

---

10. Speed (Speedo Meter) \*

Mark only one oval.

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

11. Battery status \*

Mark only one oval.

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

12. Battery Charge Level \*

Mark only one oval.

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

13. Engine Oil Status \*

Mark only one oval.

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

14. No of Kilometers Traveled \*

Mark only one oval.

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**15. Brake System Status \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**16. Number of hours engine is On \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**17. Status of air pressure in tyres \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**18. Air Conditioner Temperature \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**19. Right turn – Left turn Indicator lamp \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**20. Head light On/Off indicator lamp \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**21. Fuel Level \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**22. Radiator Fan status \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**23. Engine temperature \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**24. Current Gear status \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**25. Head lamp intensity status \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**26. Tacho Meter (RPM) \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**27. Air Bag Indicator \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**28. Ignition status \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**29. Electric power steering \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**30. Malfunction indicator \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**31. Driver seat belt indicator \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**32. ABS \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Less	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	More

**33. 2. We will show you a set of dashboards. Please compare them and give your response for below**

---

**34. The most liked one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**35. The most non confusing one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**36. The most Pleasant/aesthetic one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**37. The most simple one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**38. The most complex one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**39. The most difficult to read one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**40. The most easy to understand one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**41. The most useful one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**46. The most uncheerful(unhappy) one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**47. The most comfortable to read one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**48. The most pleasant one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

**49. The most irritating one \***

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

50. The one that has more useless items \*

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

51. the most efficient one in your opinion \*

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

52. The most safe one in your opinion. \*

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

53. The less safe one in your opinion. \*

*Mark only one oval.*

- 1
- 2
- 3
- 4
- 5

54. 3.1 What is the most attention catching in the Dashboard 1? \*

---

55. 3.2 What is the most attention catching in the Dashboard 2? \*

---

56. **3.3 What is the most attention catching in the Dashboard 3? \***

---

57. **3.4 What is the most attention catching in the Dashboard 4? \***

---

58. **3.5 What is the most attention catching in the Dashboard 5? \***

---

59. **4. When the symbol lights up/ appears what action will you take? \***

---

60. **5. Are you satisfied with the following?**

---

61. **Size of the letters \***

*Mark only one oval.*

Yes

No

62. **Size of the Icon/symbol \***

*Mark only one oval.*

Yes

No

63. **Colour of the symbol /icon \***

*Mark only one oval.*

Yes

No

64. **Size of the letters \***

*Mark only one oval.*

Yes

No

65. **6. Would you prefer labels in your mother tongue instead of English? \***

*Mark only one oval.*

- Yes  
 No

66. **7. Would you like voice instruction in your mother tongue or English? \***

*Mark only one oval.*

- Mother Toungue  
 English

67. **8.Are the various displays and switches are densely packed? \***

*Mark only one oval.*

- Yes  
 No

68. **9.I found the controls and Indications are arranged in comfortable manner? \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

69. **10.I found the controls and Indications are Informative? \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

70. **11.I found the size of all the controls is comfortably appropriate? \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

71. 12.I felt the colors used for all the controls and indications are pleasant? \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

72. 13.I found all the dashboard controls are easy to use \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

73. 14.I found all the dashboard controls are Useful. \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly agree

74. 15.If you are asked to Change /Re arrange the dash clusters desirable how you would rearrange them on the dashboard.

---

75. 16. Perform the task by responding by voice and hand moments. Set your car Air Condition controls to a comfortable temperature.

---

## Automobile Dashboard Symbols

We will show you a set of symbols used in car dashboard. For each of the symbol shown write your response for the questions below.

\* Required

1. **Is the graphic symbol recognizable? \***

*Mark only one oval.*

Yes

No

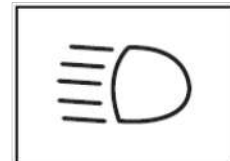
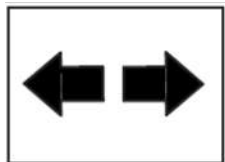
2. **1a. If yes what does it convey?**

\_\_\_\_\_

3. **1b. If Not what do you think it conveys?**

\_\_\_\_\_

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 Google Forms





**Table B. 1 Information Priorities**

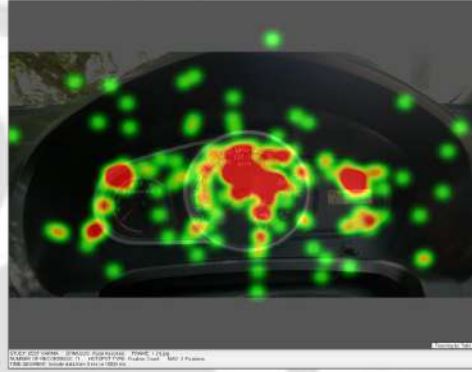
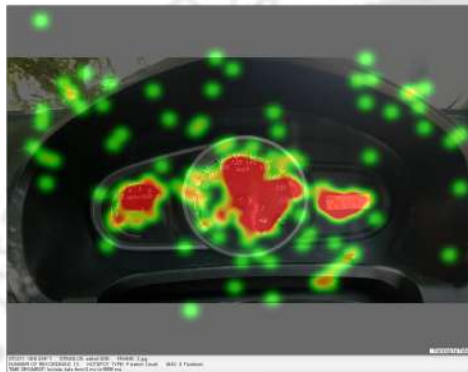
Current Gear status	3	23	Head lamp intensity status	3.47
Ignition status	3.09	22	Air Bag Indicator	3.53
Head lamp intensity status	3.52	21	Electric power steering	3.59
Number of hours engine is On	3.65	20	Number of hours engine is On	3.76
Tacho Meter (RPM)	3.87	19	Engine Oil Status	3.82
Air Conditioner Temperature	3.96	18	ABS	3.88
Electric power steering	4.35	17	Radiator Fan status	3.94
ABS	4.35	16	Current Gear status	4
No of Kilometres Travelled	4.74	15	Battery status	4
Radiator Fan status	5	14	Ignition status	4.06
Air Bag Indicator	5.09	13	Engine temperature	4.24
Driver seat belt indicator	5.3	12	Brake System Status	4.41

Battery Charge Level	5.35	11	Tacho Meter (RPM)	4.71
Brake System Status	5.43	10	Air Conditioner Temperature	4.76
Speed (Speedo Meter)	5.57	9	No of Kilometres Travelled	5.12
Engine temperature	5.57	8	Driver seat belt indicator	5.12
Status of air pressure in tyres	5.65	7	Battery Charge Level	5.18
Engine Oil Status	5.7	6	Status of air pressure in tyres	5.41
Malfunction indicator	5.74	5	Head light On/Off indicator lamp	5.71
Head light On/Off indicator lamp	6.09	4	Malfunction indicator	5.88
Battery status	6.13	3	Indicator lamp	6.06
Fuel Level	6.57	2	Speed Indicator	6.18
Indicator lamp	6.65	1	Fuel Level	6.35
RURAL Users			URBAN Users	

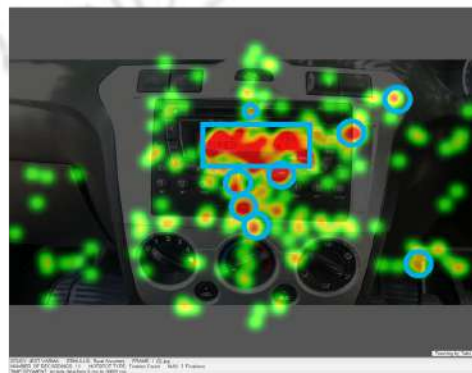
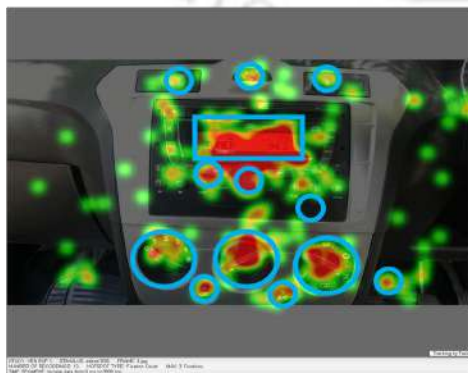
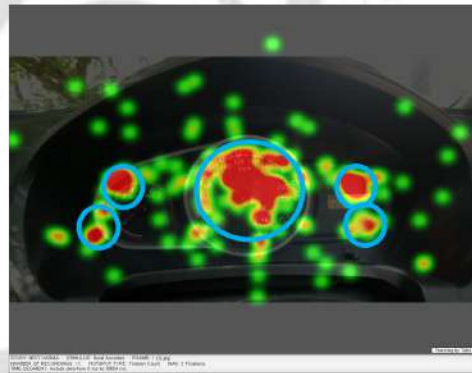
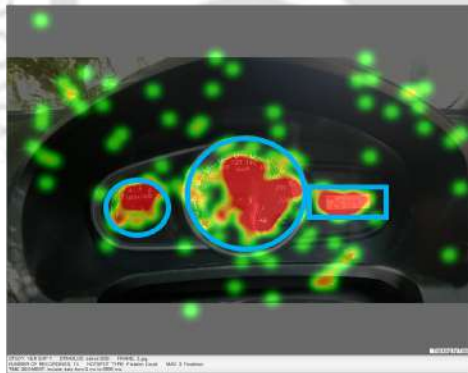
Cumulated eye movement data (hotspot technique):



Sample EMR Stimulus



Recorded Hotspots –left urban sample ,right rural sample

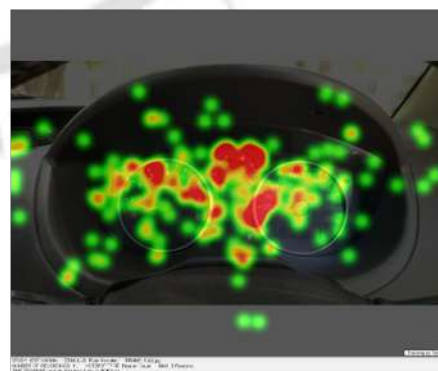
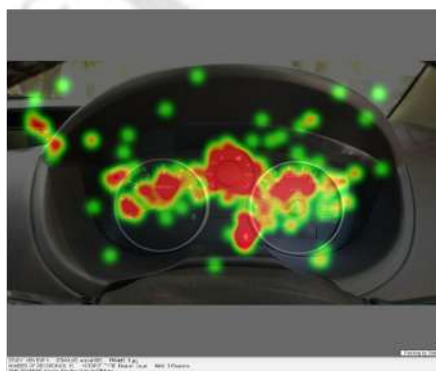
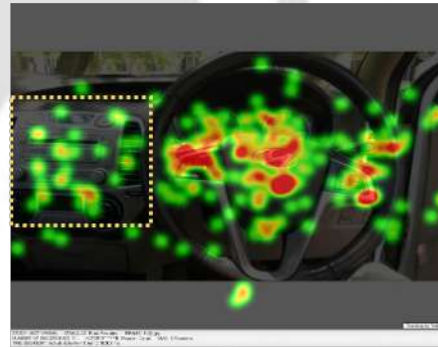
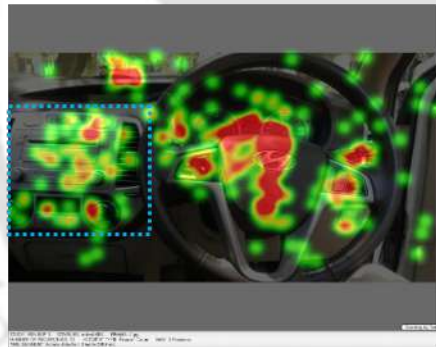
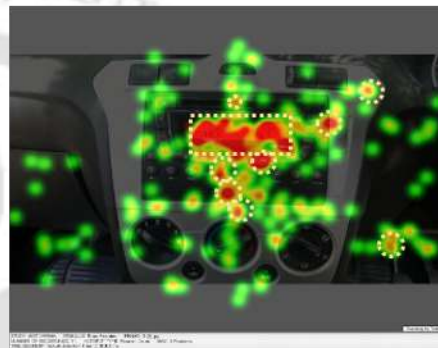
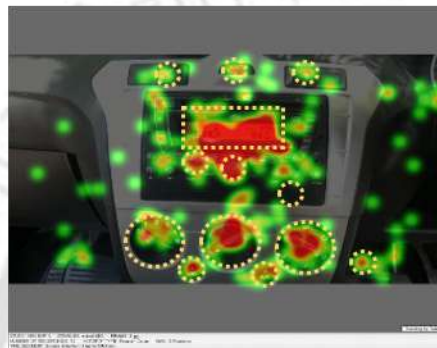
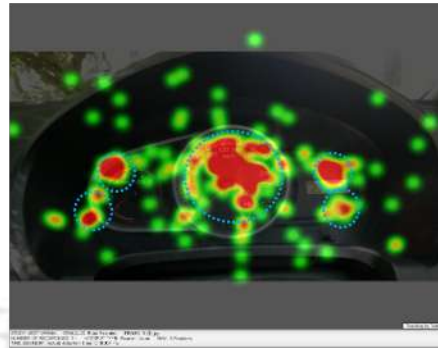
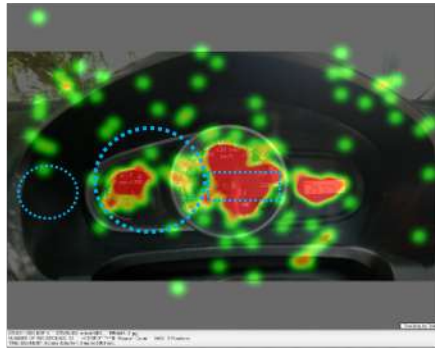


Urban Users

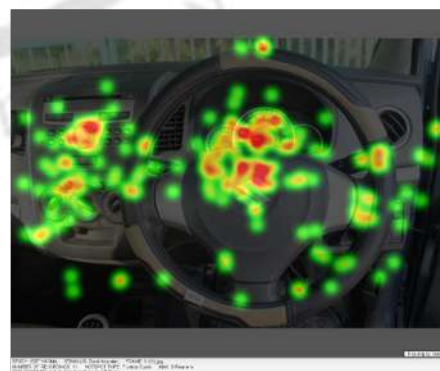
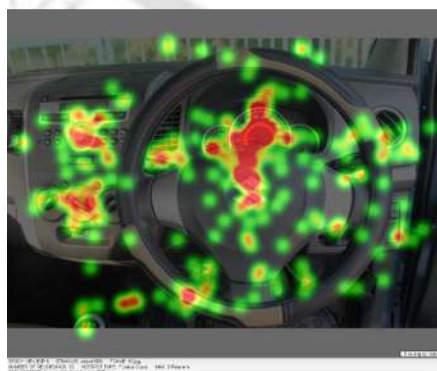
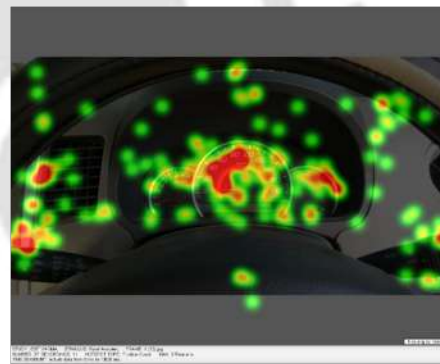
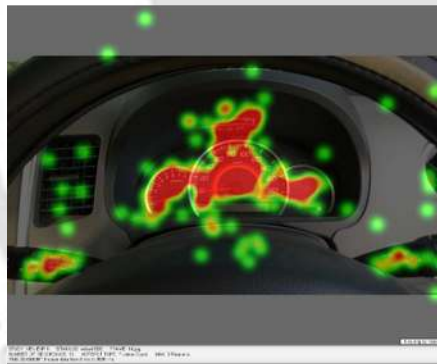
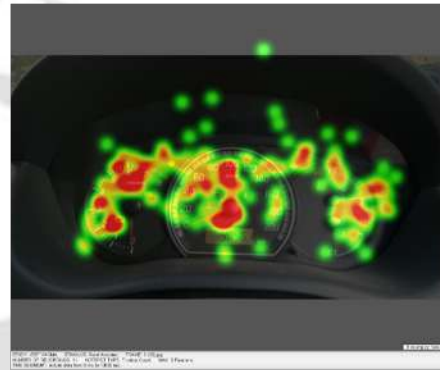
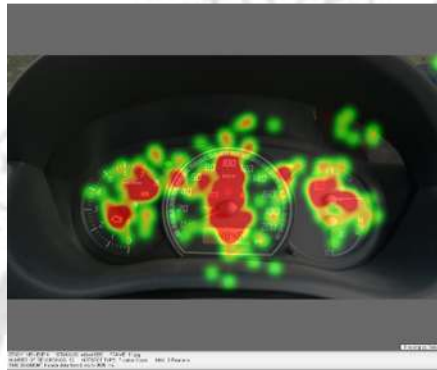
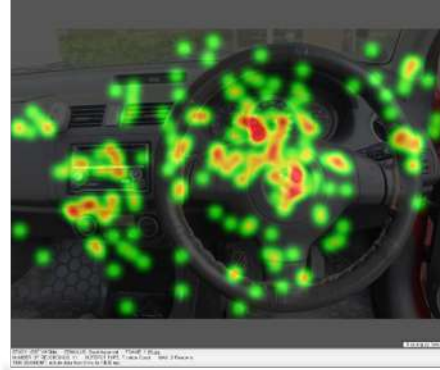
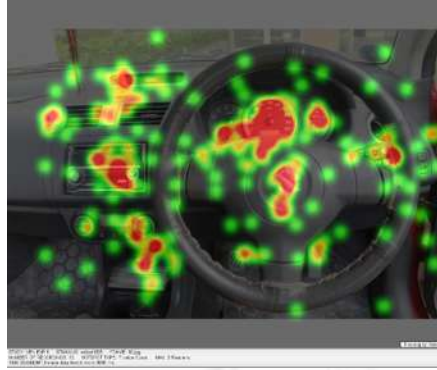
Rural Users

Cumulative hotspot patterns of Urban Users  
(left)

Cumulative hotspot patterns Rural Users  
(right)







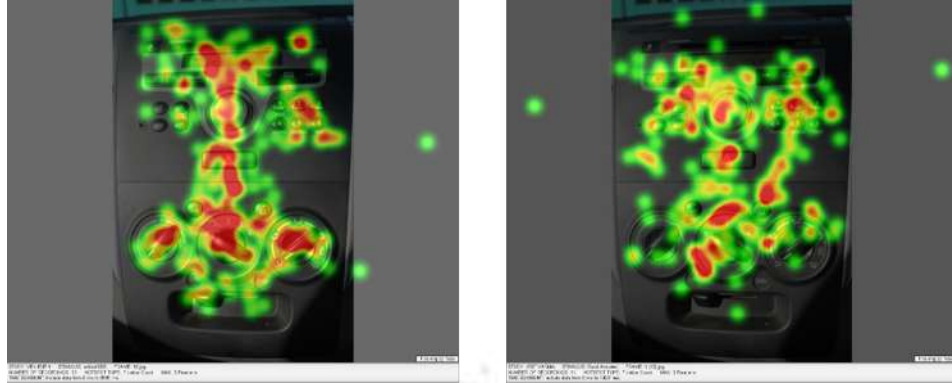
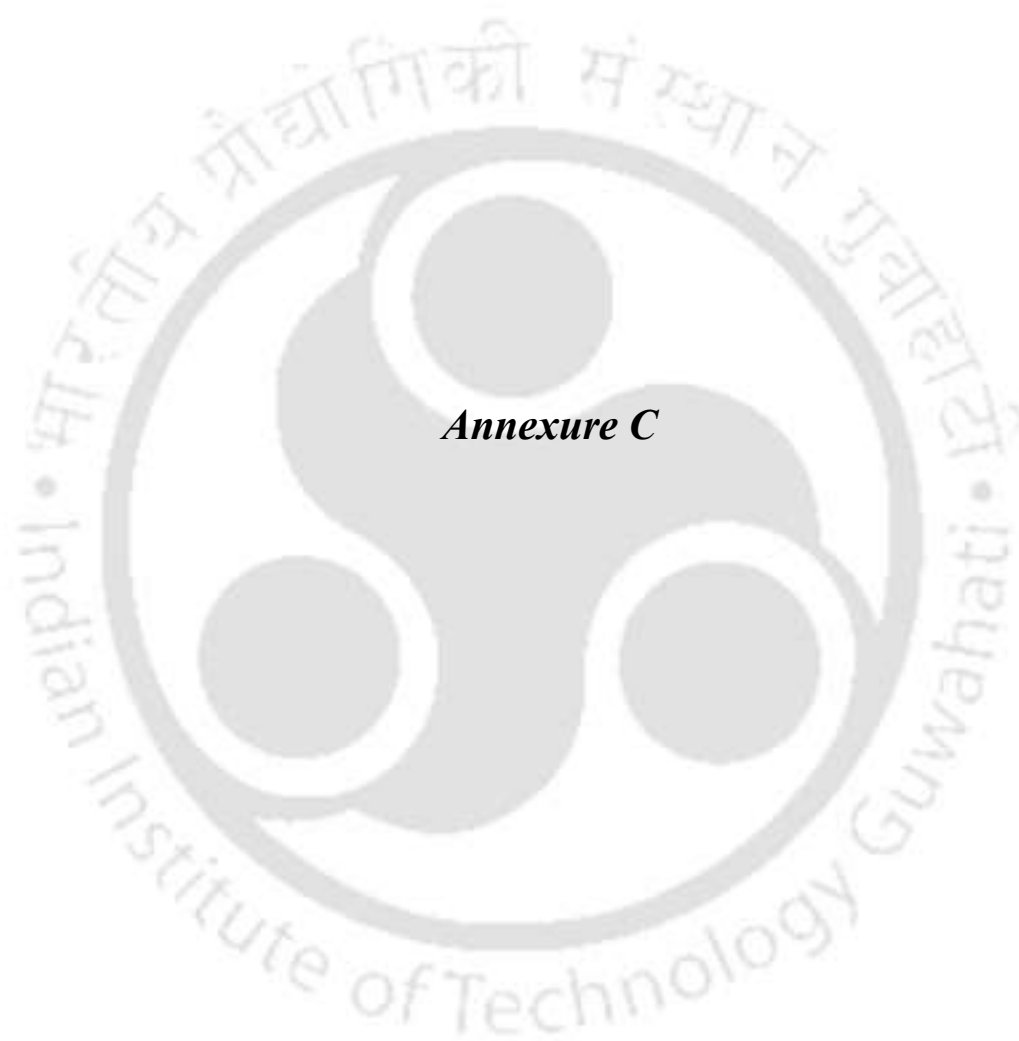


Figure B 2(a-e) shows the cumulative hotspot data from urban and rural subjects

Series of pictures shown in Figure B 2(a-e) shows the cumulative hotspot data collected from urban and rural subjects using Eye movement recorder.





*Annexure C*

### **Tasks used for IESI interface task performance tests:**

#Task 1: Find out how much is spent on consumption from the IoT smart home Interface

#Task 2: Navigate to the consumption of the Home from the IoT smart home application

#Task: Find out how to buy / sale or lend / barrow the energy from the IoT smart home interface

#Task 3: Navigate to the water pump control and take the necessary action

#Task 4: Navigate to lights control and take the necessary action

#Task 5: lend /barrow energy required from/to the community

#Task 6: Buy / sale energy required from/to the community

#Task 7: Find out energy generation of the Home from the IoT smart home Interface

#Task 8: Find out amount of energy generated in terms of money from the IoT smart home Interface

#Task 9: Navigate to the Air Conditioner Control and take the necessary action

#Task 10: How Much amount of energy is generated form the solar power until now/mention the value in terms money

#Task 11: How Much amount of energy is consumed until now/mention the value in terms money

#Task 12: Which appliances are consuming the energy right now?

#Task 13: What does the home screen Icons Convey?

#Task14: Navigate to the lights page

#Task15: Which lights are in on/off state right now?

#Task16: Find out who is offering the low tariff rate energy right now

Screen flows:

A set of screens shown in following pages



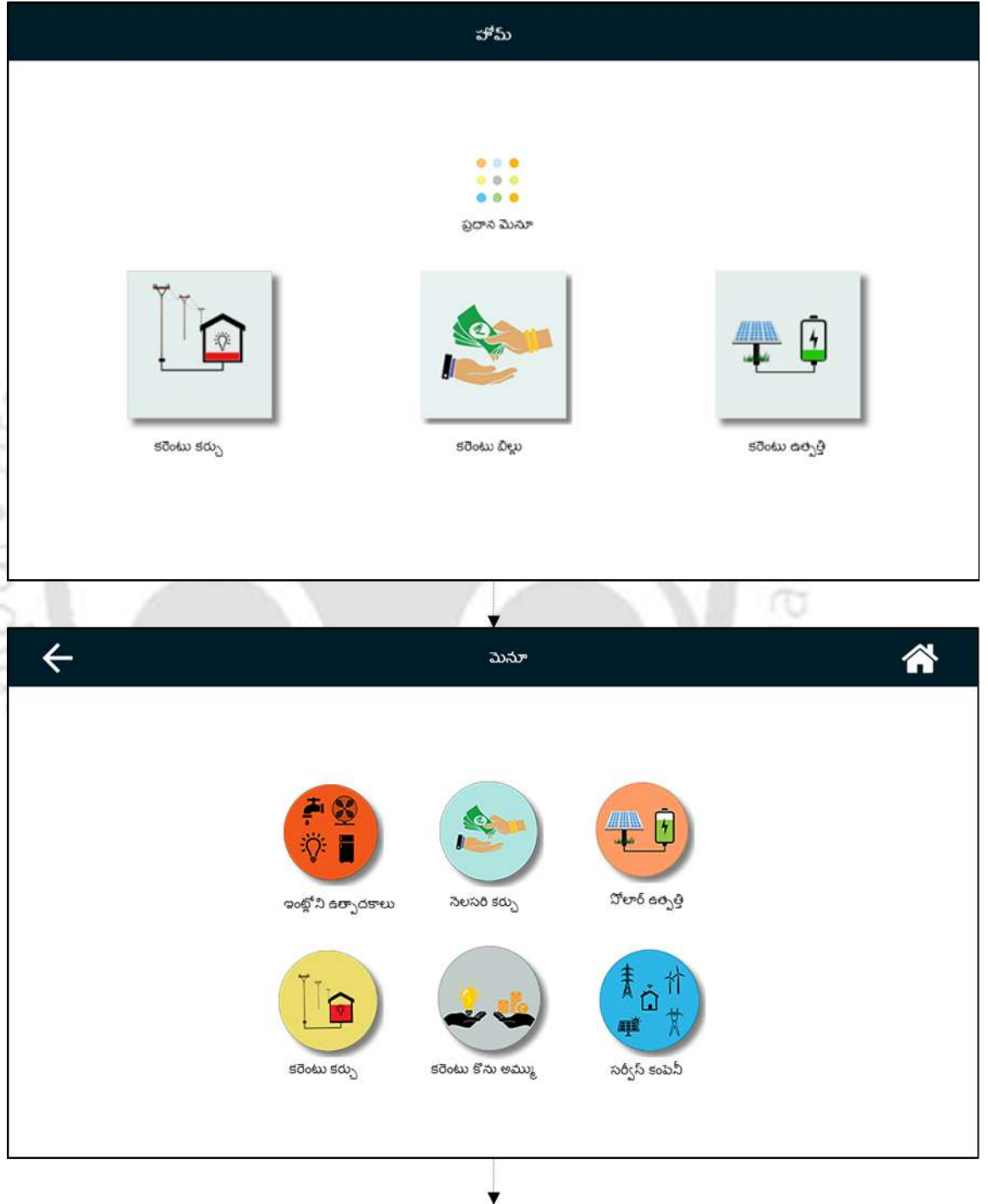
# Use cases (Rural & Urban)

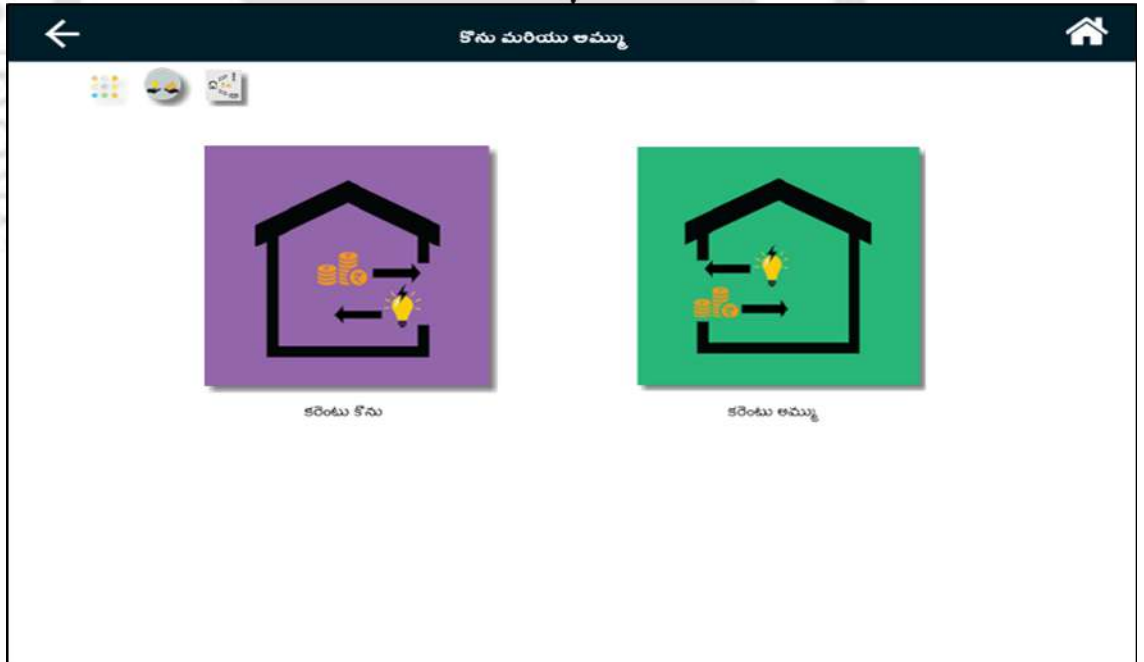
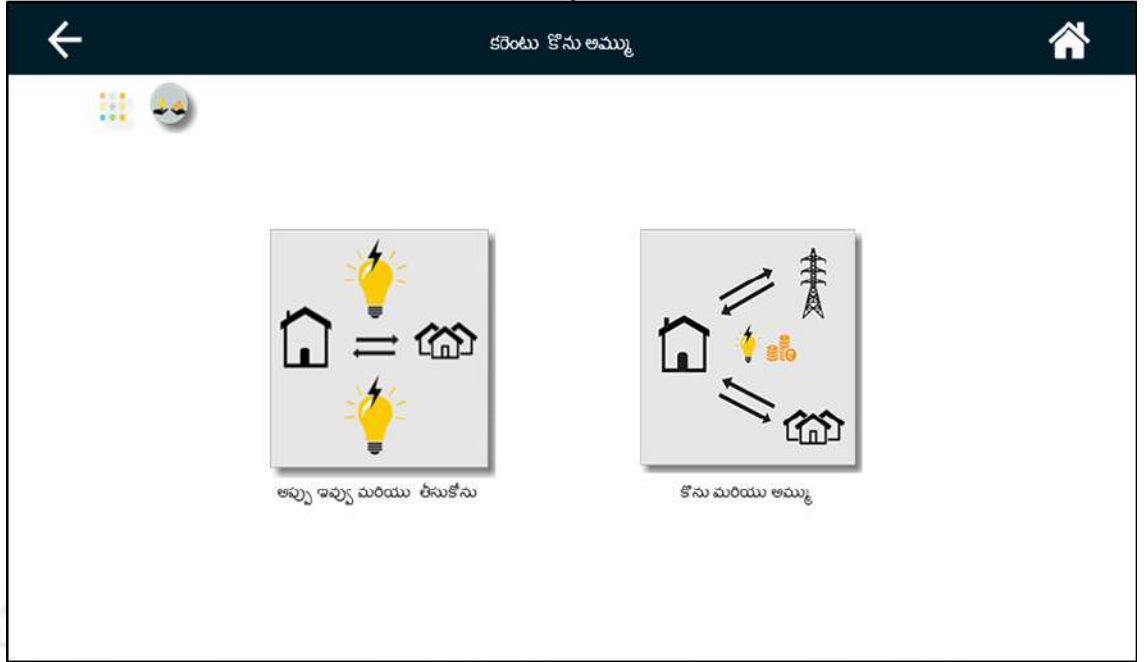
Task: Home Screen (Rural-Telugu language)

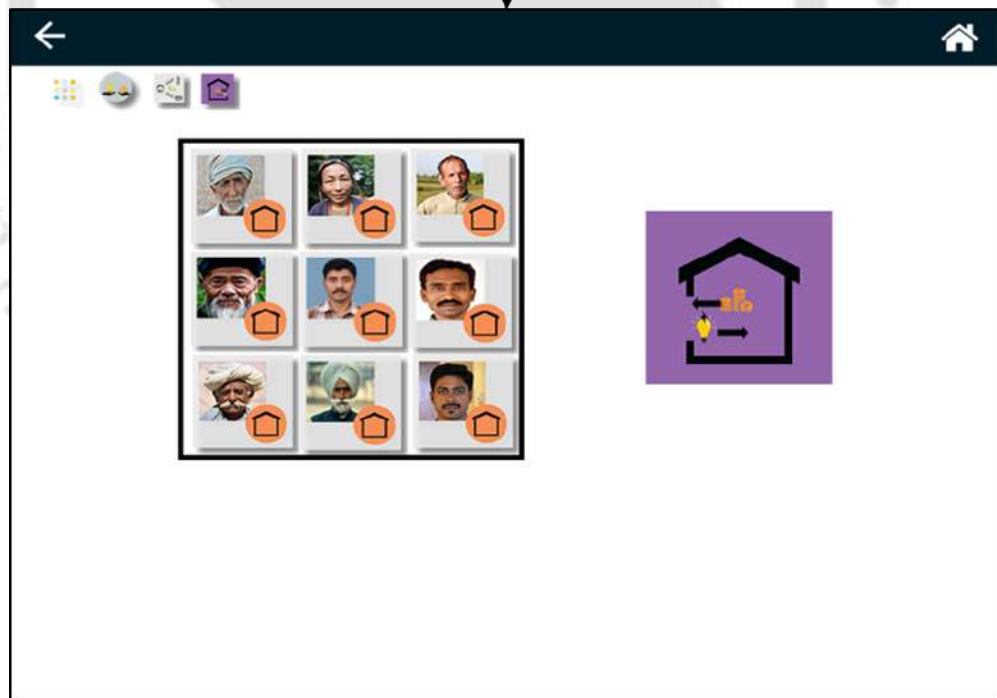


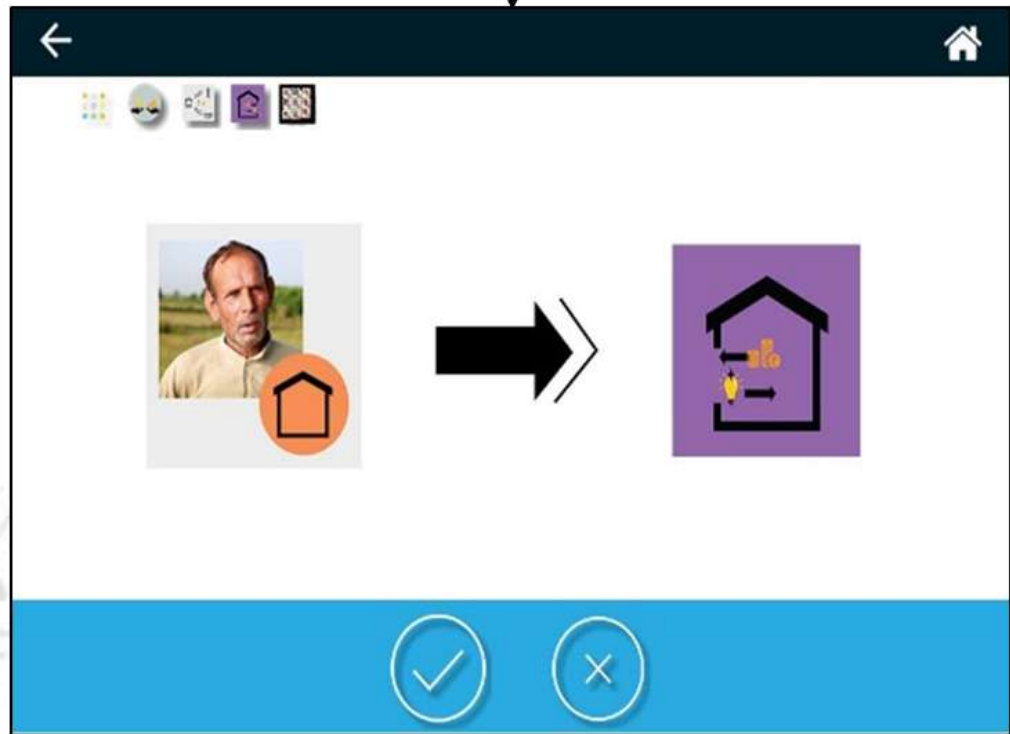
Following screens shows the screen flows for Energy buying feature for rural context, Telugu language is used Assistive text for the screens mentioned

Task: Energy Buy(Rural-Telugu language)



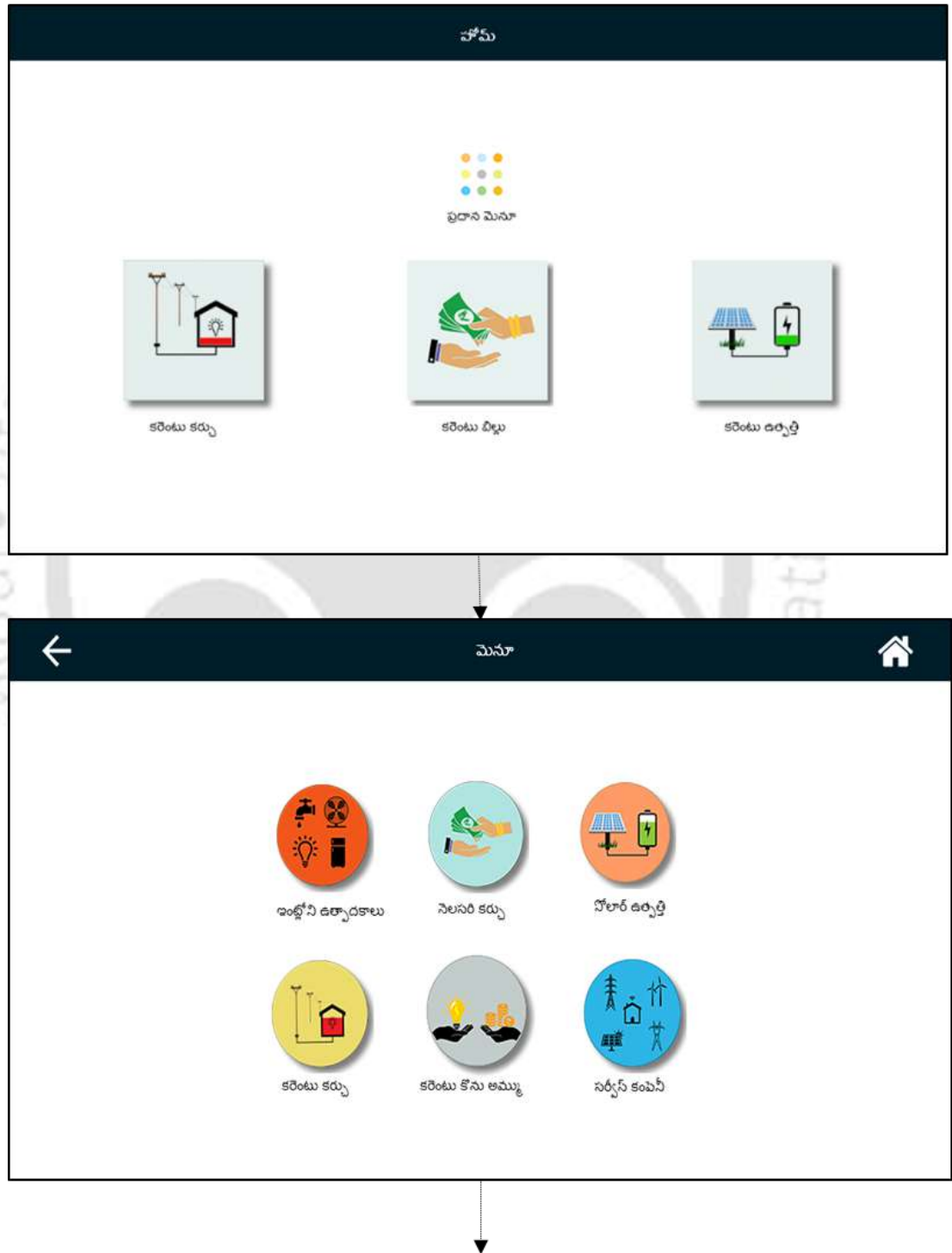




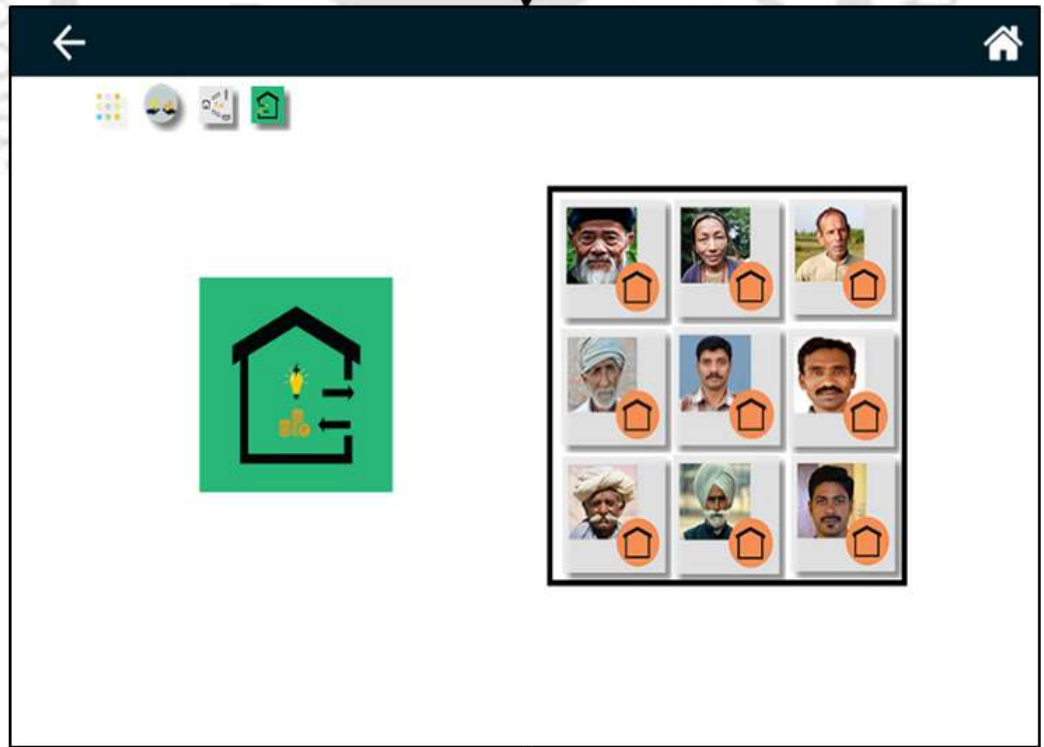
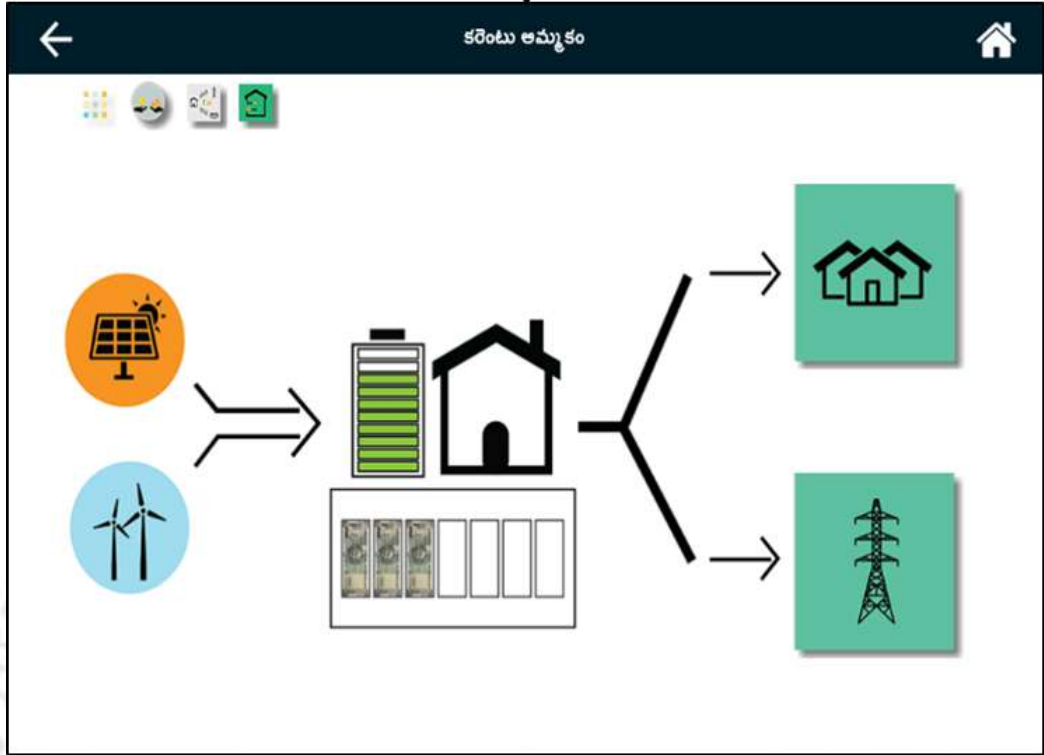


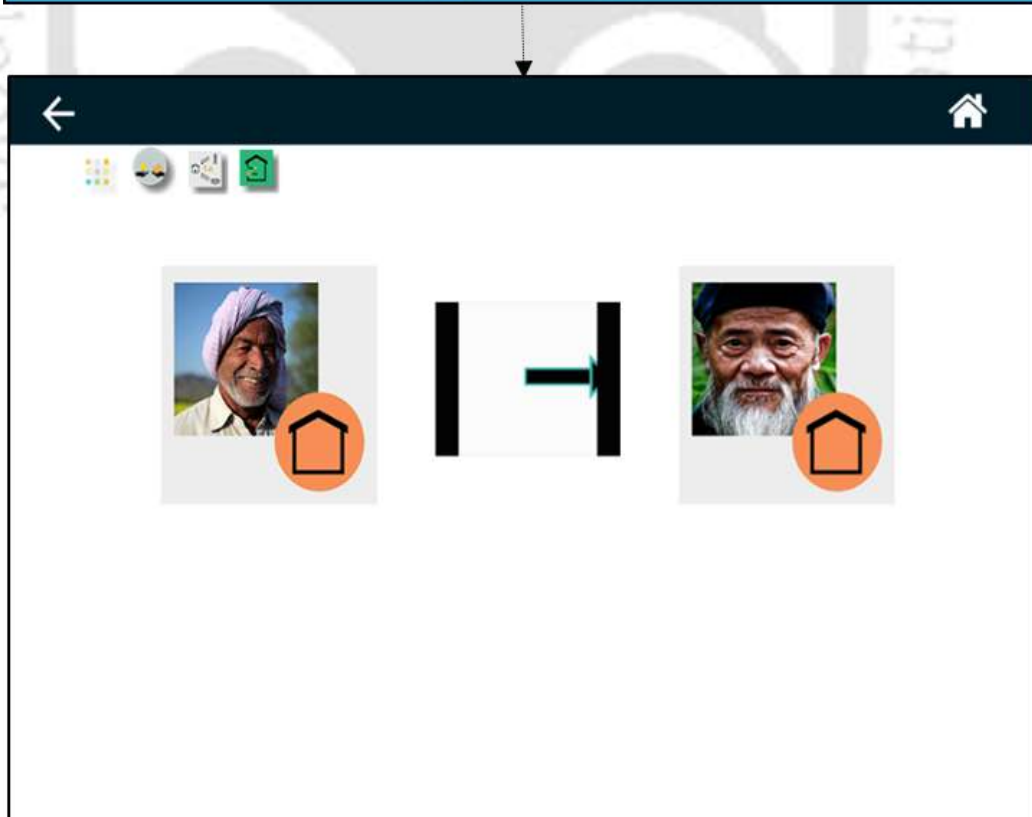
Following screen shows flow of energy selling feature of Rural UI with Telugu language as assistive text .

### Task: Energy Sell (Rural-Telugu language)

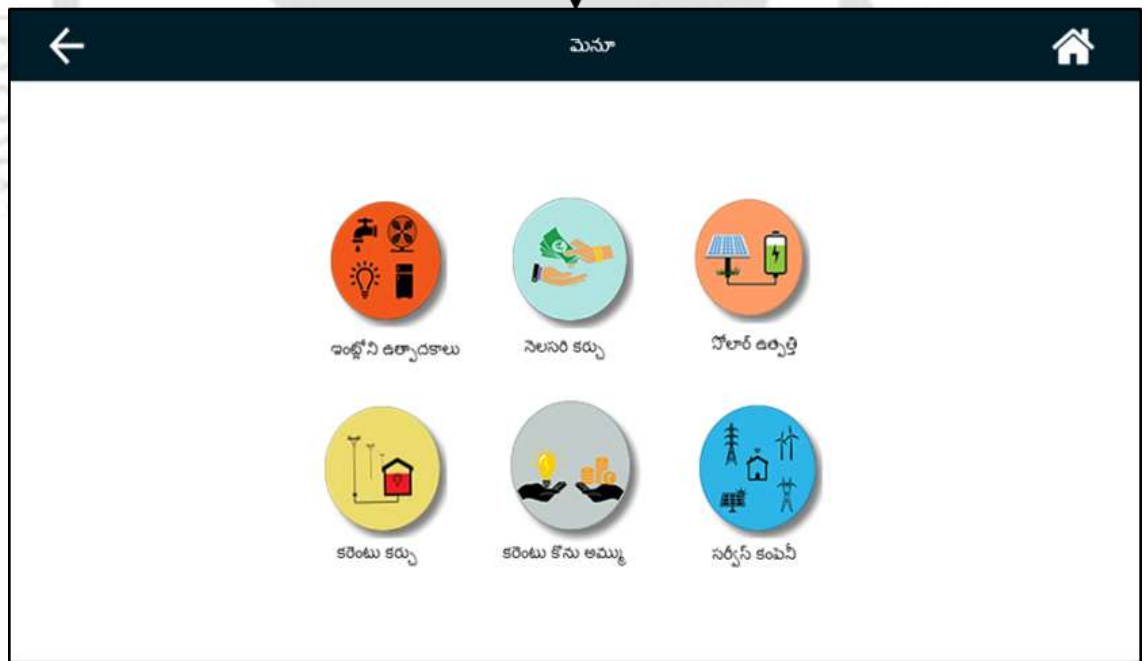
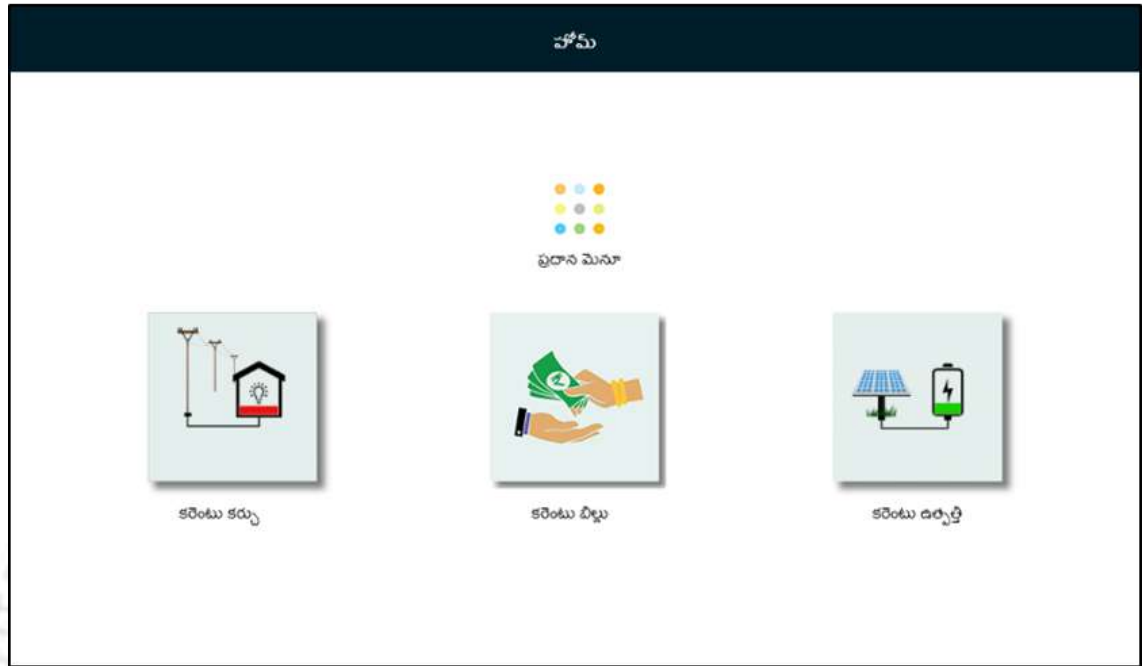




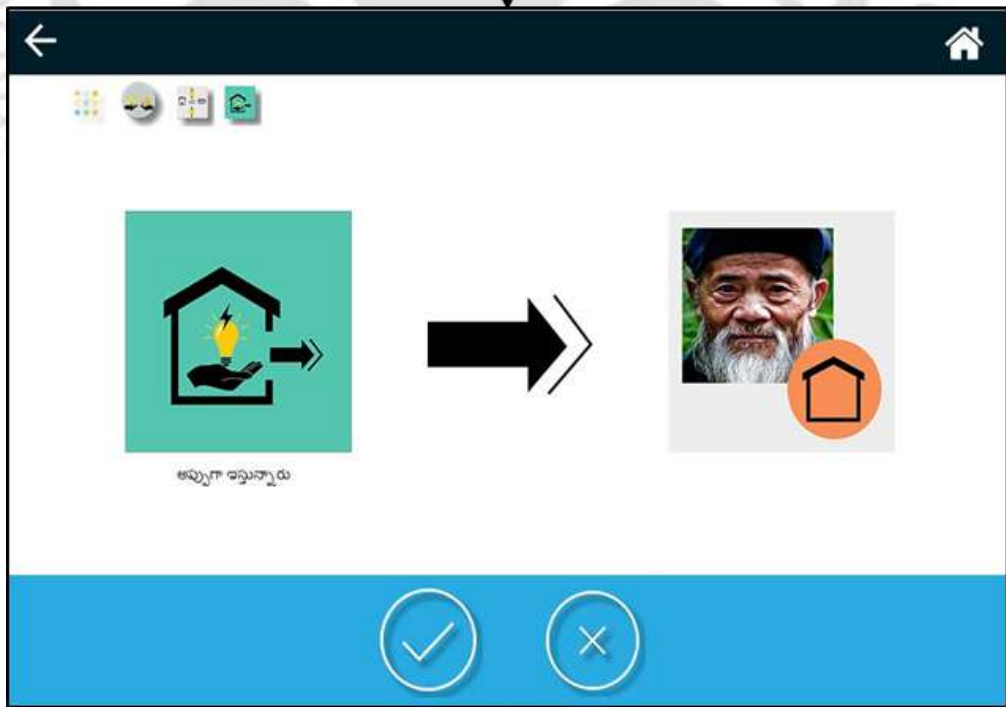
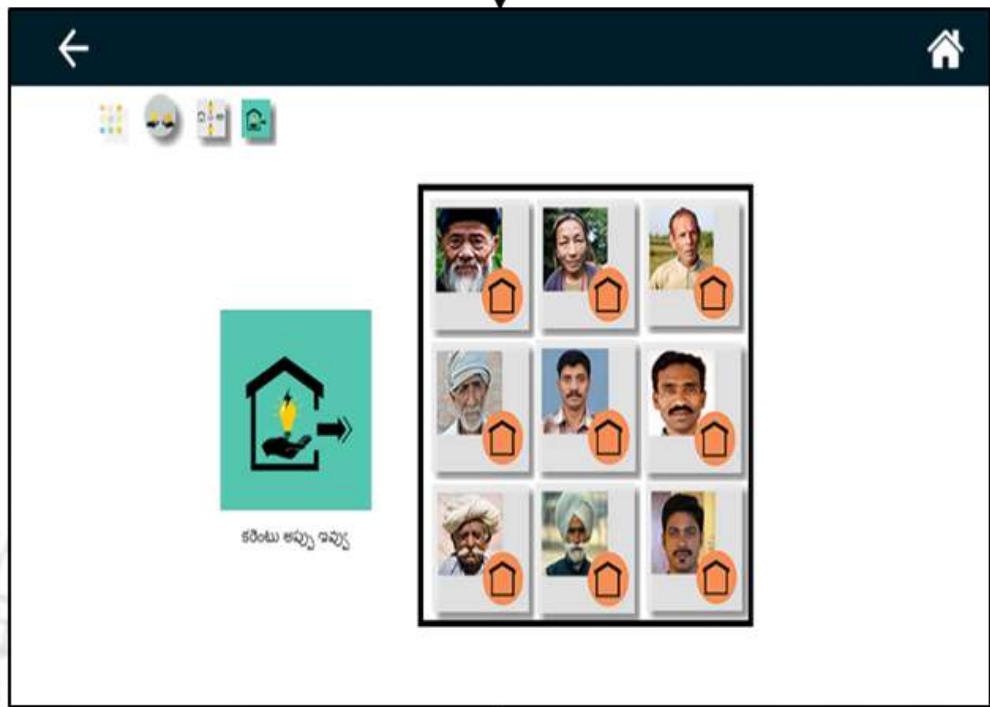




Task: Energy Lend(Rural-Telugu language)

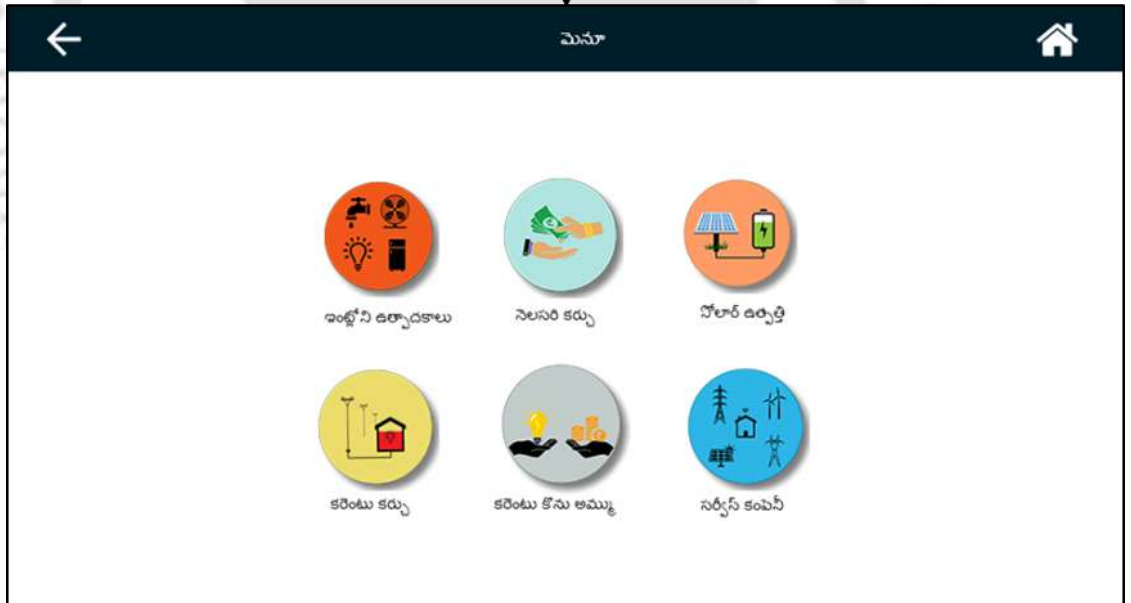
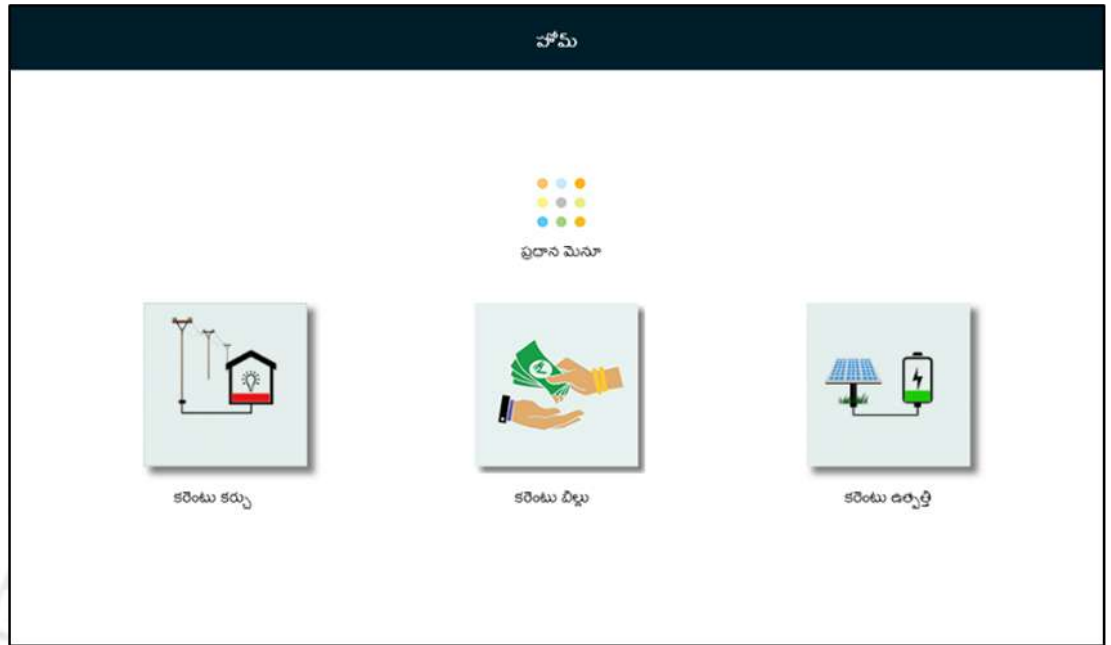


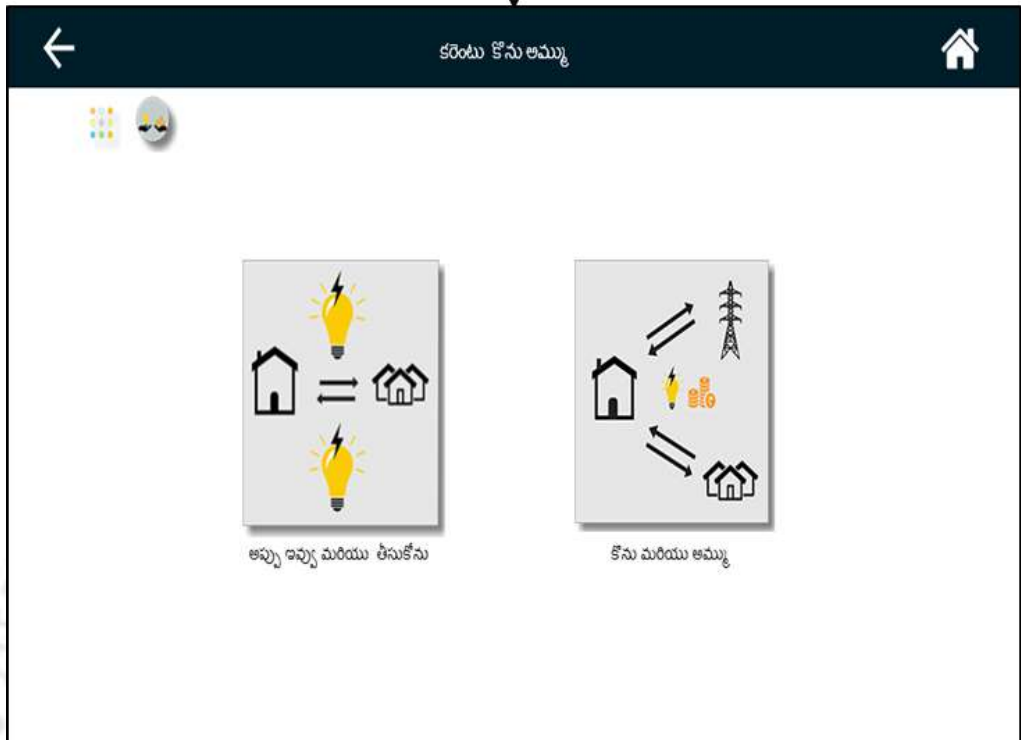


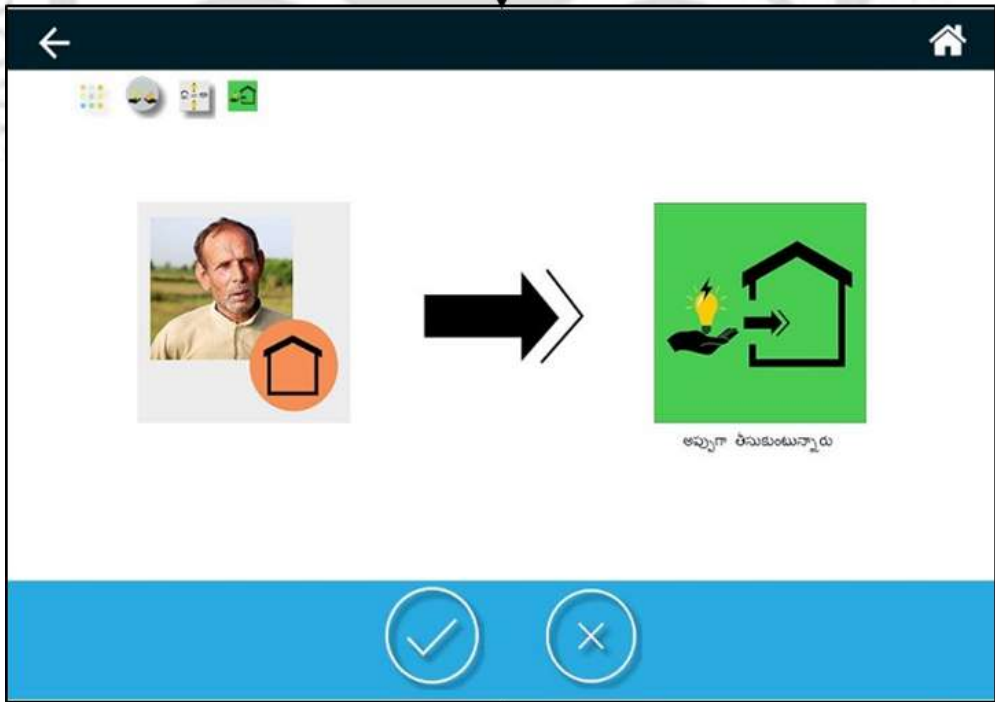
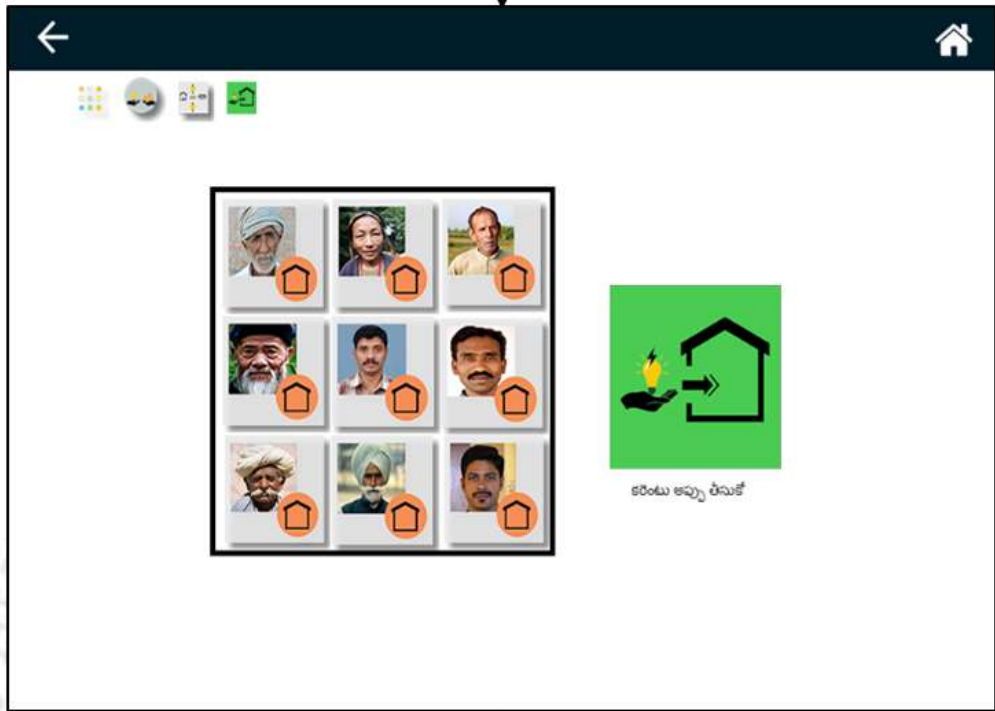




Task: Energy Borrow(Rural-Telugu language)

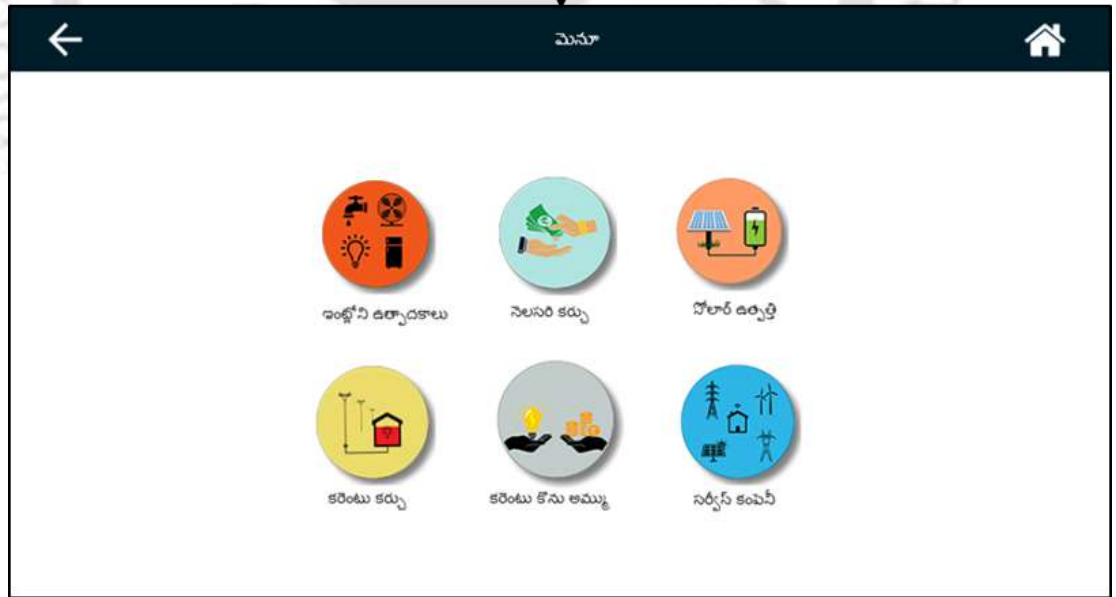
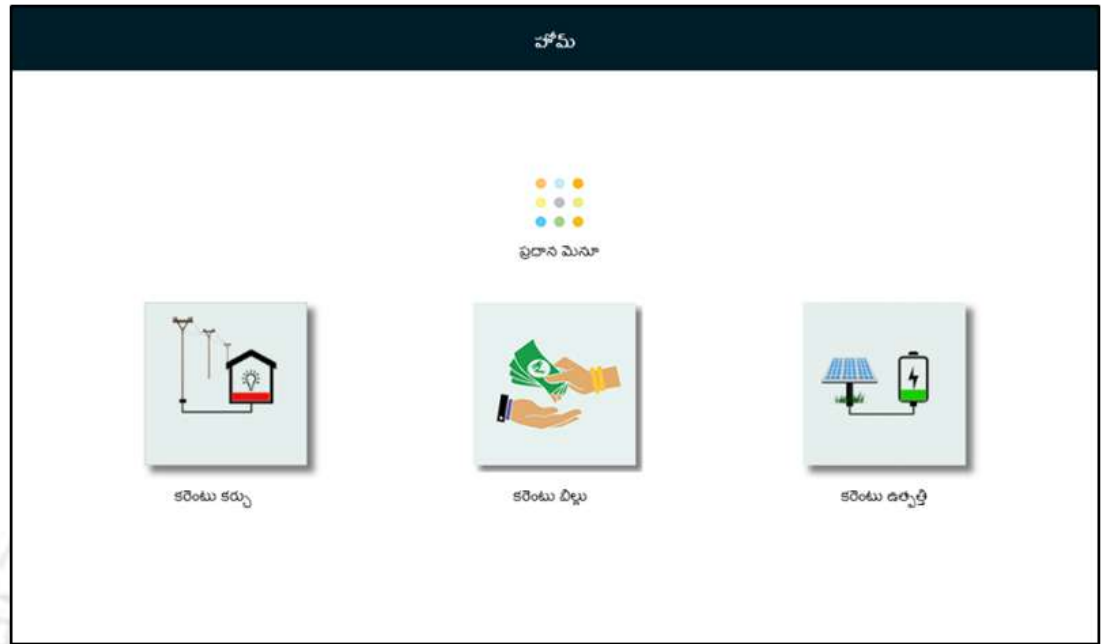


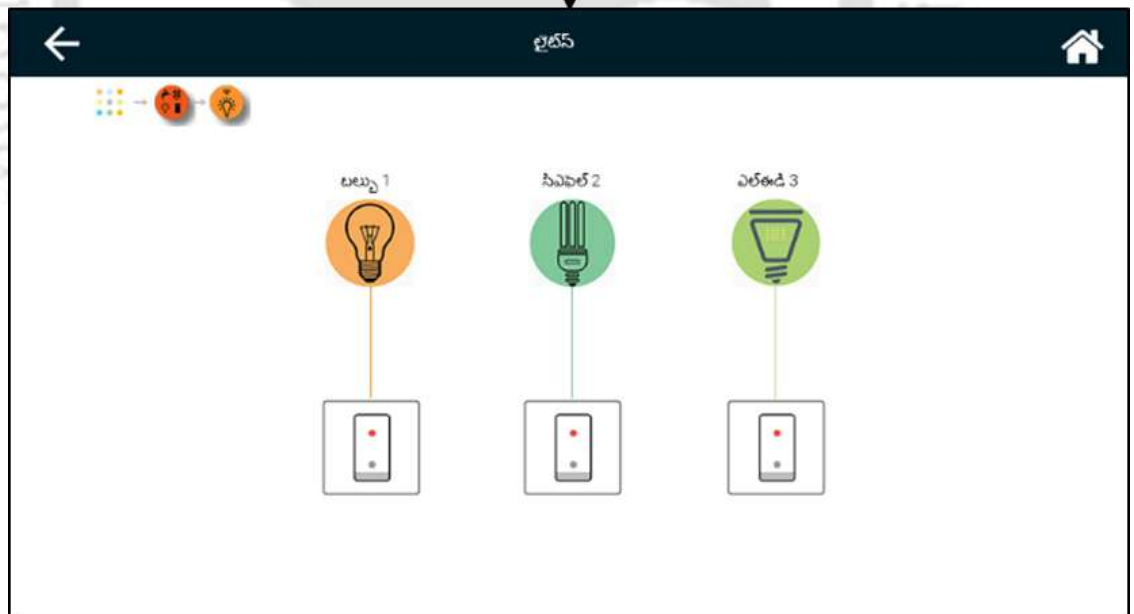




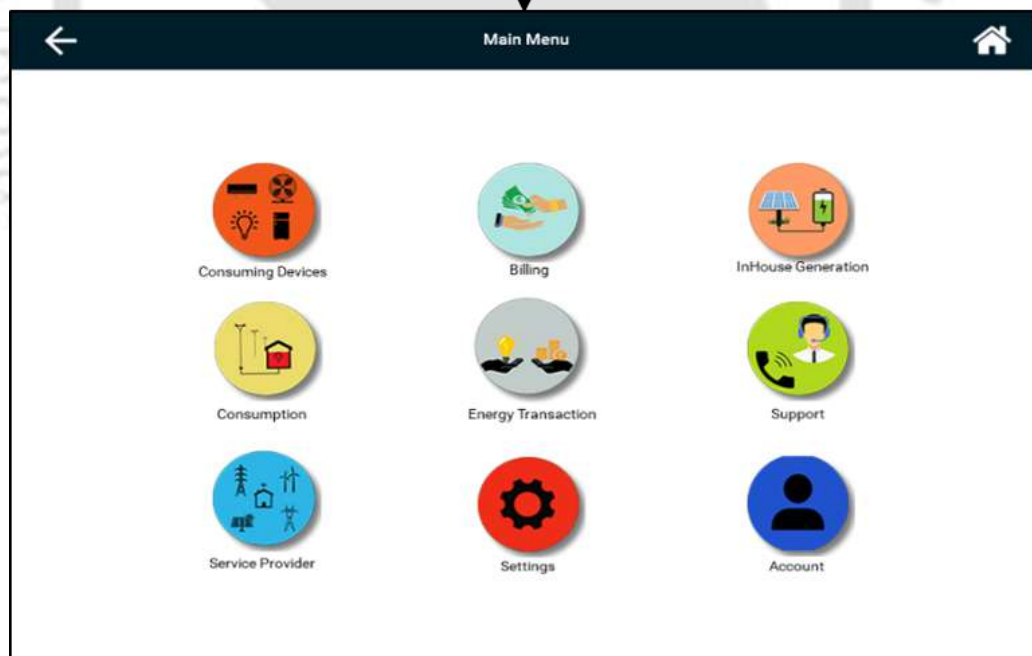
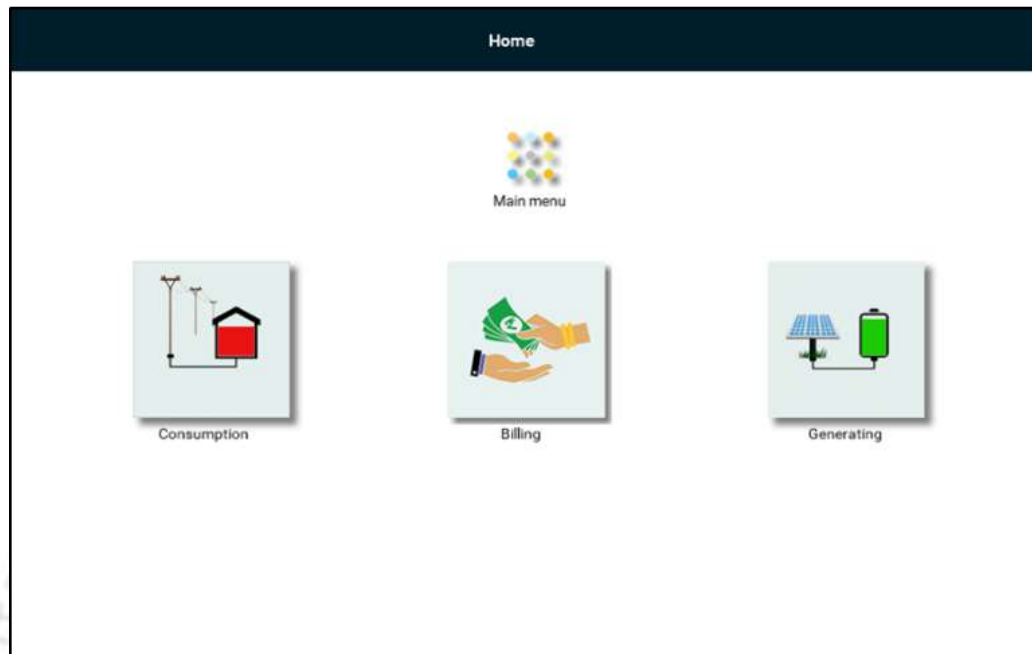


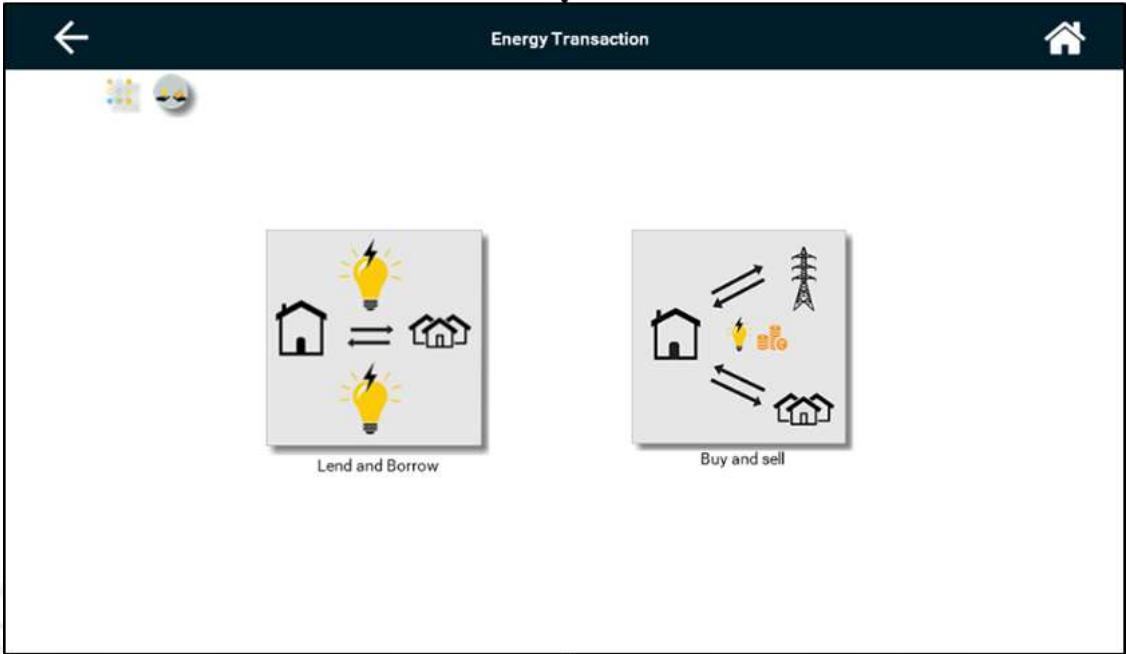
Task: Control Lights(Rural-Telugu language)

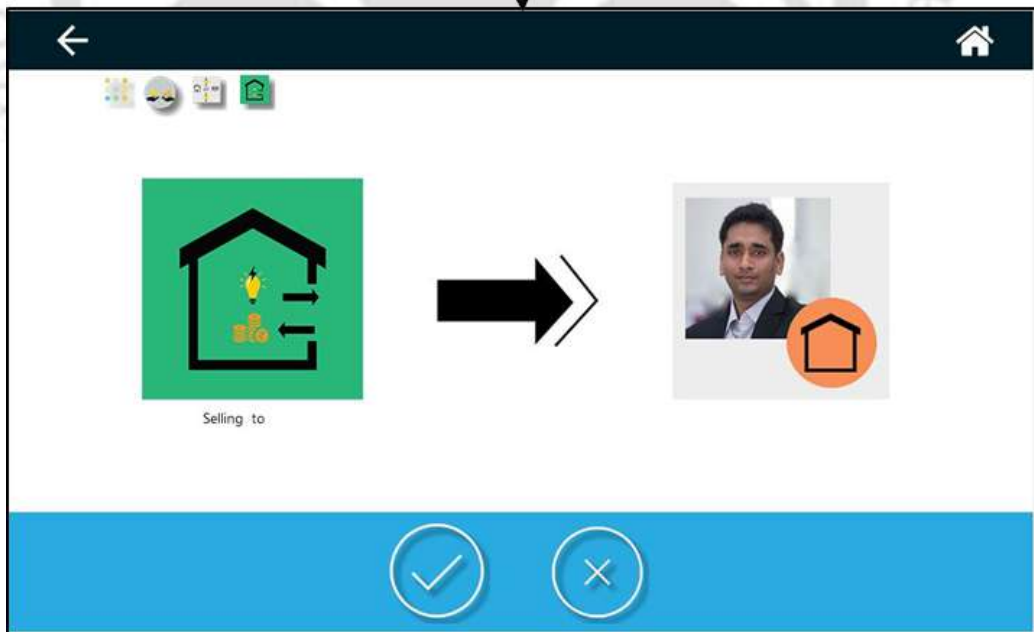
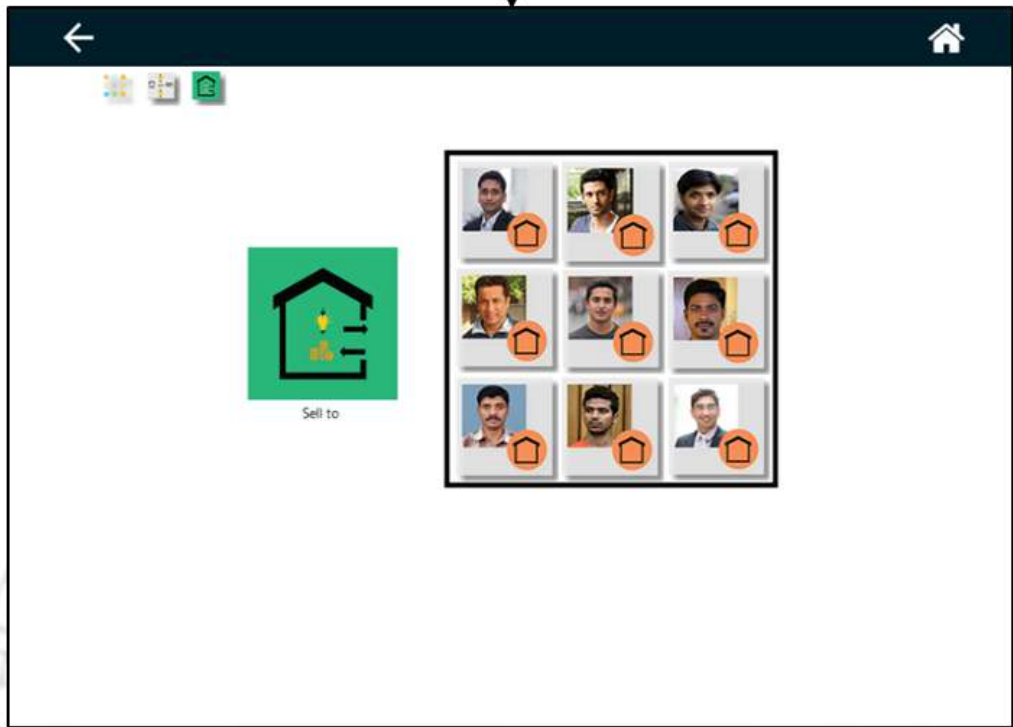


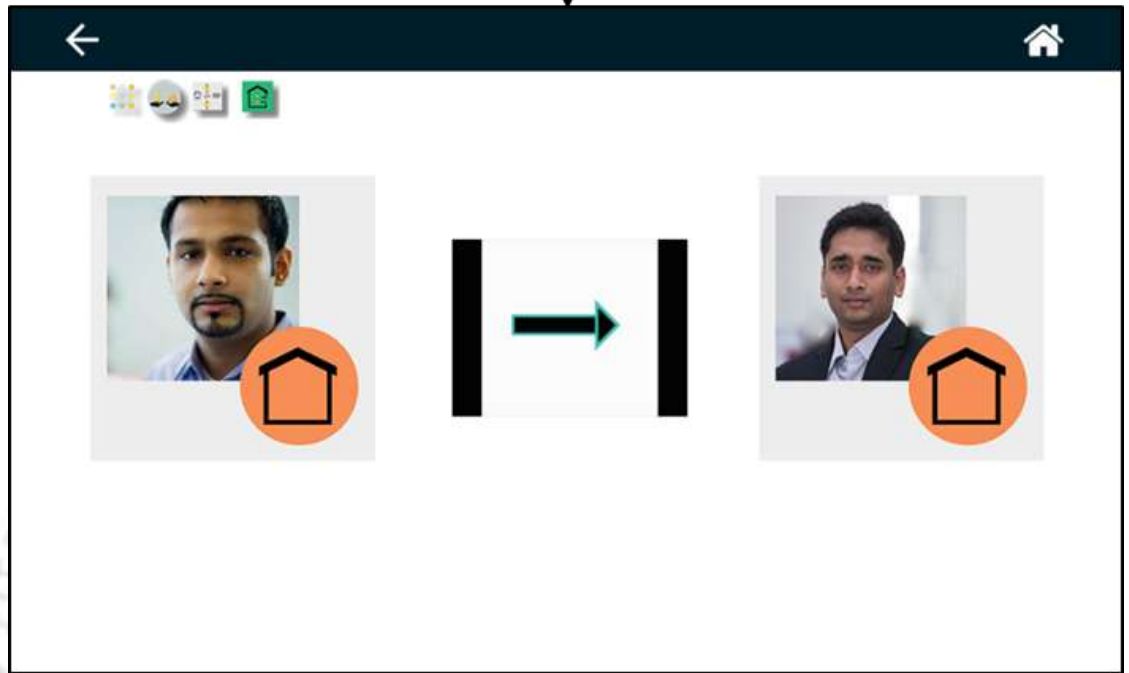


# Task: Energy Sell (Urban-English language)

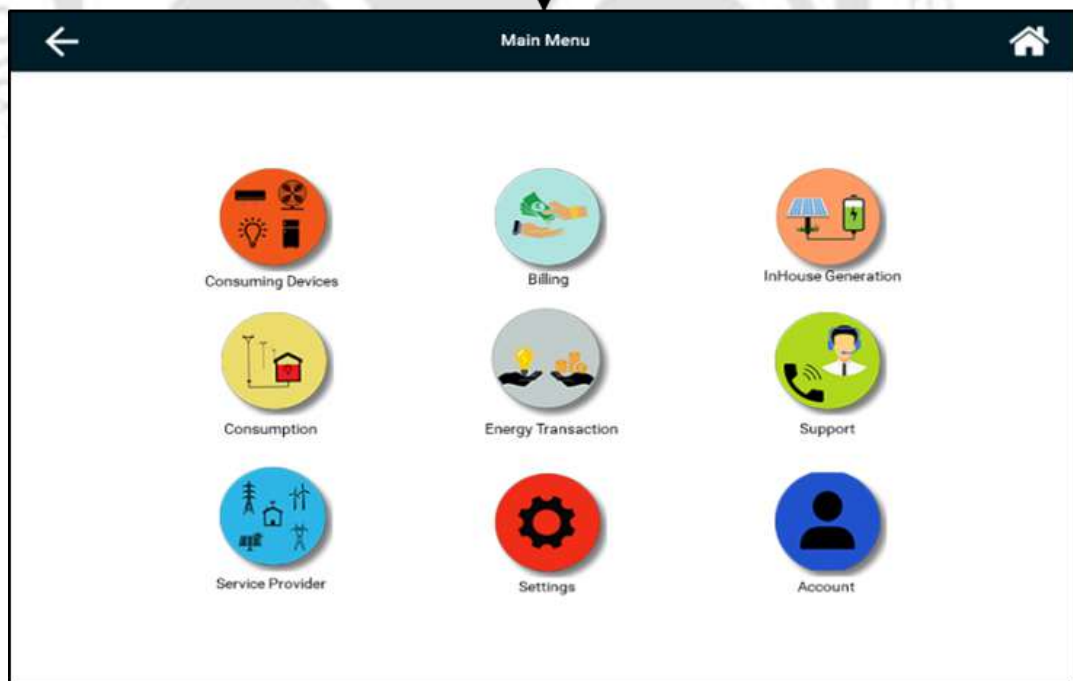
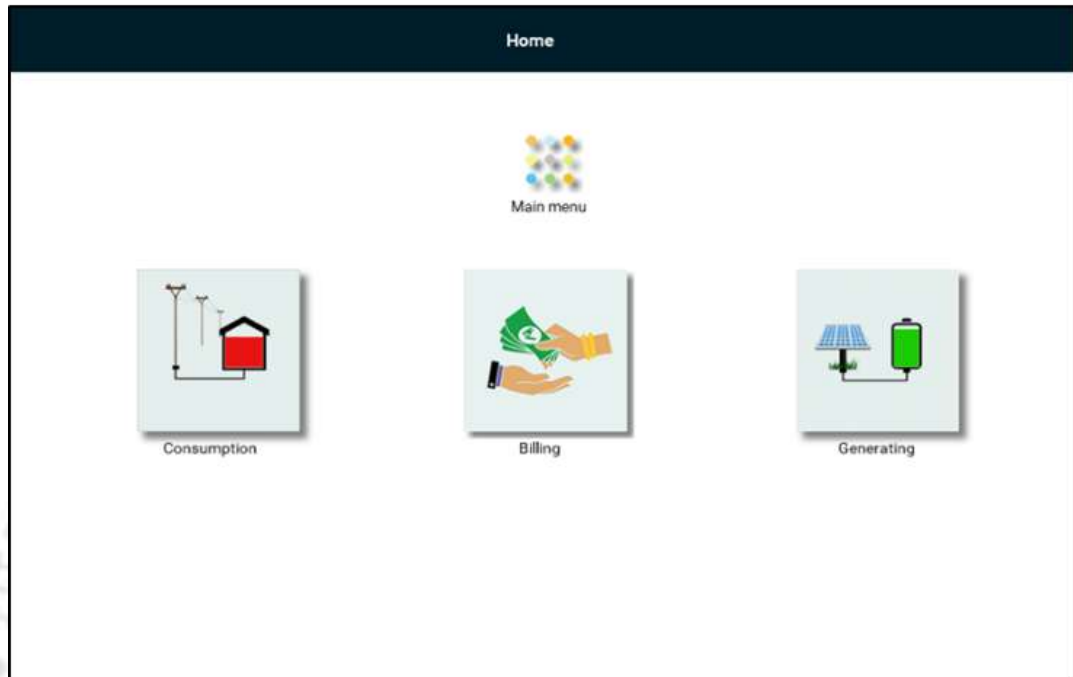


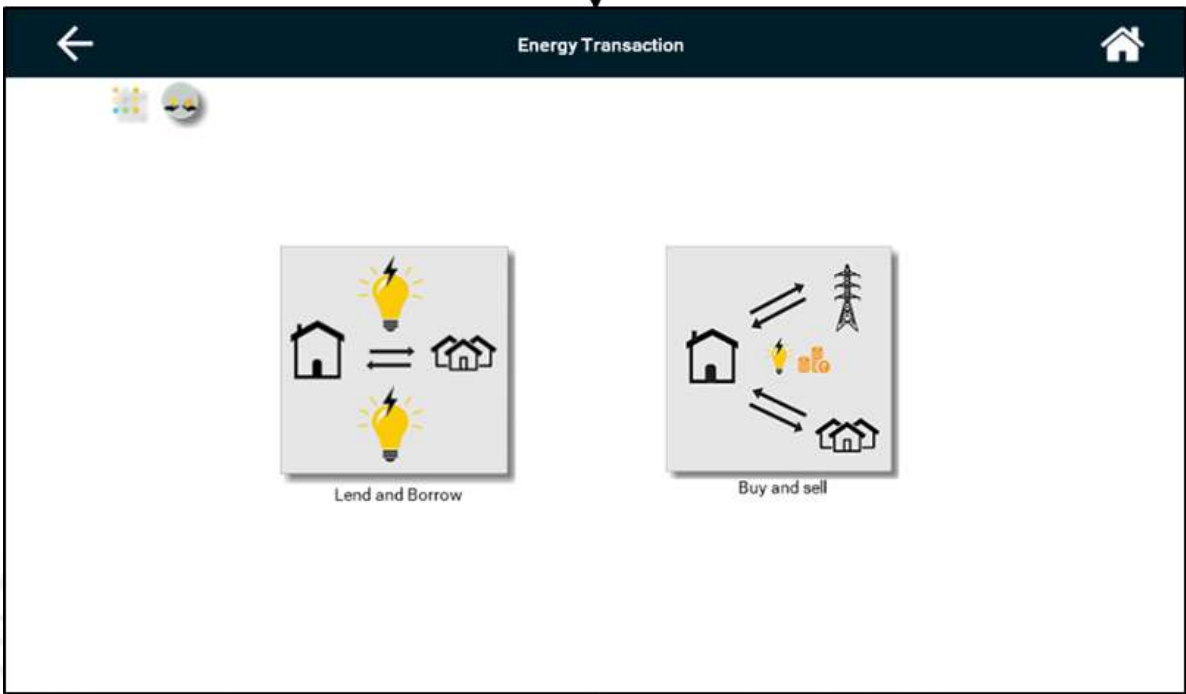


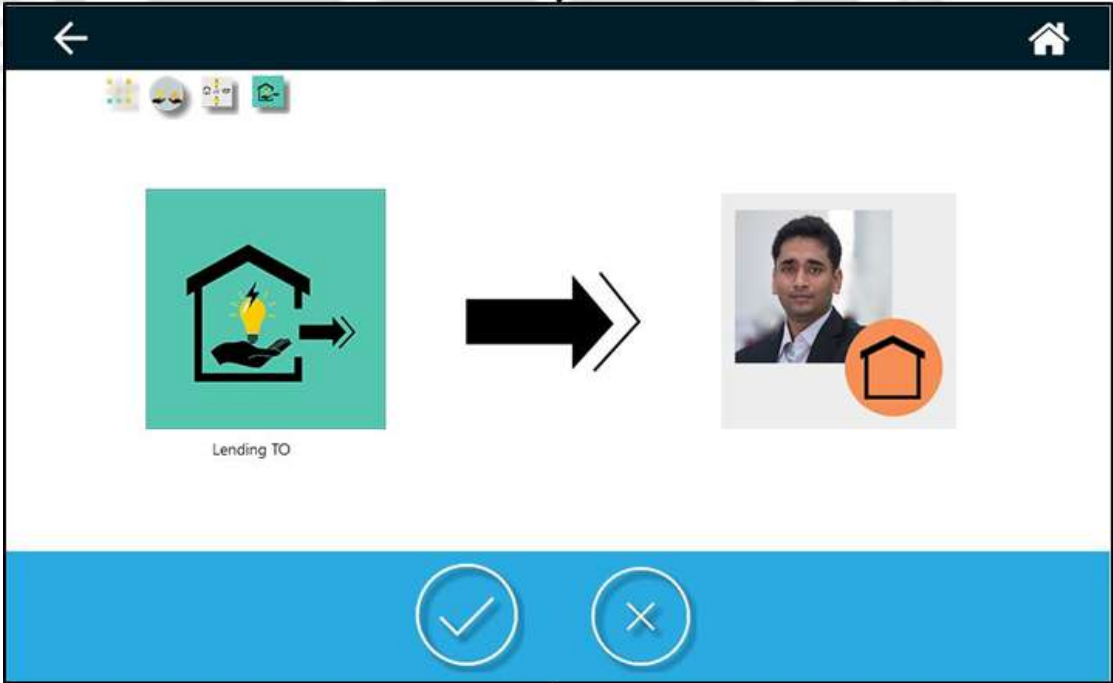
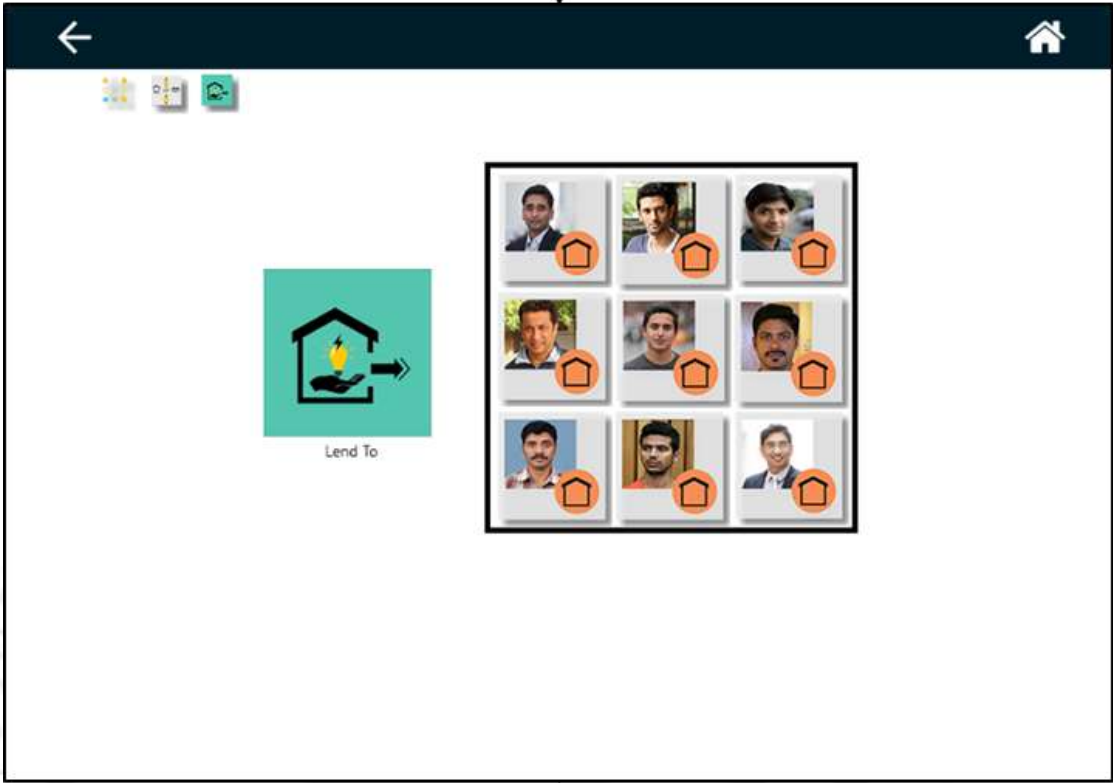


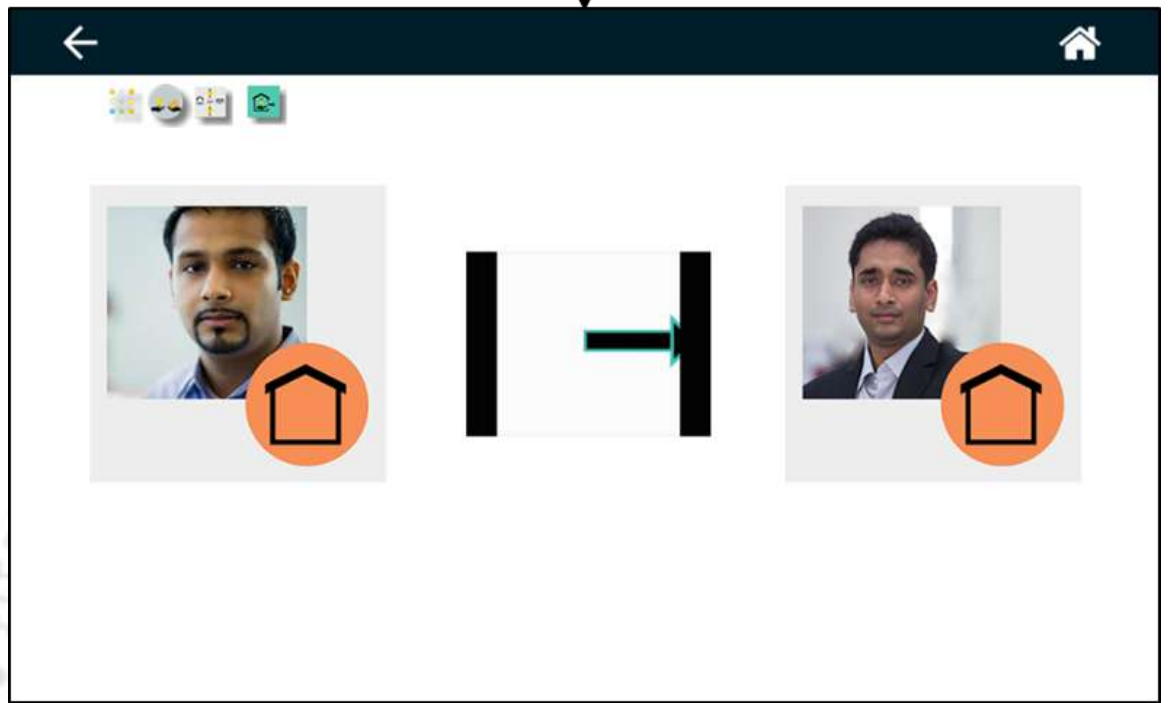


# Task: Energy Lend (Urban-English language)

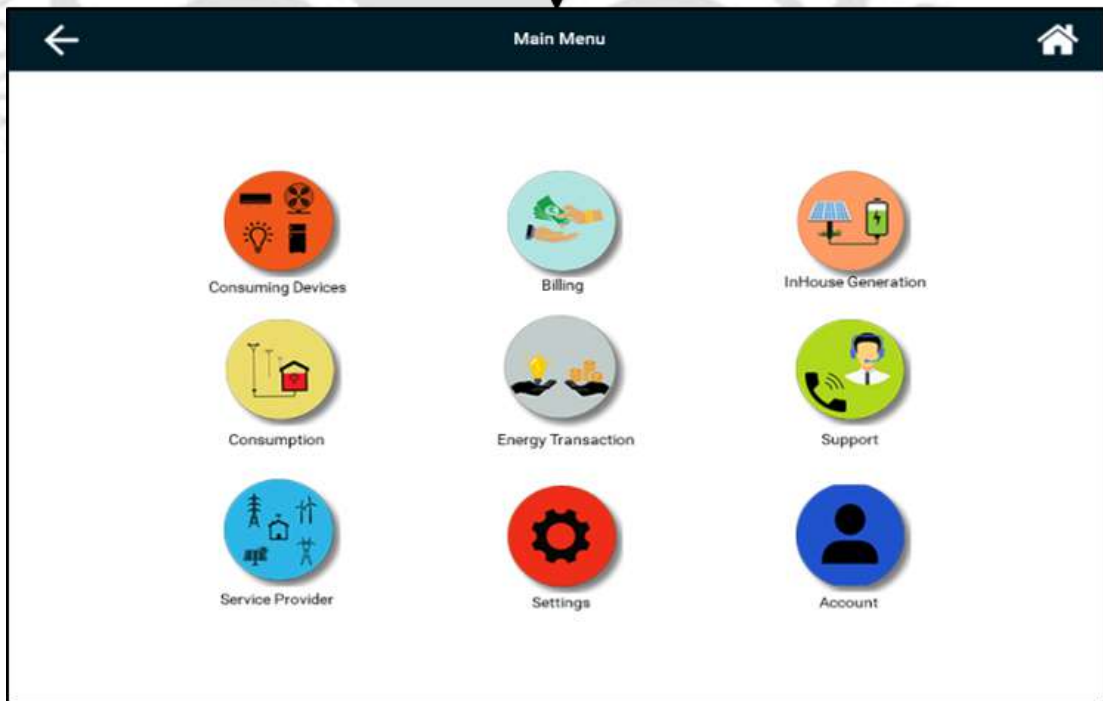
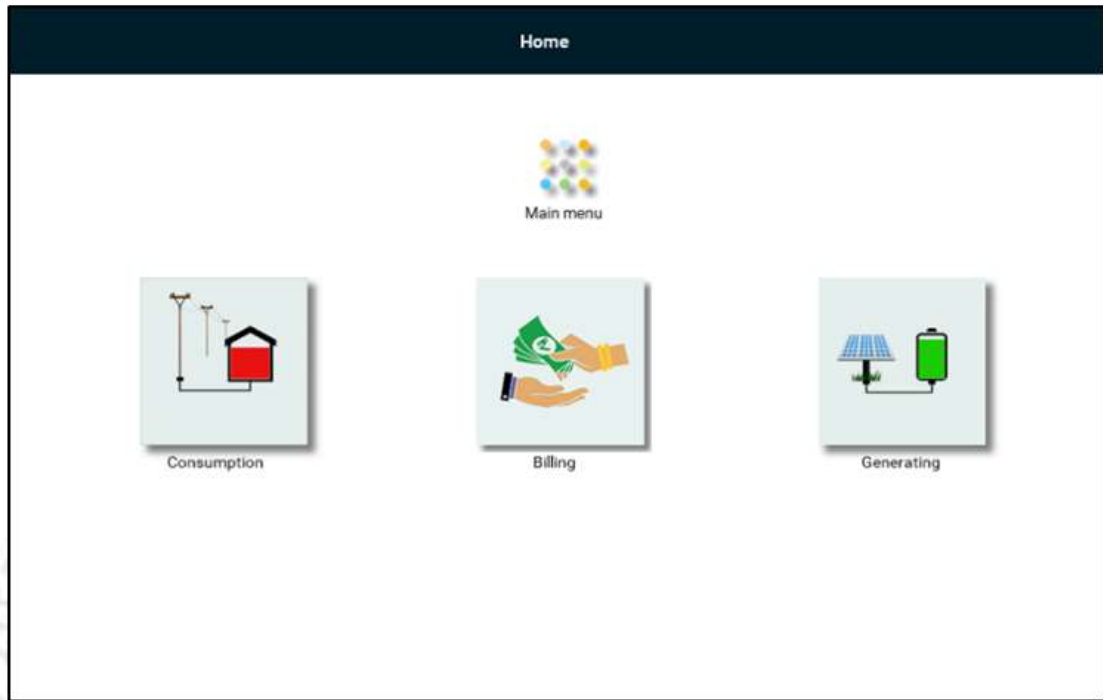


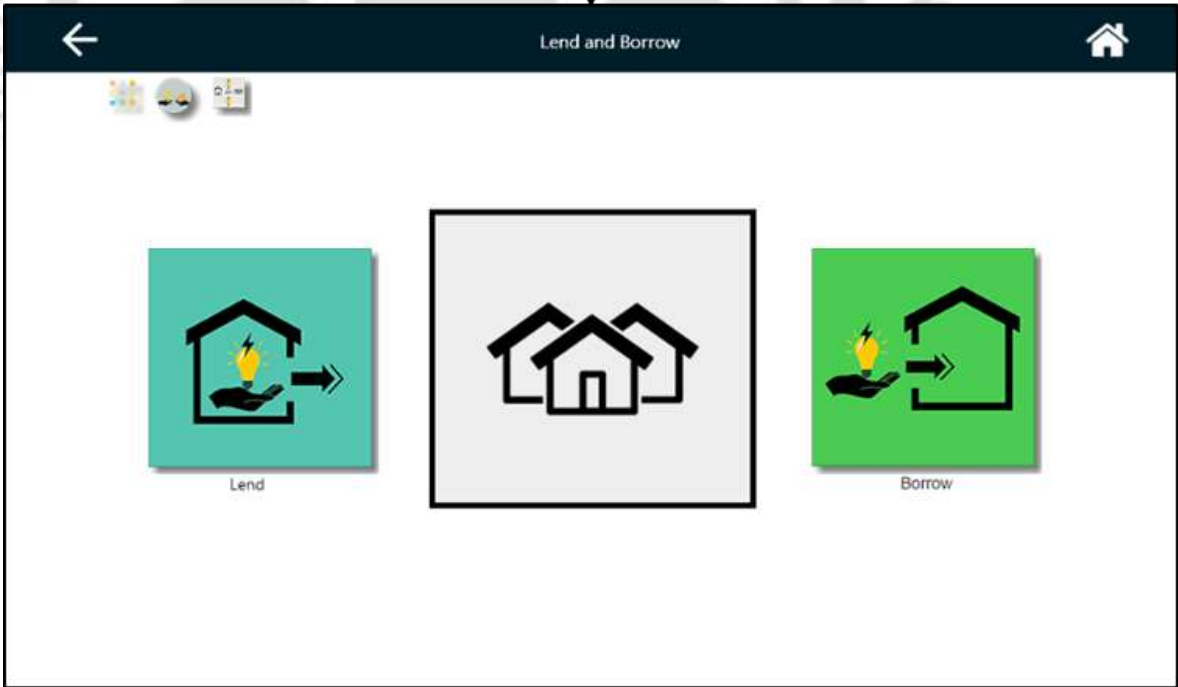
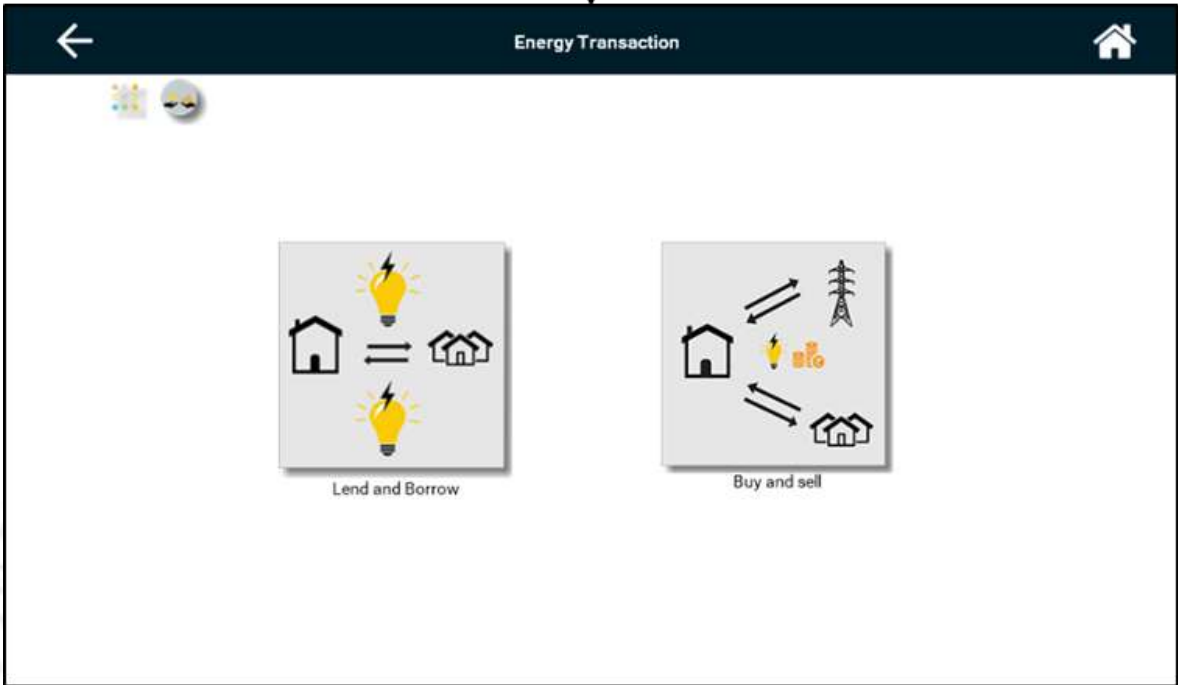


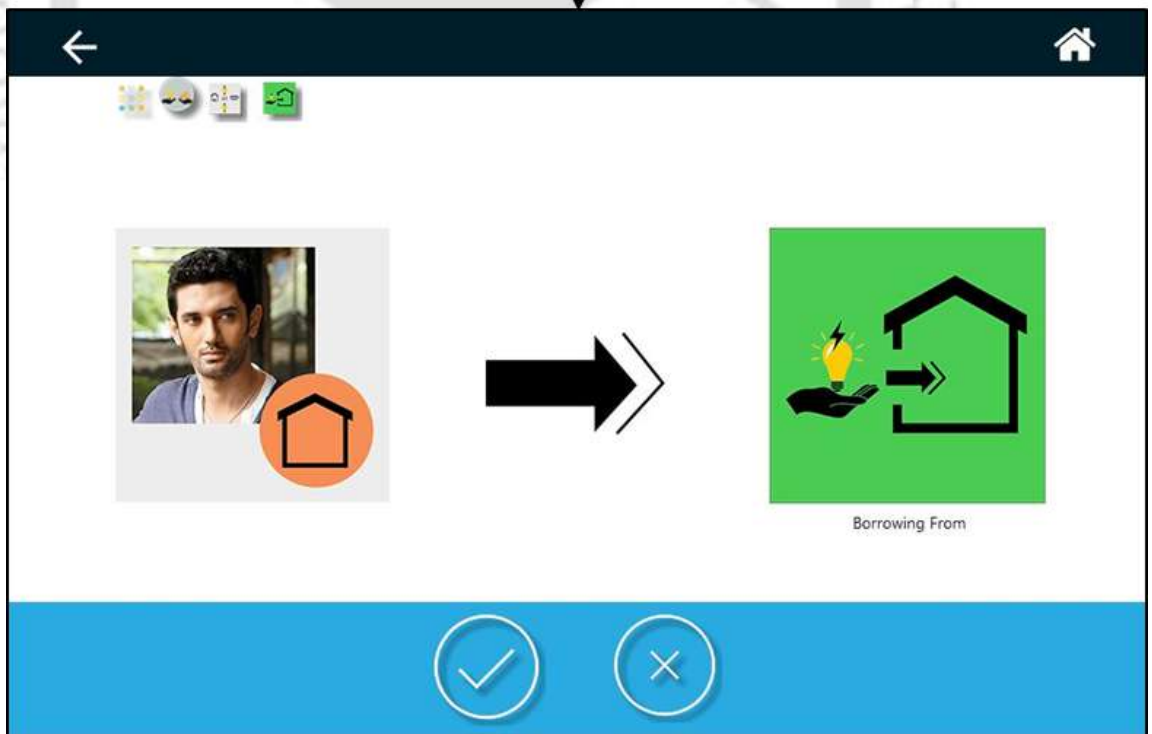
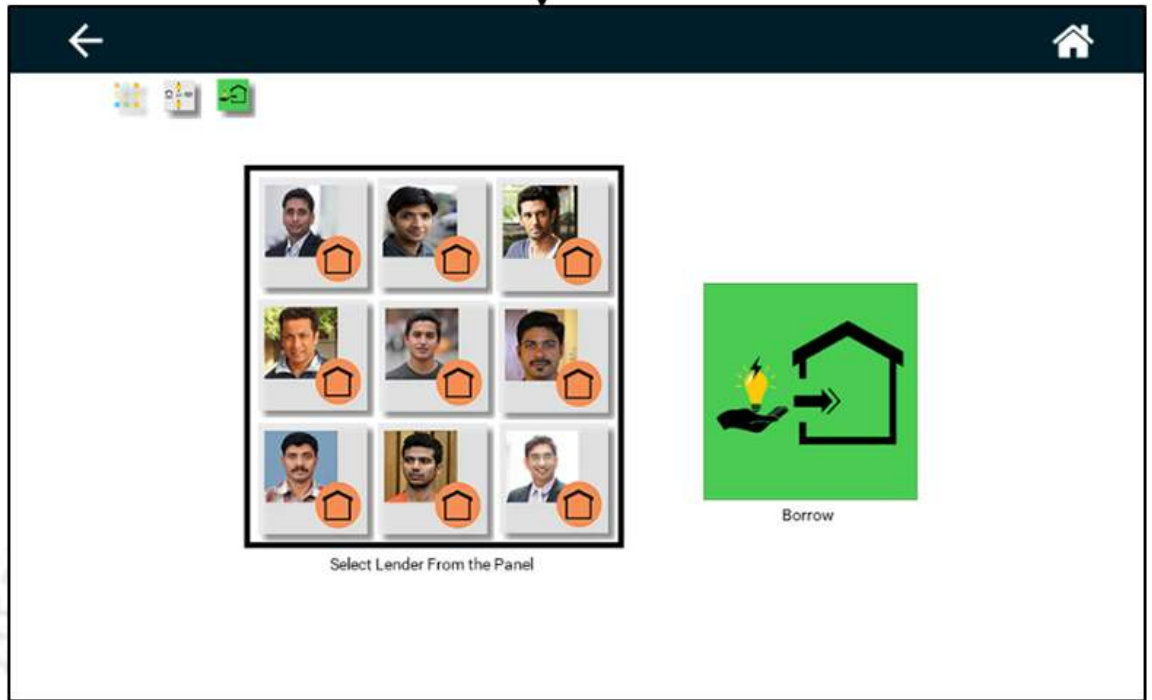


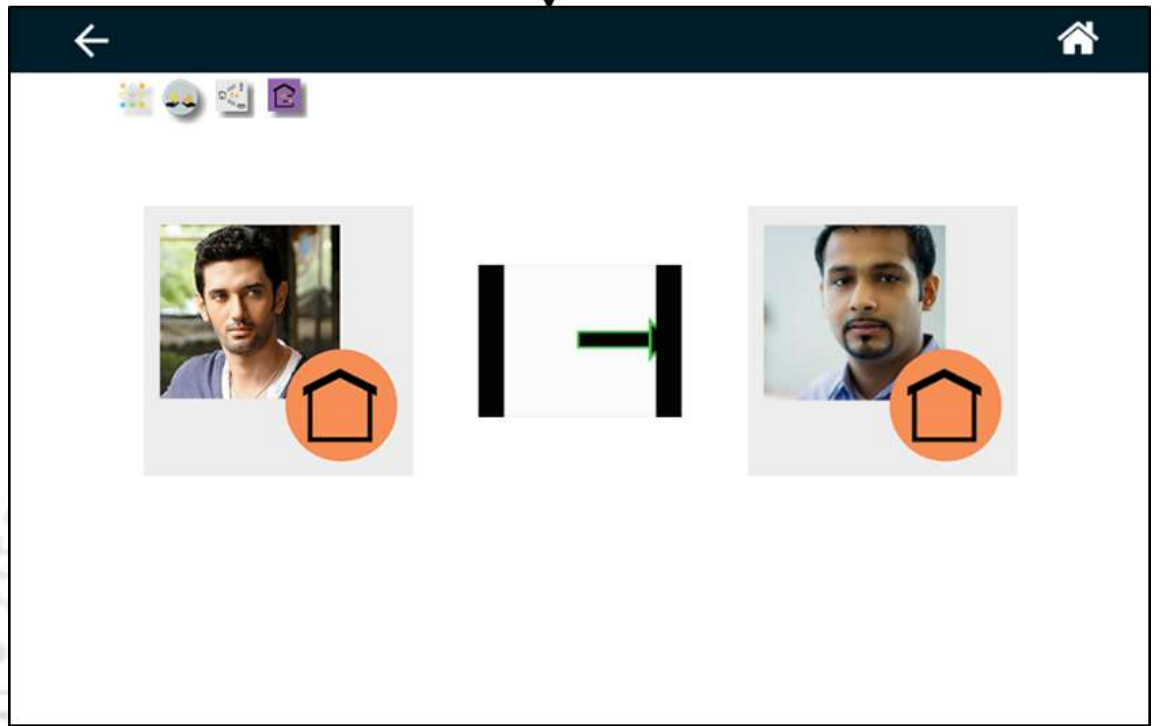


# Task: Energy Borrow (Urban-English language)

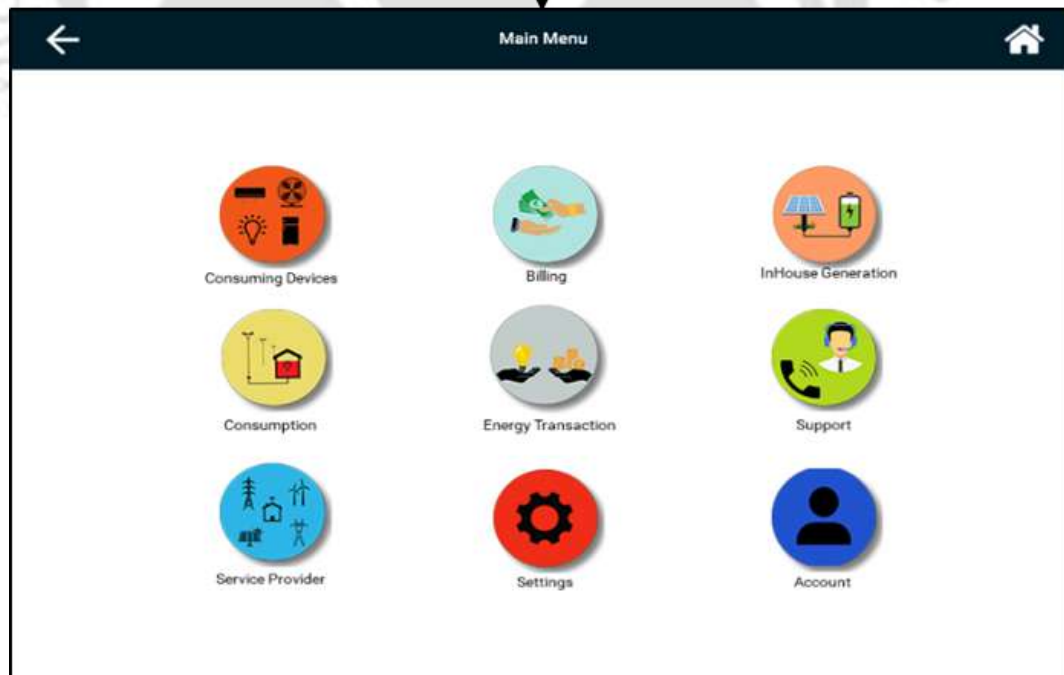
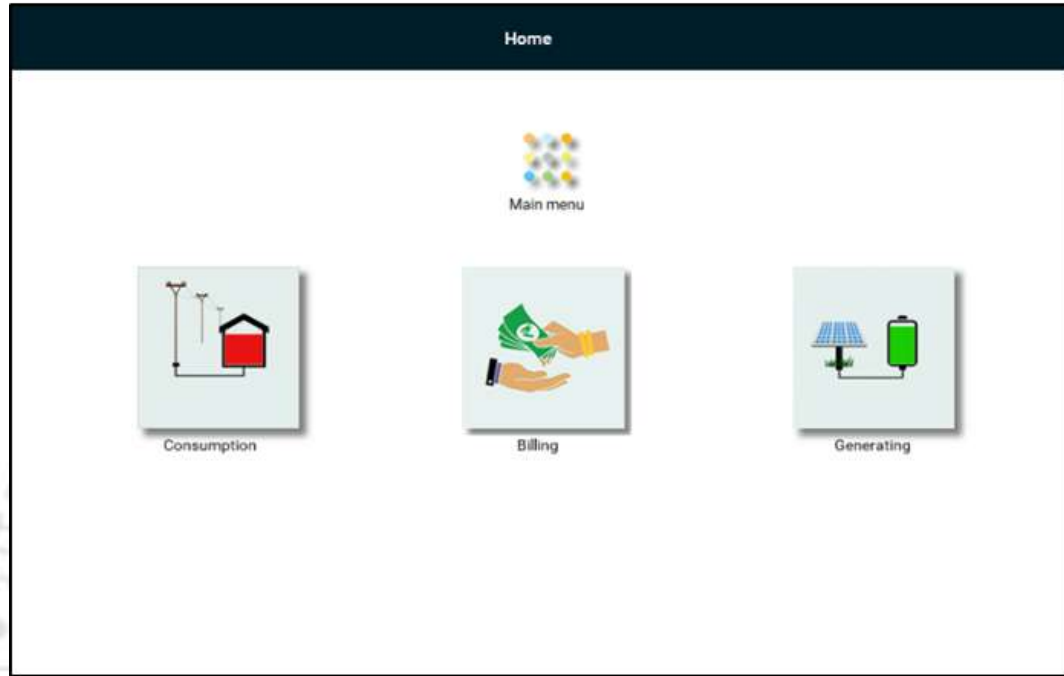


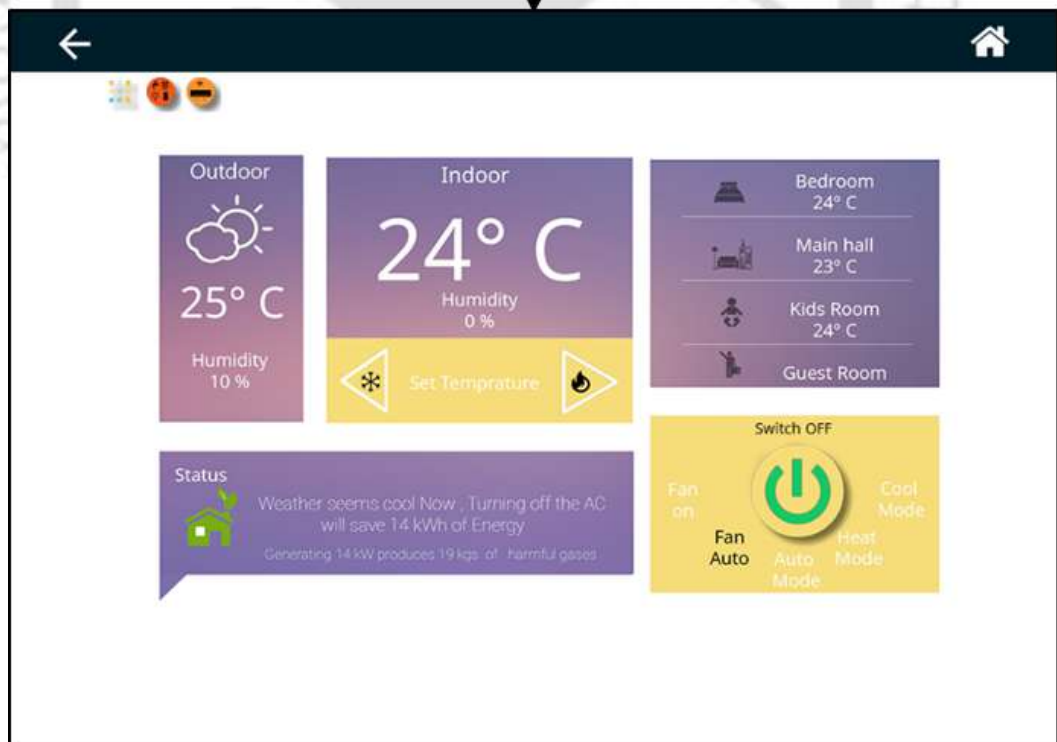
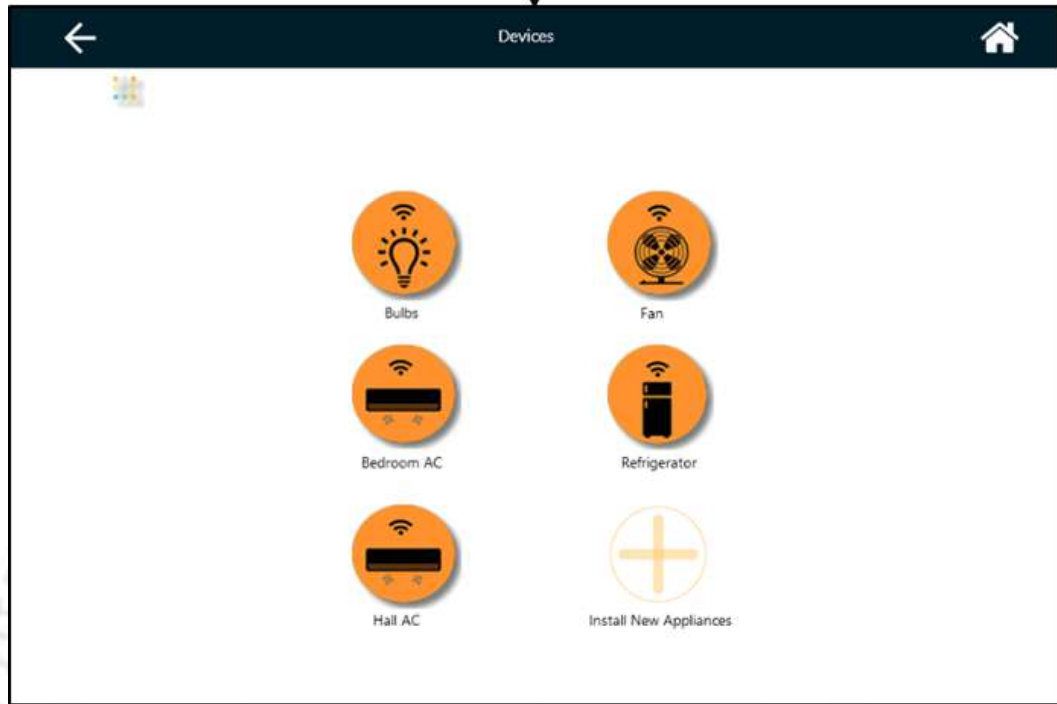


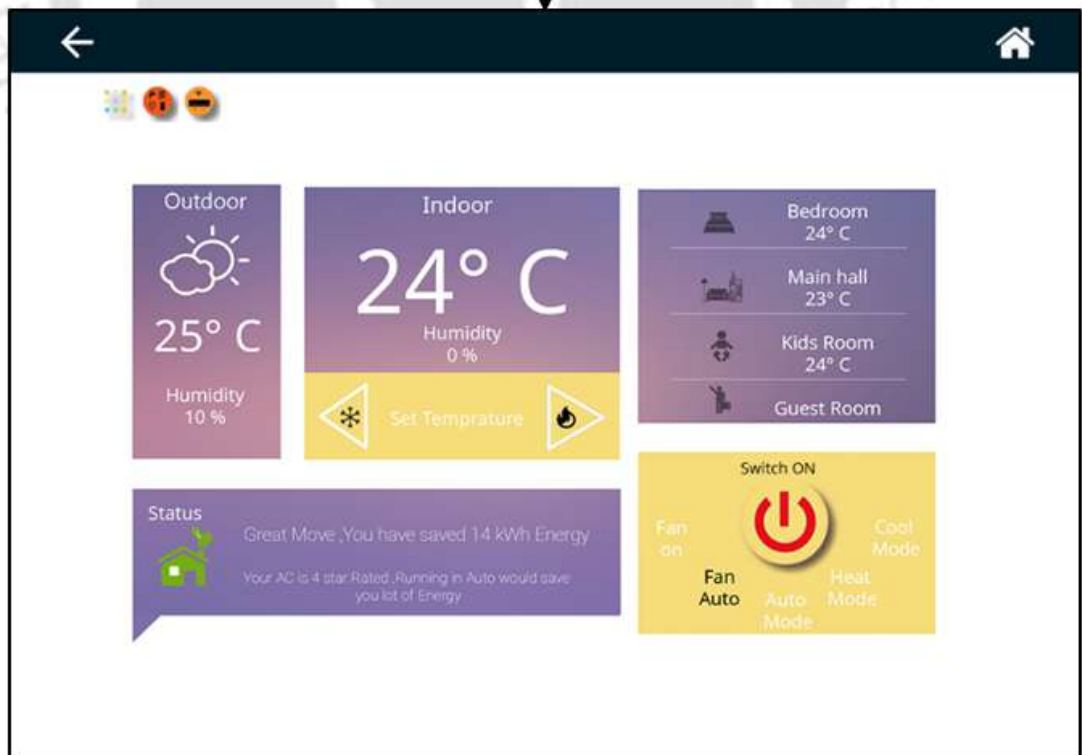
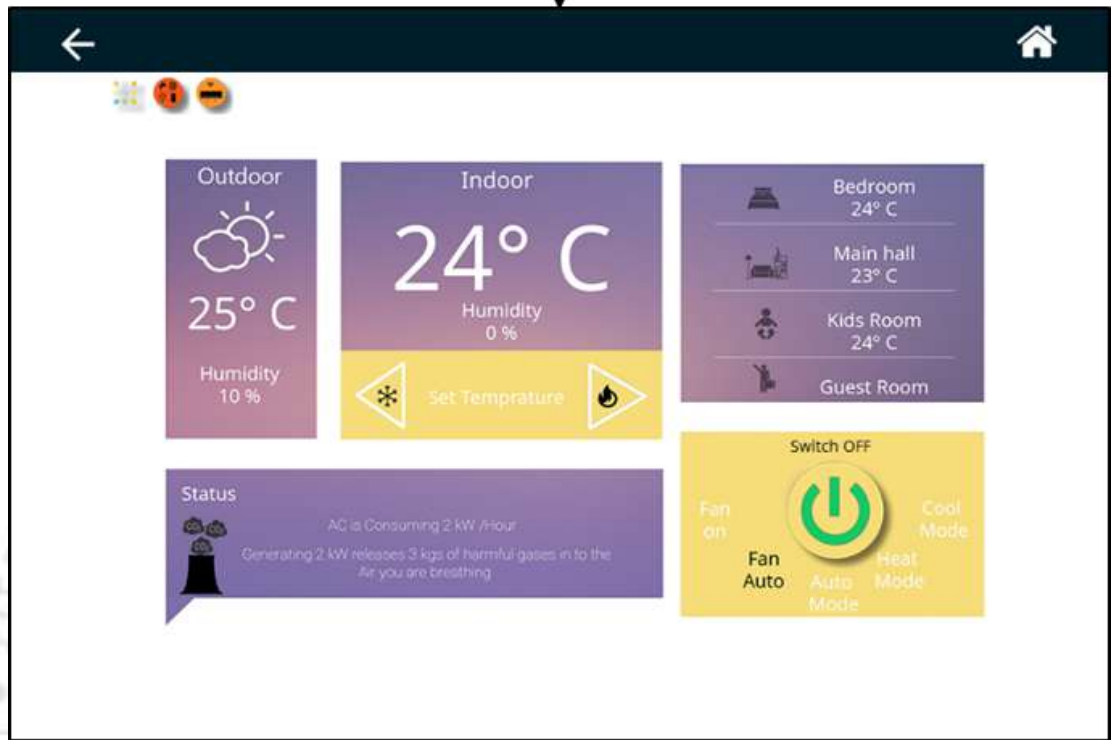




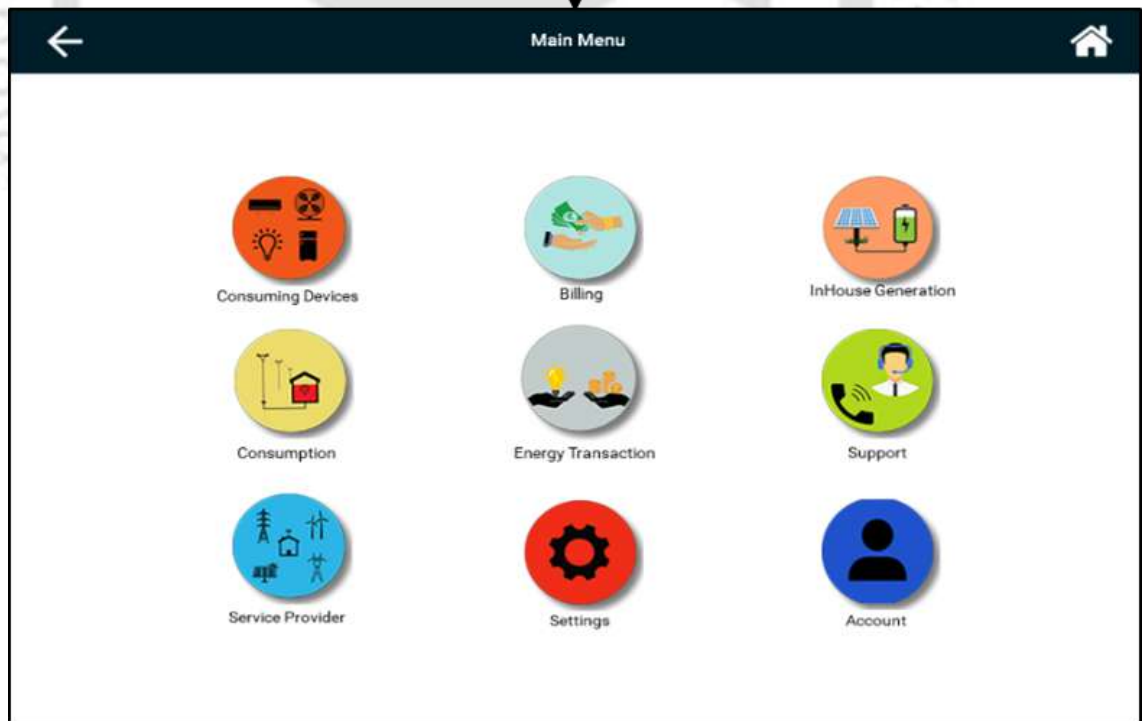
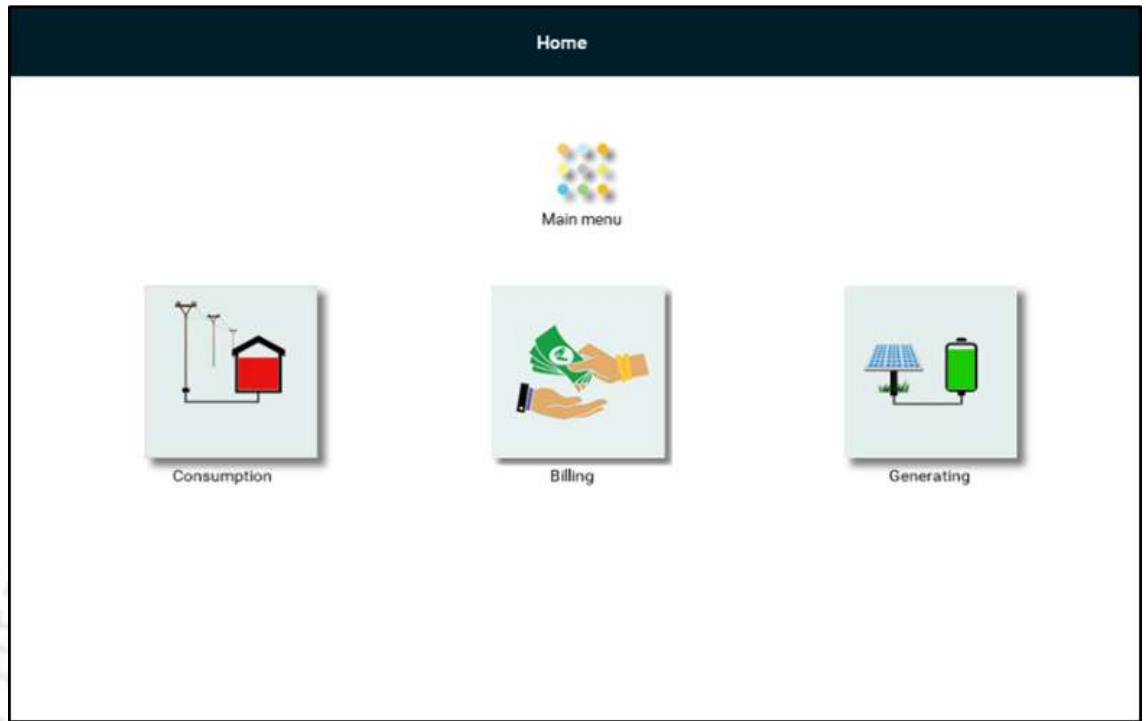
# Task: Refrigerator control (Urban-English language)

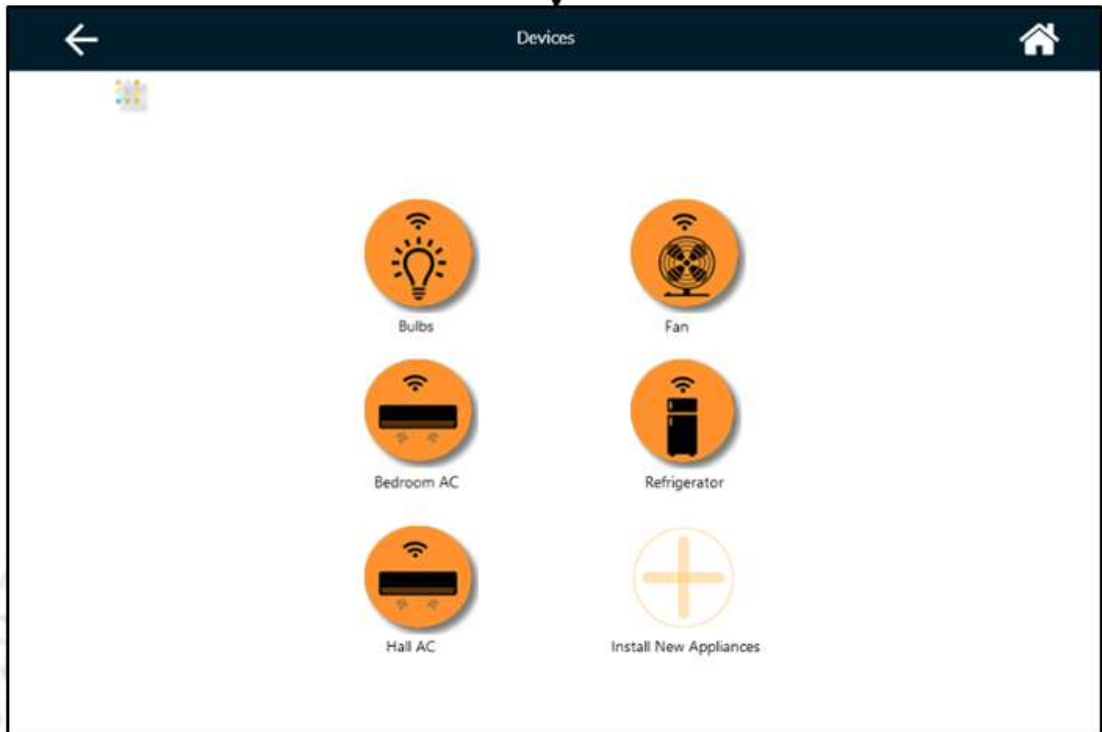




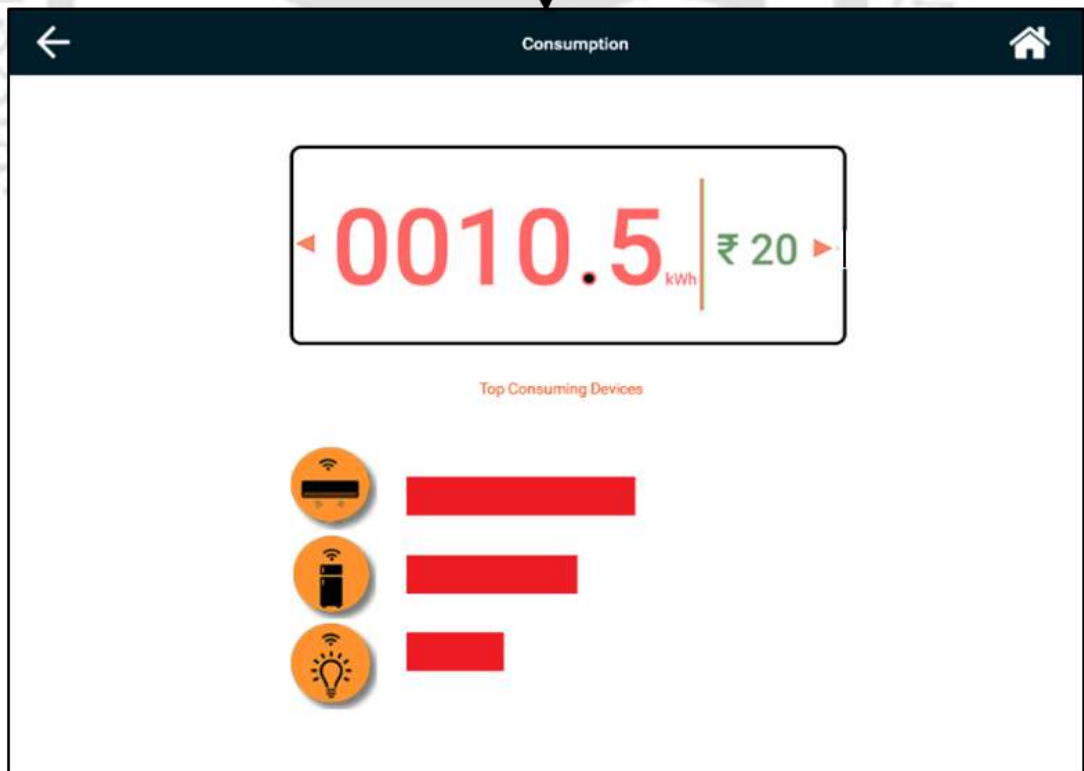
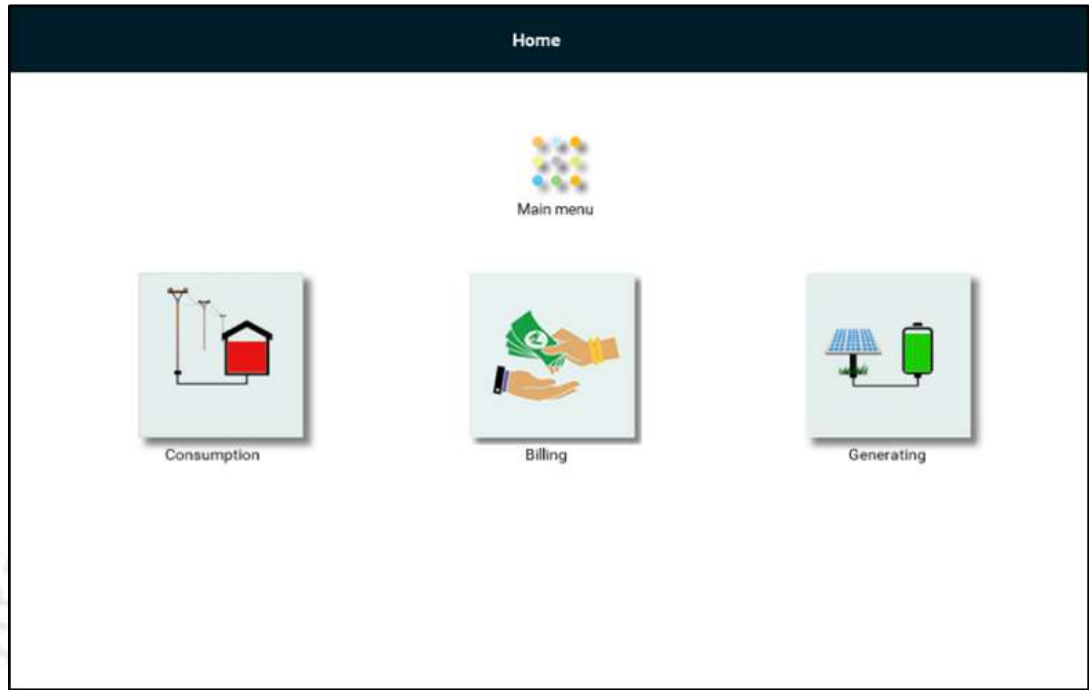


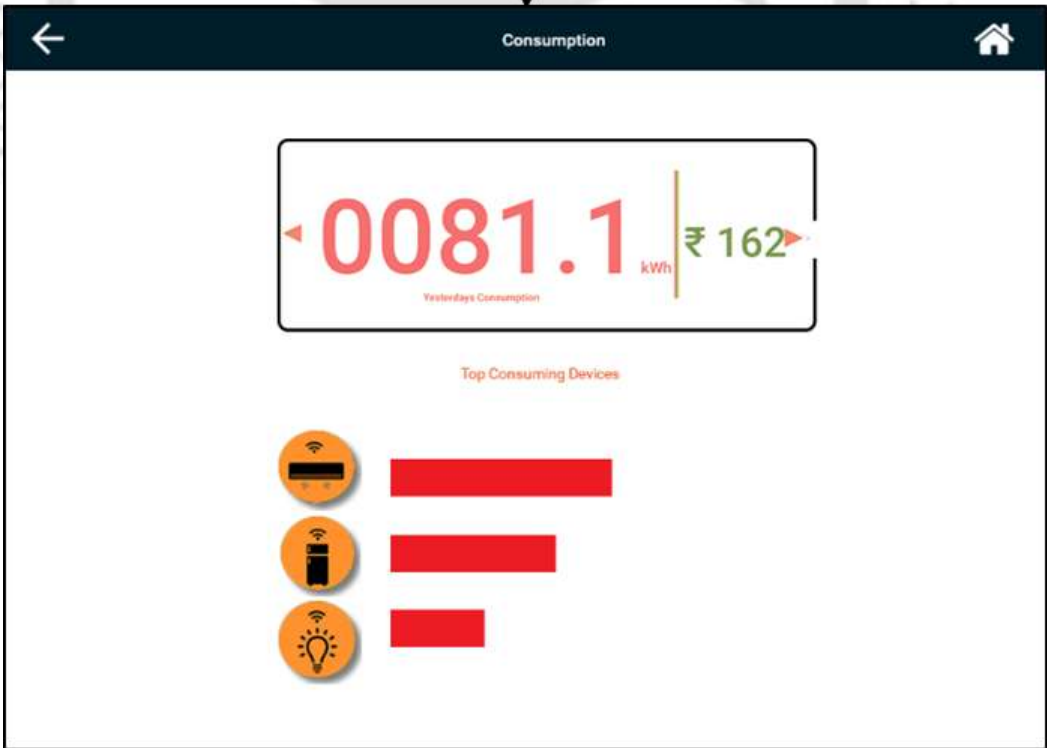
# Task: Lights control (Urban-English language)



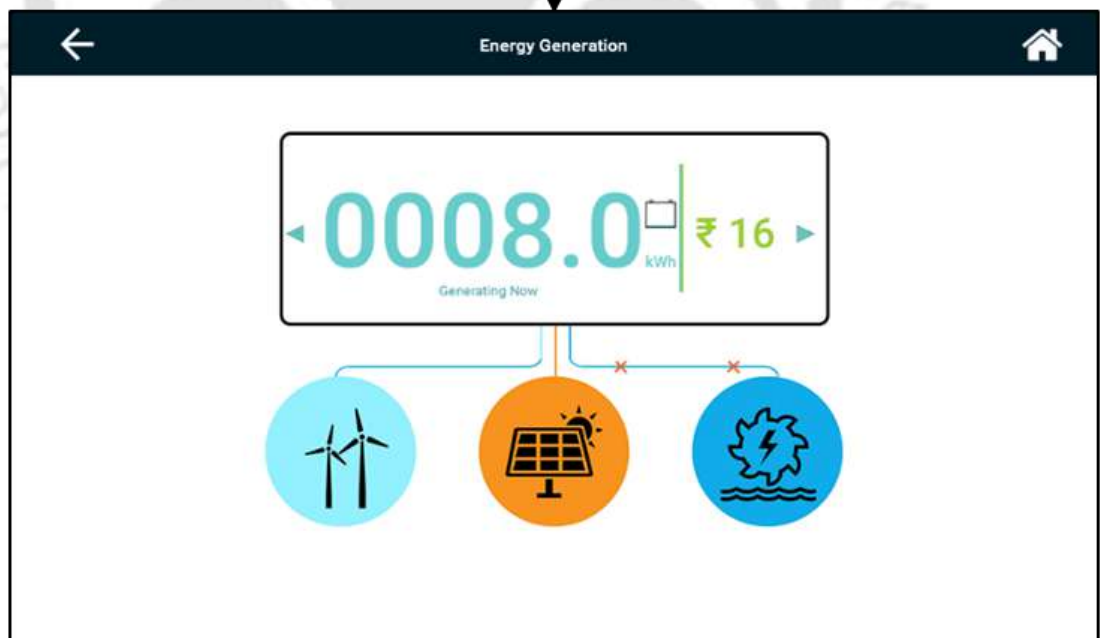
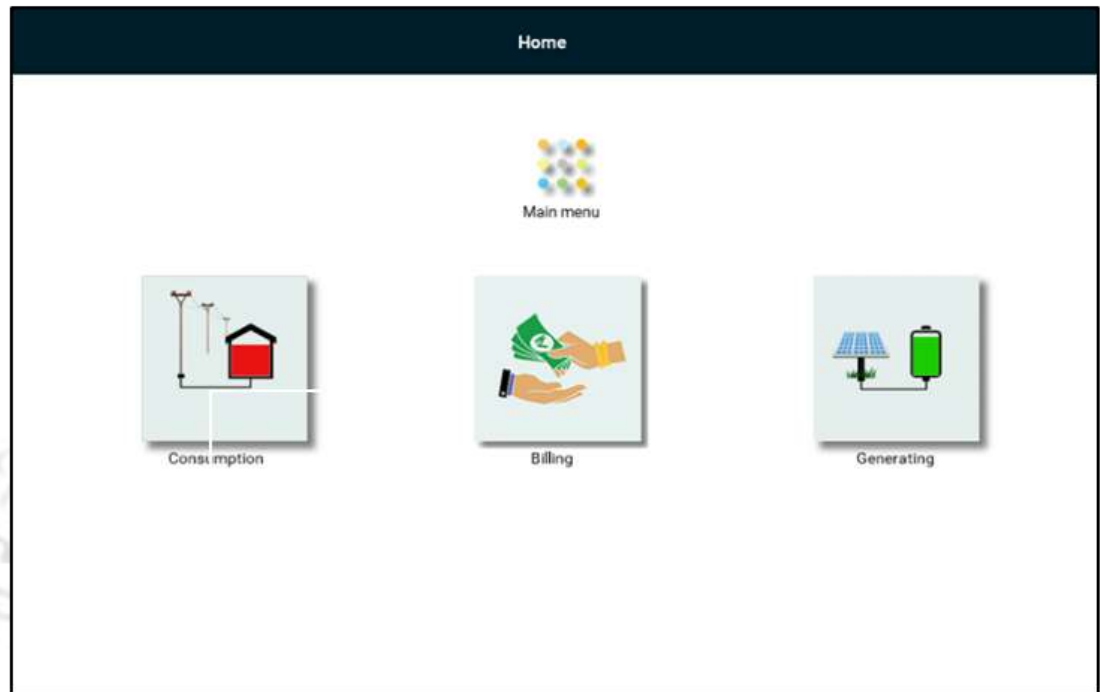


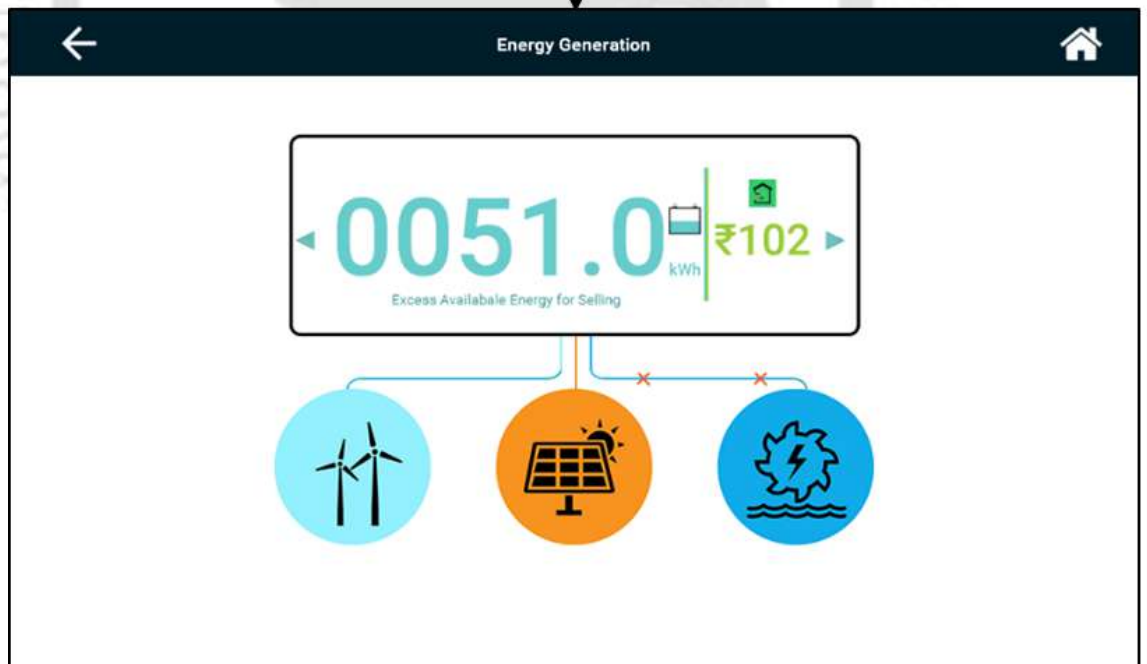
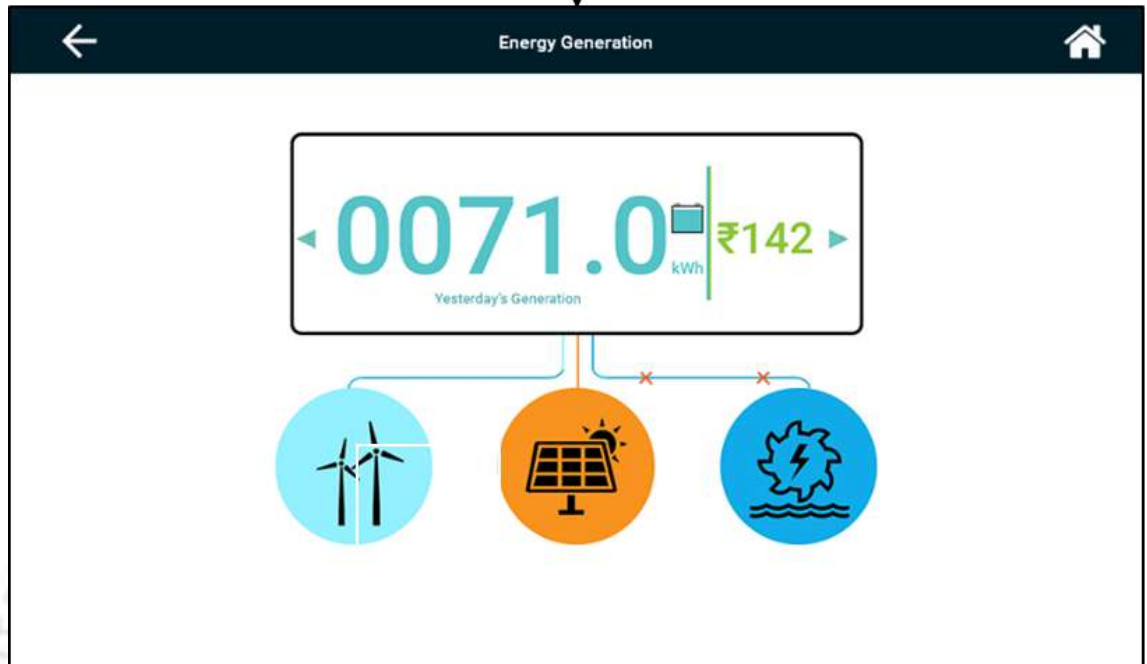
# Home Screen Live Consumption log(Urban-English language)



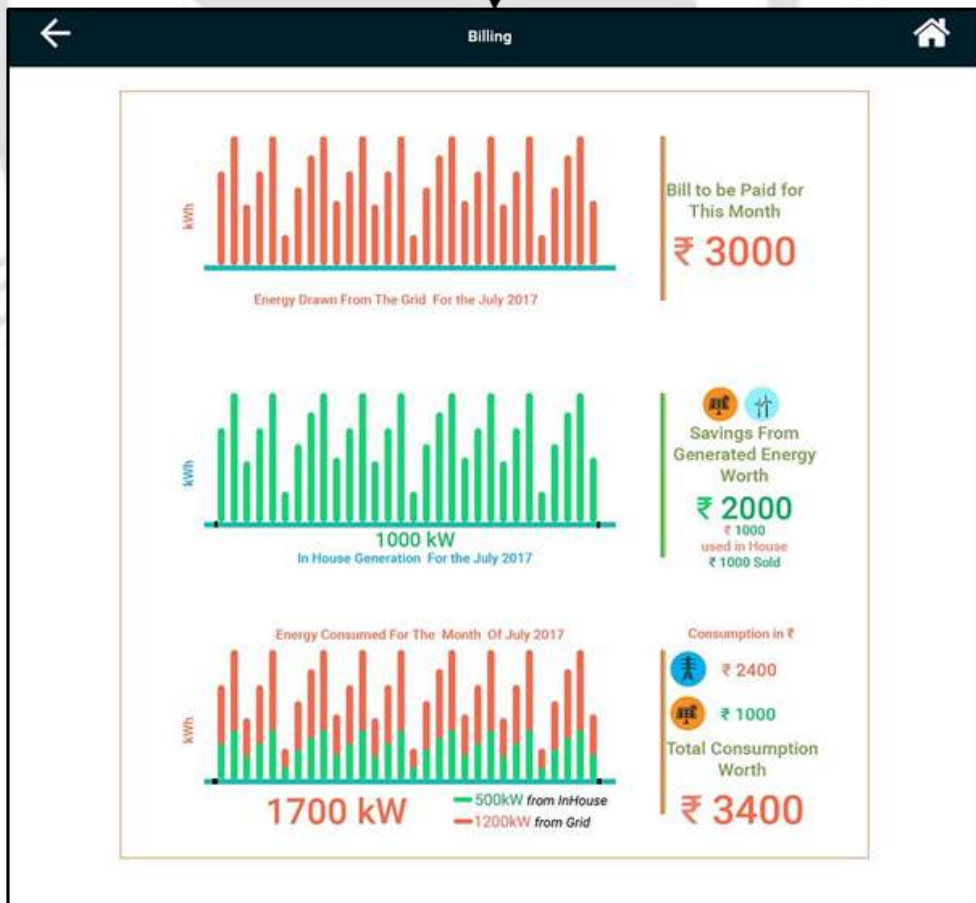
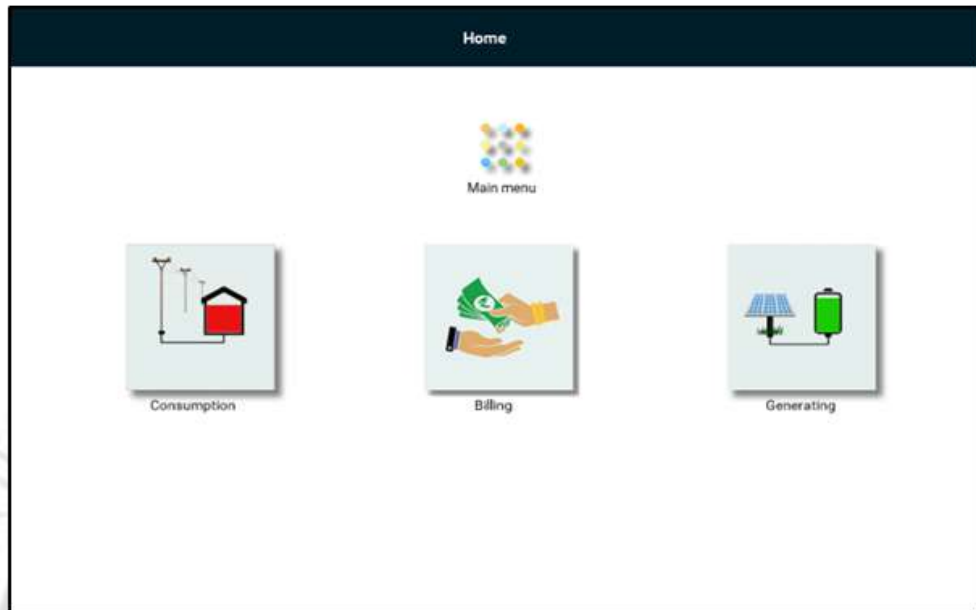


# Home Screen Live Energy Generation log(Urban-English language)





# Home Screen Live Consumption log(Urban-English language)

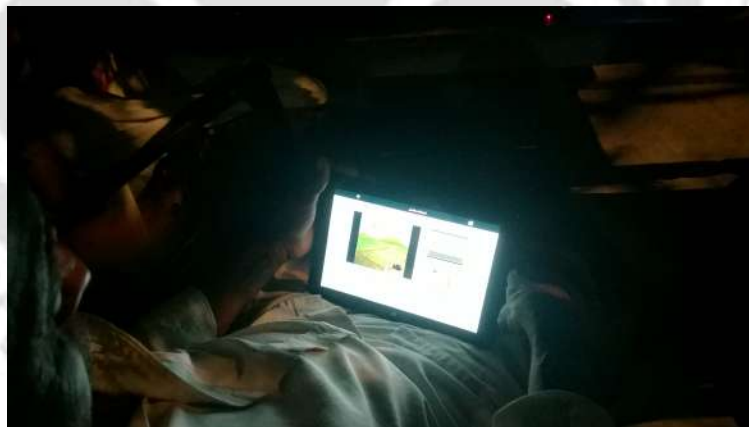




***Annexure D***

Users Interacting with Simulated GUIs and Hardware Model





(Videos of user interacting with Simulated GUI and hardware model are included in Thesis Synopsis CD drive)

# 1.Pre-Task User Information

1. Name

---

2. Age

---

3. Gender

*Mark only one oval.*

Male

Female

Other: \_\_\_\_\_

4. Do you use a mobile phone, if yes  
please mention the make and model

---

5. Have you used a Feature phone  
/Smartphone earlier

---

6. When Using the smartphone which is  
new to me ,learning to use the  
functions is generally troublesome for  
me

---

7. I Think i could learn to use  
smartphones if someone would help  
to get started

---

8. I think i could learn to use the  
smartphones all by myself

---

**9. Using smartphones make me feel distressed**

---

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 Google Forms



## Post-Task Questionnaire

All the Questions are to be answered on a Likert Scale ;Where 1 = strongly disagree, 2 = moderately disagree, 3 = somewhat disagree, 4 = neutral (neither disagree nor agree), 5 somewhat agree, 6 = moderately agree, and 7 = strongly agree

\* Required

1. Name \*

---

2. Age \*

---

3. Profession \*

---

4. Gender \*

*Mark only one oval.*

Male

Female

Other: \_\_\_\_\_

5. Education Qualification \*

*Mark only one oval.*

Nil

Primary

Upper Primary

Higher Secondary

Bachelors or Higher

6. Where do you live? \*

*Mark only one oval.*

City

Town

Village

7. Mention the name \*

\_\_\_\_\_

## Perceived Usefulness

8. Using the IOT Smart Home Interface improves my performance in Electricity Energy Management at home \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

9. Using the IOT Smart Home Interface at home for Electricity Energy Management increases my productivity \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

10. Using the IOT Smart Home Interface enhances my effectiveness in managing Electricity Energy at home \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

11. I find the IOT Smart Home Interface to be useful in Managing Electricity Energy \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## Perceived Ease Of Use (PEOU)

12. **My interaction with the IOT Smart Home Interface is clear and understandable \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

13. **Interacting with the IOT Smart Home Interface does not require a lot of my mental effort \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

14. **I find the IOT Smart Home Interface to be easy to use \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

15. **I find it easy to get the IOT Smart Home Interface to do ,what i want to do \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## Intention to Use

16. **Given that I have access to the IOT Smart Home Interface , I predict I would use it \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

17. Assuming I have access to the IOT Smart Home Interface , I intend to use it \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## Information Quality Satisfaction

18. The information provided by the IOT Smart Home Interface is Accurate \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

19. The information provided by the IOT Smart Home Interface is Complete \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

20. The Information provided by the IOT Smart Home Interface is well formatted \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

21. The Information provided by the IOT Smart Home Interface is relevant \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

22. The Information provided by the IOT Smart Home Interface is up to date \*  
Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## Overall Information Satisfaction

23. Overall the Information provided by the IOT smart home Interface is of High-quality \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

24. Overall I am Satisfied by the Information Provided by the IOT Smart home Interface System \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## Extended -Information Satisfaction

25. IOT Smart home Interface Provides me with Complete set of Information \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

26. IOT Smart home Interface Produces Comprehensive Information \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

27. IOT Smart home Interface Produces all Information i need \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**28. IOT Smart home Interface Produces Correct Information \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**29. There are Few errors in the Information \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**30. Information Provided by IoT Smart home Interface is well formatted \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**31. Information Provided by IoT Smart home Interface is well laid out \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**32. Information Provided by IoT Smart home Interface is clearly presented \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**33. This IoT Smart home Interface produces with most recent Information \***

*Mark only one oval.*

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

34. This IoT Smart home Interface produces most current Information \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

35. Information Provided by IoT Smart home Interface is always up to date \*

Mark only one oval.

	1	2	3	4	5	6	7	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

## SUS

36. I think that I would like to use this IoT Smart Home Interface frequently \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

37. I found the IoT Smart Home Interface unnecessarily complex \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

38. I thought the IoT Smart Home Interface was easy to use \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

39. I think that I would need the support of a technical person to be able to use this IoT Smart Home Interface \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

40. I found the various functions in this IoT Smart Home Interface were well integrated \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

41. I thought there was too much inconsistency in this IoT Smart Home Interface \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

42. I would imagine that most people would learn to use this IoT Smart Home Interface very quickly \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

43. I found the IoT Smart Home Interface very cumbersome to use \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

44. I felt very confident using the system IoT Smart Home Interface \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

45. I needed to learn a lot of things before I could get going with this IoT Smart Home Interface \*

Mark only one oval.

	1	2	3	4	5	
Strongly Disagree	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	Strongly Agree

**Spearman's rho correlation tables:**

Correlations					
			PU	PEOU	IU
Spearman's rho	PU	Correlation Coefficient	1.000	.243*	.519**
		Sig. (2-tailed)	.	.021	.000
		N	90	90	90
	PEOU	Correlation Coefficient	.243*	1.000	.031
		Sig. (2-tailed)	.021	.	.770
		N	90	90	90
	IU	Correlation Coefficient	.519**	.031	1.000
		Sig. (2-tailed)	.000	.770	.
		N	90	90	90

Spearman's rho	OIS	Correlation Coefficient	.430**	-.080	.465**
		Sig. (2-tailed)	.000	.456	.000
		N	90	90	90
	IS	Correlation Coefficient	.496	.171*	.461**
		Sig. (2-tailed)	.000	.108	.000
		N	90	90	90

			OIS	IS
Spearman's rho	OIS	Correlation Coefficient	1.000	.529**
		Sig. (2-tailed)	.	.000
		N	90	90
	IS	Correlation Coefficient	.529**	1.000
		Sig. (2-tailed)	.000	.
		N	90	90

\*\* . Correlation is significant at the 0.01 level (2-tailed).

\* . Correlation is significant at the 0.05 level (2-tailed).