

Internet of Things (IoT) Technology in Smart Homes: Vitalizing Human-Computer Interaction

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Abstract

Internet of Things (IoT) as a novel technology has transformed the consumer market. IoT technology enabled smart homes has provided convenience and effortless living to consumers through its technologically creative offerings. Extensive focus on IoT products has been the mainstream, while the domain of “smart” homes with embedded IoT technology has been less explored. Moreover, such studies have been confined to the Western and developed regions, and less focus has been on emerging markets. The aim of this paper is to systematically review the smart home literature and survey the current state of play from the users’ perspective. The review presents a comprehensive view of smart home definitions and characteristics. Then the study precisely discusses about of the smart home types, related services and benefits. After outlining the smart home benefits, the review discusses the challenges and barriers to smart home implementation. This review concludes by providing suggestions for future research. Additionally, the review contributes theoretically to the growing body of research on IoT adoption along with practical implications for marketers from the Indian consumer’s perspective.

Keywords: Internet of Things (IoT) Technology, Smart homes, Smart Living

1.0 Introduction

The contemporary technological literature often employs the term “smart” as a broader expression denoting innovative systems characterised by artificial intelligence (AI) structures (Pal et al., 2021). This underlying novel technology, generally referred to as the “Internet of Things” (IoT), is one of the driving factors behind the Industrial revolution 4.0 and aims to enhance work efficiency and improve consumers' quality of life (Naveed et al., 2018). One of the inherent elements of smart systems technology is the competence to retrieve data from the adjacent systems and respond subsequently (Balta-Ozkan et al., 2015). Although researchers in the past have examined the constructs that influence the adoption of IoT related “smart” home services, some aspects still need to be investigated (Gupta et al., 2021). Furthermore, researchers believe it is vital to explore factors detailed to the Indian context to elucidate the intent to use IoT (Mital et al., 2018). Also, the

Indian “smart” home marketplace is expected to grow considerably and reach nine billion US dollars sales-wise (Statista, 2021a).

Interestingly, the word “smart” has recently become an umbrella term for innovative technology that possesses some degree of artificial intelligence. The key attributes of a smart technology are the ability to acquire information from the surrounding environment and react accordingly (Balta-Ozkan et al., 2015). The wave of the transformation of products and services into smart ones has triggered the rise of device interoperability and contributed to the growth of smart home technology turnover globally (Khedekar et al., 2017). The benefits made possible by smart technology have fuelled the interest of both academics and practitioners alike. Significant attention has been paid to home appliances, where smart technology has become intensively researched and practically applied (Balta-Ozkan et al., 2015).

Along with increasing investments of enterprises into the smart home sector, the academic community has intensified its efforts in examining the concept of the smart home, the technological capabilities, its implications and the impact on people’s lives. A number of review papers have been published covering smart technologies from different angles (De Silva et al., 2012). Despite the increasing number of reviews, and beyond the narrow scope of the context examined, research in this domain is confined within the boundaries of three themes namely multidimensionality of the concept of the smart home, technological perspective related to smart devices and lastly potential benefits that smart home technology is capable of capturing (Czaja, 2016), while providing little empirical evidence regarding the users’ perception of the challenges and benefits of the smart home technology use.

Given the growth in the smart home segment, both in India and worldwide, it is of the essence to explore the aspects that propel its acceptance amongst the users. There is a strong need to revisit and review the current state of the literature. The objective of this review paper is to adopt a user perspective, by focusing on the user as the unit of analysis and the recipient of smart home technology services and capabilities. This paper aims to synthesise emerging themes that are pertinent to the area of the implications of smart home technology in the key spheres of users’ lives. The paper will provide a review of smart home functions, benefits and implementation in a comprehensive way. The next section will outline the methodological steps followed, before proceeding to review the relevant literature and suggest future research avenues.

2.0 Methodology

The review analysed and synthesised the smart home literature from a user perspective following a systematic approach. In order to ensure that the findings were reached in a reliable and valid manner the study followed a three-stage approach, as proposed by Tranfield et al. (2003) namely: planning the review,

conducting the review by analysing papers and reporting emerging themes and recommendations. These stages are further discussed in this section.

2.1 Planning Stage

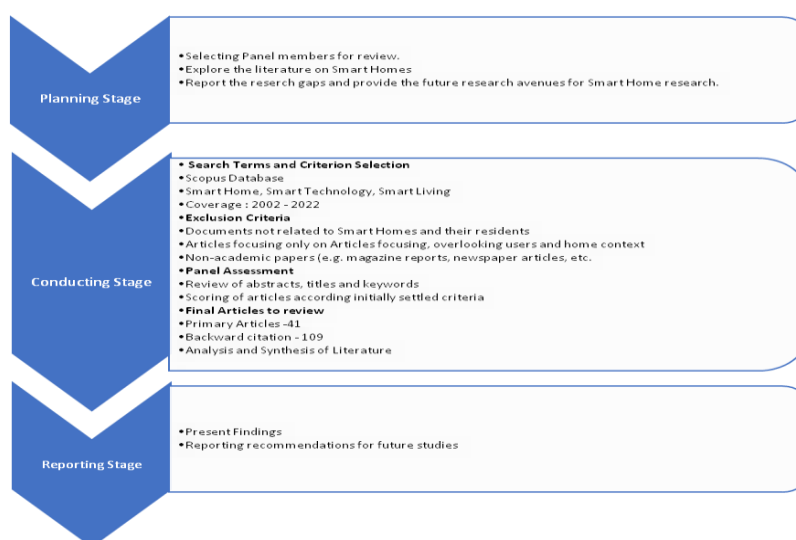
The planning stage of the review, which included the preliminary scoping of the literature aiming to identify and refine the objectives of the study and develop review protocols, was undertaken by two reviewers. The expertise of the reviewers on the topic facilitated and enhanced the potential of the study to identify novel themes and extend the insights into the topic (Hasson, Keeney, & McKenna, 2000).

2.2 Conducting Stage

The conducting stage of the review involved the systematic search, based on relevant search terms. The electronic database Scopus was selected as it represents the largest database of citations and abstracts of the research literature and provided a wide coverage of the review topic (Bar-Ilan, 2008).

In order to ensure the rigorousness of the review and eliminate the risks of bias related to inappropriate use of methodology, subjective exclusion of articles and the selectivity of findings, this study adhered to the three following procedures. First, a systematic approach of protocol development and database search was closely followed. Second, the involvement of more than one reviewer and clearly identified exclusion criteria minimised the risk of bias in the paper selection process. Lastly, to eliminate the selectivity of findings, the documents extracted from the electronic database were organised in such a way as to provide the opportunity for panel members to review and assign relevance scores independently. The aforementioned procedure made it possible to finalise the relevance of the downloaded articles and increase reliability (Tranfield et al., 2003).

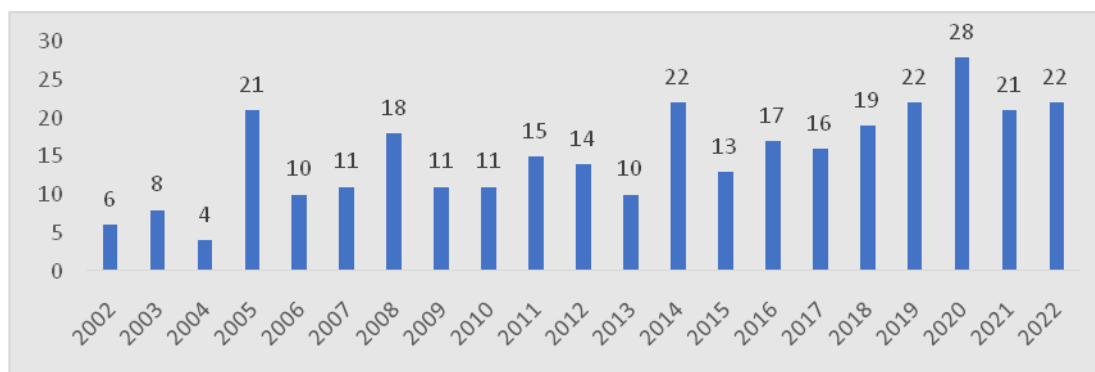
**Figure1: Summary of Smart Home Literature Review (Adapted from
Tranfield, 2003)**



2.3 Reporting stage

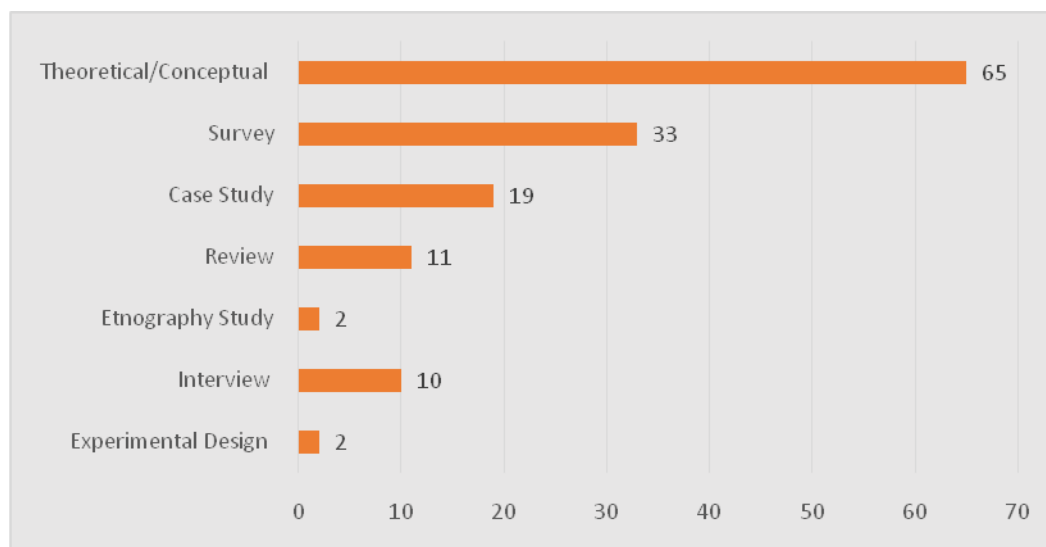
The final stage of the review process was to report the descriptive statistics of the literature used in the review, the findings of the analysis undertaken and develop recommendations for future research. The frequency analysis demonstrated the publication year of the studies, the research methods employed, the technological domains covered and the keywords used.

Figure 2 : Publication Period



The majority of authors tended to generate theoretical/conceptual papers. Other types of publications included 11 review papers, 33 papers adopting a survey method, 19 case study-design papers, 2 papers adopting an experimental approach, 10 papers based on interviews and only two ethnography study (Figure 3).

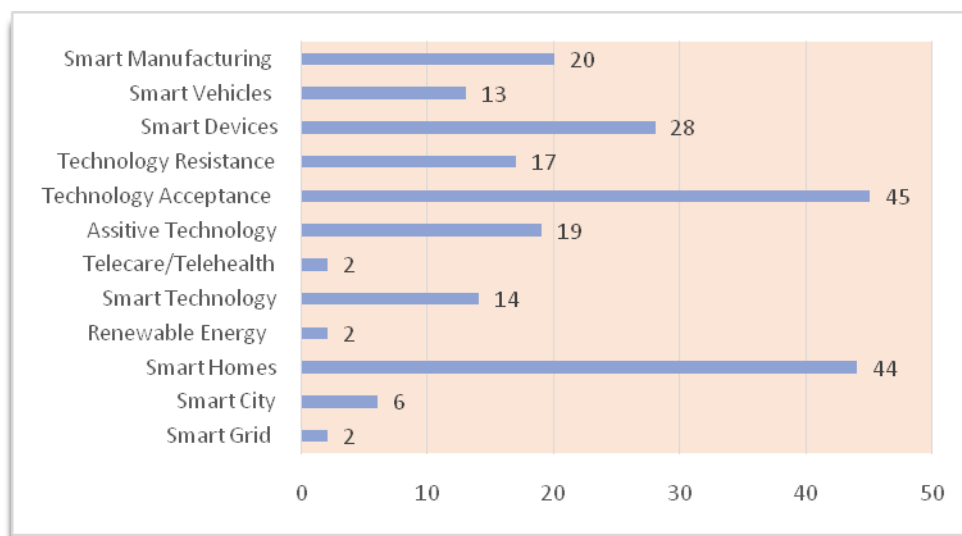
Figure 3: Research Methods Utilised by the Reviewed Articles



The majority of the studies contextualised their approach towards a specific technological domain. The primary domain was smart homes applications inside the house (Figure 4). Among other broad research themes are the benefits and

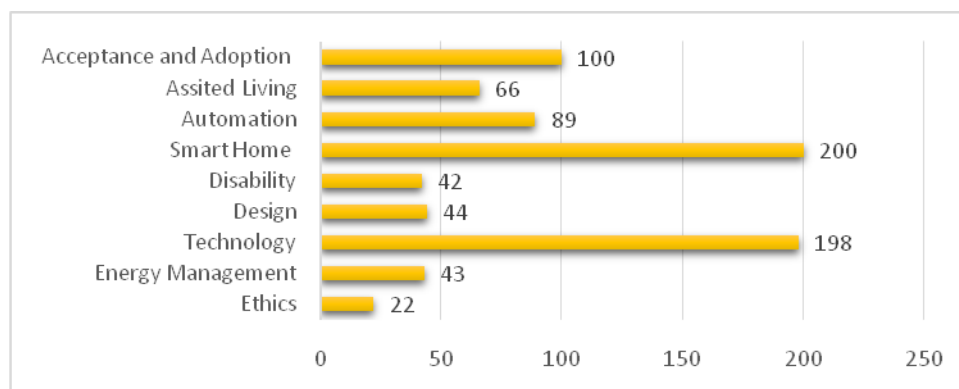
challenges of smart homes and smart technologies, while thirteen articles focused on smart vehicles and two on smart grid.

Figure 4: Primary themes discussed in the reviewed papers



To identify the specific focus of the reviewed papers across broad domains, a semantic categorisation of keywords was applied. The semantic analysis enabled the identification of the nature of the text and allowed a visual presentation of the concepts discussed in the papers (Goddard, 2011). Having utilised the statistical approach proposed by Baker (2004), the most frequently mentioned keywords were extracted from a single or a group of documents. After the extraction process, keywords with synonymous meanings were grouped and calculated, resulting in a number of frequently-mentioned key words, such as technology, smart home and ageing (Figure 5). Basic semantic clusters acted as a touchstone for developing themes for this review.

Figure 5 : Frequency of Keywords detected in the reviewed articles



3.0 Literature Review

3.1 Internet of Things (IoT) and Smart Homes

IoT has also been described as the informational and communication technological system, allowing intelligent utilities via interactivity between entities connected through both connected and wireless networking (Park et al., 2018). Home-based IoT applications are often considered the most representative type (Lau et al., 2018). As per the work of Balta-Ozkan et al. (2015), Home IoT is “a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants”. Various definitions have been used to conceptualise and define smart homes (Table 1).

Table 1 : Definitions and characteristics of Smart Homes

| Definition theme | based on | | Technology | | | Services | | | Users' Needs | | | | | |
|---------------------|----------|---------|--------------------|-----------------|-------------------|--------------------|------------------------|-----------------|--------------|-----------|----------|------------|-----------------|----------------|
| Authors | Sensors | Devices | Integrated systems | Control/monitor | Energy management | Support and assist | Anticipate and respond | Cost-efficiency | Comfort | Emotional | Security | healthcare | Quality of life | Sustainability |
| Aldrich | | | x | | x | | x | | x | x | x | | x | |
| Lutolf | | | x | | x | | | x | x | | x | | x | |
| De Silva | | | x | x | | | | | | | | | x | |
| Reinisch and Kofler | | | x | x | x | | | x | x | | | x | x | x |
| Scott | | x | x | | x | | | x | x | | | | x | x |
| Balta-Ozkan | x | x | x | x | | | | | | | | | x | |

Aldrich (2003) defined a smart home as “a residence equipped with computing and information technology, which anticipates and responds to the needs of the occupants, working to promote their comfort, convenience, security and entertainment through the management of technology within the home and connections to the world beyond”. Their definition embraced the technological component of the phenomenon, the services and functions it provides and the types of users needs that smart homes aim to meet. Balta-Ozkan et al. (2015) definition states that the “smart home is a residence equipped with a high-tech network, linking sensors and domestic devices, appliances, and features that can be remotely monitored, accessed or controlled, and provide services that respond to the needs of its inhabitants”. When it comes to lifestyle support, a smart home represents a house with sensors and domestic devices, linked through a communication network. It empowers users to remotely control household appliances and decrease the burden of everyday household activities (Chan et al., 2009). Connected devices provide an opportunity for smart home residents to effectively manage their energy usage, while enhancing their convenience and comfort in their daily routine. Fully-automated devices have the potential to improve the quality of life and encourage the independent living of residents, especially for an ageing population through constant health management, and they even provide virtual medical assistance in cases of need (Gupta et al., 2021). The smart home represents smart devices and

sensors that are integrated into an intelligent system, offering management, monitoring, support and responsive services and embracing a range of economic, social, health-related, emotional, sustainability and security benefits.

3.2 Types of Smart Home Technology Services

This section presents the two main typologies of smart home technologies suggested by De Silva et al. (2012) . De Silva et al. (2012) came up with three types of smart homes, classifying them based on the types of services they promote. The first category of smart homes provides assistance to occupants by recognising their actions. This type of home promotes the well-being of occupants inside the house. The services that these smart homes provide are divided into three types: homes providing care for the ageing population, assisting in child care and overall health care. The second type aims to detect and gather multi-media information in the form of videos and photos of the occupants' lives. This type of smart home concept may raise privacy concerns and a feeling of intrusion. The third type is the “surveillance home”. This aims to process data to forecast and alert residents in case of upcoming natural disasters or security interventions. The function of these smart homes is to capture the data from the environment to detect and make people aware of burglary threats. The typology of smart homes provided by De Silva et al. (2012) can be potentially extended by an additional category. A number of scholars recognised that the emergent drive for ecological awareness has led the way to a special type of smart home . Additionally, the user benefits in context of smart homes have been precisely discussed in Table 2.

Table 2: Perceived User Benefits of Smart Home Adoption

| Benefits | Service | Immediate Advantage | Long-term impact | Frequency of papers |
|-------------------------|-----------------|---------------------------------------|--|---------------------|
| Health-Related Benefits | Comfort | Care accessibility and availability | Promote well-being of ageing and vulnerable people | 39 |
| | Monitor | Users' safety | | |
| | Consultancy | Social connectivity and communication | | |
| | Support | Detection of life-threatening events | | |
| | Deliver therapy | Reduction of medical errors | | |

| | | | | |
|--|-------------|---|-----------------------------------|----|
| Environmental Benefits | Monitor | Reduce energy usage | Environmental sustainability | 22 |
| | Consultancy | Feedback on consumption Suggestions how to use electricity efficiently | Reduction of carbon emissions | |
| | Comfort | | | |
| Financial Benefit | Consultancy | Cheaper cost of virtual visits | Affordability of health care | 33 |
| | Monitor | | Sustainable Consumption | |
| Psychological Wellbeing and Social Inclusion | Support | Entertainment, | Overcome the feeling of isolation | 7 |
| | | Virtual interaction | | |

3.3 Smart Home Implementation and Barriers

Despite the potential benefits of smart homes, the adoption and diffusion rate remain low. It is therefore important to examine smart home acceptance and adoption and the users' perspective on the barriers (Table 3) which may hinder the implementation of smart homes. The section discusses the main technological barriers which were considered to be the major stumbling block when it comes to the adoption of smart home technology. Slightly less emphasis was given to the concerns related to financial, ethical and legal issues and the barriers caused by the knowledge gap and psychological resistance.

Table 3 : User's perspective on Barrier's to Smart Home Adoption

| Barriers | Examples | Frequency of papers |
|------------------------------|--------------------------------|---------------------|
| Technological | Security | 45 |
| | Usability | |
| | Privacy intrusion | |
| | Reliability | |
| | Complexity | |
| Financial, Ethical and Legal | Price | 33 |
| | Cost of installation | |
| | Cost of repair and maintenance | |

| | | |
|--|---|----|
| | Concern about misuse of private data | |
| | The requirement for formal consent from patients | |
| | Lack of legal conduct | |
| | Uncertainty with regulation conflicts between smart home service providers and users | |
| Knowledge Gap and Psychological Resistance | Human Barrier Resistance to using innovative technology Lack of prior knowledge or/and experience | 19 |

Technological Barriers

Technology fit is the most important factor to address when developing smart homes (Alraja et al., 2019). It can be described as the users' perception of the technology compatibility, connectedness and the system's reliability. These three factors are strongly associated with the perception of the technology's usefulness (Aldossari & Sidorova, 2020). In line with this perspective, smart home technology adoption studies have been gradually increasing their focus on the features of technology that could potentially pose threats to users and influence the perception of the technology.

Financial, Ethical and Legal Concerns

The second group of barriers comprises financial, ethical and legal concerns. The financial factors include the price of the technology, and the cost of installation, repair and maintenance, which discourages users from adopting smart home technology (Mocrii et al., 2018). Some people expressed a lack of understanding of how smart homes could help them save money, which triggers mistrust towards the technology. Healthcare related literature indicated that the implementation of the technology in the health industry is cost-intensive. This finding does not support the assumption that assistive home devices can financially benefit both the users and hospitals, by replacing a traditional visit with virtual therapy (Nikou, 2019).

Knowledge Gap and Resistance to Change

The low rate of the perceived usefulness of smart homes can be explained by the lack of knowledge, trust and experience to embrace the benefits of the technology (Marikyan et al., 2019). As smart home technologies are emerging technologies, people are not fully aware of their functions, potential risks and benefits. Lack of knowledge regarding smart home technologies impedes the wider implementation of smart homes in the mass market (Mital et al., 2018).

4.0 Discussion

This review outline's significant themes across which the papers related to smart home technology have been published namely technological barriers associated to the implication of smart homes , financial , ethical and legal concerns associated with the smart homes and knowledge gap and resistance to change associated with the smart homes and smart home devices. A number of scholars recognised that the emergent drive for ecological awareness has led the way to a special type of smart home . Additionally, the user benefits in context of smart homes have been precisely emphasized across health-related benefits , environmental benefits , financial benefits and psychological well being and social inclusion which highlights the growing importance of ecological awareness among the potential users of smart homes.

5.0 Implications

This work has mostly contributed theoretically to the growing body of research on IoT study. Foremost, this study has provided scholar a major perspective concerning the “perceived user benefits for smart homes ” and “barriers and challenges in implementing the smart homes ” . Concerning practical implications, the study has also some suggestions for business managers. With, this review concluding the need to improve the knowledge and awareness related to smart homes and the related devices , business managers in newer markets where the adoption of this technology is still in the preliminary phase can increase awareness amongst the consumers. They can also communicate the features of this technology to improve its adoption. Marketers must improve their brand image by focussing on key differentiating attributes while communicating the brand.

6.0 Limitations and future research

With the limited availability of time , the research papers reviewed had been limited in number . The future scholars can enhance opt for reviewing and presenting the comparative review of smart homes adoption between developed and developing nations , to enhance the generalizations of the findings. Some aspects of the research concerning technological adoption like cultural dimensions can also be studied in the future. Future works can also adopt experimental design or cross-sectional studies to enhance the study's findings.

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Conflicts of Interest “The authors report there are no competing interests to declare.”

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