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The Perception of Smart Home Technology in Residential Properties

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Abstract: **— recently, Smart Home Technologies (SMHT) drew a tremendous interest from homeowners, the general public, and the research community. They have been viewed as one of the main alternative methods of reducing energy consumption in residential and non-residential properties. The purpose of this research work is to examine the perception of various individuals on smart home technologies to determine correlations between different socio-economic characteristics of the participants and their views on diverse set of utility cost saving systems. The research methodology employed to attain the abovementioned research objectives starts with a comprehensive analysis of the up-to-date literature. Following this review, the paper investigates five research hypothesis, namely H1: People who are more familiar with Smart Home Technology are more likely to implement the technology; H2: The higher the income level of the participants, the likelihood of implementing smart home technology increases; H3: Individuals living in detached homes are more likely to implement smart home technology; H4: In deciding whether or not to implement smart home technology, the cost will play the biggest role in comparison to time and reliability of the system; H5: With outside temperature increase the preferred indoor temperature should decrease and vice versa. The results of the survey were thoroughly analyzed through statistical analysis and simulations. Findings from this research provide much needed insight on the perception of smart home technologies and utility cost saving systems in residential properties to help people to make more informed decisions.**

Keywords: **-**Smart Home Technology, Utility Cost Saving Systems, Residents Behavior, and Tenant Perception.

I. INTRODUCTION

The increase in energy consumption, greenhouse gas emission, and constant rise in energy demand have caused the global community to shift its attention more towards smart home technologies, renewable energy, environmentally friendly and more sustainable mechanisms to offset the drawbacks of global warming, and finally respond to an ever increasing demand for energy. In consideration to increasing energy costs, reduction in energy consumption has economic and environmental benefits not only in national level but also in the global scale. As stated by Reinisch et al. (2010) [1], development and utilization of Smart Home Technology (SMT) in residential properties allow residents to utilize these modern home automation systems to substantially decrease their energy consumption and utility bills while improving the quality of their lives. Smart homes are also referred to as intelligent buildings, integrated home systems, and automated home systems, which will be used interchangeably over the course of this paper. Smart homes have been evolving over several decades [2]. Hence, in the current age of information renaissance and advancement of modern smart technology such as tablets, phones, wearable devices, various types of sensors, motion detectors and solar panels, the possibility of creating a sustainable and renewable energy systems is more than ever before. Traditionally, smart home systems were only utilized to control basic environmental and physical aspects of a home such as heating, cooling, lighting and locking/unlocking doors and gates [3]. Nonetheless, today's smart home systems accomplish far more sophisticated tasks and activities. By incorporating and centralizing diverse set of smart devices into one unit, smart home systems establishes communication with all those devices [4]. Thus, the system makes continues decisions based on studying, monitoring and gathering data from the occupant's daily activities and decision-making patterns. Consequently, based on the gathered data, it automatically adjusts different sensors and various

aspects of a home to perform in the most optimal comfort and cost effective level [5]. However, due to the complexity and high cost of installation of the home automation systems, vast majority of homeowners have very minimal experience dealing with these systems. As a result, the full potential and growth of smart home technologies in residential properties still lies ahead of us.

II. RESEARCH OBJECTIVES & HYPOTHESIS

In recent years, the research community undertook studies on different aspects of smart home technologies, namely cyber security, Internet connectivity, remote monitoring and controlling, as well as energy savings, and thermal comfort. However, there has not been a large-scale research done on analyzing tenant's perception on smart home technology based on their socio-economic characteristics influencing their decision-making on various energy saving systems. Therefore, the objective of this study is to examine the views of Ball State University students, faculty and staff members on smart home technology to determine correlations between different socio-economic characteristics of the participants influencing their views on diverse set of utility cost saving systems. Here are the lists of hypotheses (H)that this paper will examine:

H1: People who are more familiar with Smart Home Technology are more likely to implement the technology.

H2: The higher the income level of the participants, the likelihood of implementing smart home technology increases.

H3: Individuals living in detached homes are more likely to implement smart home technology

H4: In deciding whether or not to implement smart home technology, the cost will play the biggest role in comparison to time and reliability of the system.

H5: With the increase of outside temperature, the preferred indoor temperature should decrease and vice versa.

III. LITERATURE REVIEW

To meet the research objectives, the research team has performed a comprehensive analysis of peer-reviewed publications. The literature reviews for this research consisted of an overall 40 different articles and publications. The content of each and every publication was analyzed to ascertain its applicability to the current research work. Therefore, here are the some of the previously published research works that led the research team to pursue the current field of study for the paper.

On the topic of energy consumption, increase in global energy demand, increase in utility costs, and scarce natural resources, many researchers and scholars, including Agarwal at al. (2010) [4], Lu at al. (2010) [5], Reinisch at al. (2011) [1] and many more have published their findings. In their research works, Agarwal at al. (2010) [4], Lu at al. (2010) [5], Reinisch at al. (2011) [1] state that the significant portion of the United States' energy consumption in buildings can be associated to HVAC systems that provide thermal comfort to its occupants. They argue that most HVAC systems employed today run on a fixed schedule and do not have the capacity to automatically adjust its temperature in the absence of the occupants. Furthermore, Mozer (1998) [6] suggests a need for an alternative method in which a home system adjusts itself to accommodate the lifestyle and desires of the occupants.

As a result, Reinish at al. (2011) [1] among many other scholars have proposed a solution by developing a home automation system that operates on an extensive knowledge base, including studying, monitoring and gathering data on the occupant's daily activities. The goals of these systems are to provide energy efficiency and thermal comfort. Additionally, Ivanov, Borodulkin and Ruser (2002) [7] have argued that the utmost goal of such systems, such as smart home automation should be improving the occupant's comfort and security, while reducing overall energy consumption. Subsequently, Ivanov at al. (2002) [7] claims that the subjective perception of thermal comfort and inner air quality within the walls of buildings are influenced by numerous physical parameters, such as room temperature, the corresponding air humidity, air velocity and the CO2 accumulation. Therefore, when constructing smart home systems, these physical and chemical parameters should be taken well in to the consideration.

In 2013, two researchers Mr. Hu and Mr. Li (2013) [8], from the Department of Electrical Engineering and Computer Science from University of Tennessee, have published their NSF funded research work named: "Hardware Design of Smart Home Energy Management System with Dynamic Price Response". In this paper the authors demonstrate the hardware design of smart home management system **(**SHEMS**)** with the utilization of communication systems, sensing technology and

machine learning algorithms. According to the proposed design, consumers can have a real-time, price-responsive management strategy administering different aspects of a home, such as heating, ventilation and conditioning **(**HVAC), dishwasher, washing machine and dryer, electrical water heater and others.

As it was mentioned earlier in the introduction and background section of the paper, today's smart home systems can make decisions based on the activity and decision making patterns of the occupants. Having said that, in 2013 scholars including Nguyen and Aiello (2013) [9] and Yu et al. (200) [10] conducted a survey to analyze how the intelligent buildings respond and adjust based on the behaviors and activities of the occupants. Additionally, the researchers have studied the most valuable activities or behaviors that significantly impact energy saving potential [11], [12], [13], [14]. Thus, they found that smart homes and utility cost saving systems do respond well to the presence and activities of the occupants by adjusting and adapting different features of the home while reducing overall energy consumption [15], [16]. Therefore, based on their simulation outcomes, it shows that intelligent building systems can result in 10-40% on energy saving for HVAC system. In addition, the investigation reveals that occupant's satisfaction level can be improved by employing dynamic HVAC sensors [17]. Moreover, Nguyen and Aiello (2013) [9], Lu et al. (2010) [5] and Barker et al. (2012) [18] argue that many smart energy management system projects are still in the prototype stage, but it will soon enter the market as a viable industrial and broad applications product.

IV. RESEARCH METHODOLOGY

1. Data Collection

Participants of the sample received the URL of the Qualtrics web-based survey system by email, which directed them to online questionnaire. The questionnaire consisted of 28 different questions including informed consent form, which were approved by the Institutional Review Board **(**IRB**)** of Ball State University. The survey participants were required to be older than 18 years old in order to participate in this study.

2. *Data Processing*

The results of the survey were thoroughly analyzed through statistical analysis and simulations using IBM SPSS Statistics 23 software and Quality web-based survey system. Additionally, Microsoft Office was used to view, examine and display the outcomes of the collected data.

3. *Analysis of Results*

In consideration to time and resources limitations 388individuals participated in taking our web-based survey. Some of the participants opted out of responding to some of the survey questions. However, the sample size is sufficiently large comparing to previous studies. Figures below display different demographic information of the participants.

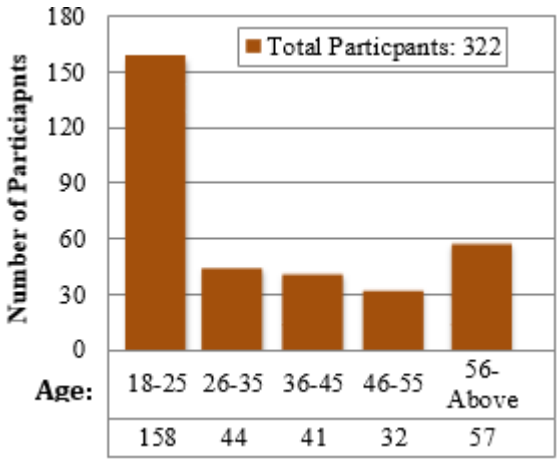

Figure: 1 democratic information: age distribution

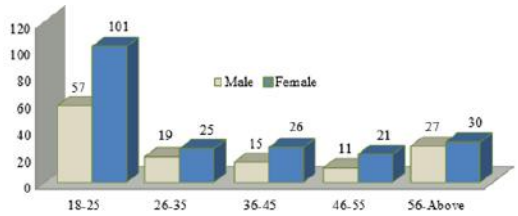

Figure:2 democratic information: Gender distribution

Education Level	Frequency	Sample %
High School	85	26%
2-year of college	45	14%
4-year degree	68	21%
Masters	81	25%
Doctorate	50	15%
Total:	329	100%

Figure 3-Education Level of the Participants

From observing figures 1 and 2, the vast majority of the participants were students from the age of 18-25. A further look at the gender distribution figure it shows that the large portion of the participants is female across all age groups. Figure 3 demonstrates highest level of education earned by the participants. For the question of "In what type of housing do you live in?" 330 participants responded, from which 192

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participants indicated that they live in detached home, 85 in flat or apartments and 53 in dormitories. Looking at figure 4, the majority of the participants live in detached homes across all income groups. Moreover, observing the gathered data there is a pattern that the higher their income level the more people move away from living in apartments and dormitories to detached homes.

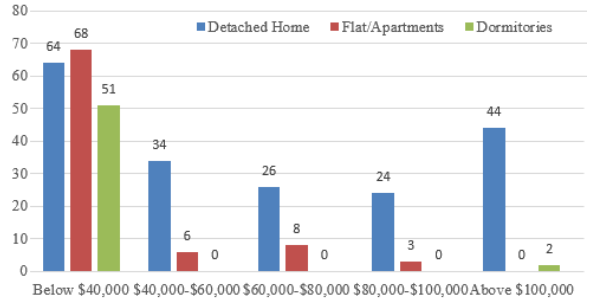

Figure 4-Income and Housing Type Distribution

V. HYPOTHESIS ANALYSIS/RESULTS

The research contains a total of 5 hypotheses (H), which emphasizes on critical aspects of the Smart Home Technology. Each hypothesis is examined and presented in the following sections. According to Rand Europe report [19], by 2020, it is estimated there will be 40 to 50 billion new gadgets and devices will be connected to the Internet. This numbers indicate that individuals are very motivated and optimistic in regards to Internet of Things (IoT), which is the connectivity of Internet to our surrounding objects. The IoT goes far beyond consumer products such as smart watches, phones, self-monitoring refrigerators, cars, washing machines, air conditioners and almost anything else that you can imagine. IoT is a new and more efficient industrial ecosystem concept, which enables smooth transition to the implementation of the Smart Home Technology" [19]. The purpose of IoT is to make our lives easier, safer and more efficient. Our residential properties and buildings are natural fit for IoT. Implementation of Smart Home Technology becomes more accessible and makes monitoring and controlling different aspects of a home a lot easier. Individual parts of a smart home technology such as censors, regulators, etc. are connected to the main database and monitoring system via Internet [20]. With the development of IoT and implementation of the Smart Home Technology "corrective maintenance becomes preventative maintenance to avoid expensive repairs and lost work times [19]". As the Internet of Things converts our physical world in to a digital world, it will guide and help us to understand, foresee, manage and mitigate the risks and issues that rise after implementation of smart home technology in our residential properties by providing and communicating early warning signs to us. As the world of technology constantly moves forward and produces new concepts and developments, enhancing features of a different product it causes the prices of older products to decrease. According to The New York Times (2016) [19], the price of sensors, which are the integral elements of Smart Home Technology have dropped for more than 50 percent during the past decade and the processing costs lessened by more than 60 percent. As the prices continue to drop the likelihood of implementing Smart Home Technology increases.

H1: People who are more familiar with Smart Home Technology are more likely to implement the technology.

According to the gathered data and the survey analysis, there is a strong correlation between people who are familiar with what Smart Home Technology and their likelihood of implementing the technology. Thus, according to this data analysis people who are somewhat to very familiar with the Smart Home Technology concept and are aware of its benefits are more likely to implement the system (See Figure 5). Therefore, increasing public awareness on the subject matter can boost wide spread adoption of the technology.

		Familiarity with Smart Home Technology	Smart Home Technology Implementation
Familiarity with	Pearson Correlation	1	0.353**
Smart Home	Sig. (2-tailed)		0.000
Technology	N	330	328
Smart Home	Pearson Correlation	0.353**	1
Technology	Sig. (2-tailed)	0.000	
Implementation	N	328	330
****. Correlation is significant at the 0.01 level (2-tailed).**			

Figure-5: Correlations between Familiarity of SMHT and Implementation.

H2: The higher the income level of the participants, the likelihood of implementing smart home technology increases.

Our second research hypothesis was that the higher the income level of the participants the more likely people would invest in implementing Smart Home Technology in their homes, however according to our collected data that's not the case. Participants responded "maybe" or "most definitely" to implement Smart Home Technology in disregards to their socio-economic and more

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specifically their income level. Looking at the data, it can be concluded that the smart home technology is perceived and believed to be as a positive boost or add on to any home rather than costly and ineffective system. Therefore, there are no significant correlations between income and implementation of smart home technology (See Figure 6 and 7 for detailed numbers). The systemic seen as an enhancement to a home that will provide an effective way of gaining convenient life style while reducing utility bills.

		Income Level	Implementing SMHT
Income Level	Pearson Correlation	1	-.021
	Sig. (2-tailed)		.716
	N	326	304
Implementing SMHT	Pearson Correlation	-.021	1
	Sig. (2-tailed)	.716	
	N	304	326

Figure 6- Correlations between Income and SMHT Implementation

Figure 7 of the paper shows the income level, number of respondents and their responses to whether or not they could implement Smart Home Technology their residential properties.

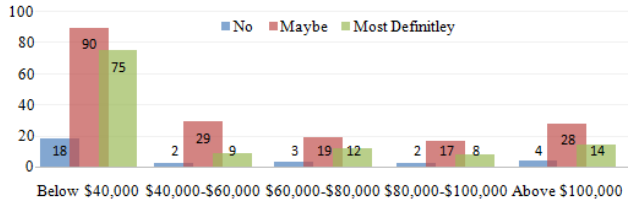

Figure 7-Would You Implement Smart Home Technology?

Types of Housing Living In	No	Maybe	Most Definitely	Total
Detached Homes	19	115	58	192
Flat/Apartments	5	36	44	85
Dormitories	6	31	16	53

Figure 8- Would You Implement Smart Home Technology?

H3: Individuals living in detached homes are more likely to implement smart home technology.

According to the collected data from the survey, 192 individuals living in detached homes, 85 in Flat/Apartments and 53 in Dormitories have responded whether or not they would implement Smart Home Technology. Examining significant correlations between types of housing and would they implement Smart Home Technology there were no significance.

		Types of Housing	SMHT Implementation
Types of Housing	Pearson Correlation	1	.008
	Sig. (2-tailed)		.892
	N	330	306
SMHT Implementation	Pearson Correlation	.008	1
	Sig. (2-tailed)	.892	
	N	306	330

Figure 9-Correlations between Type of Housing and SMHT Implementation

H4: In deciding whether or not to implement smart home technology the cost will play the biggest role in comparison to time and reliability of the system.

Even though 91 percent of the respondents indicated that they maybe or most likely to implement smart home technology in disregards to their current income and socio-economic status, 66 percent of them have specified that when it comes to implementing smart home technology the cost is their number one concern above all other, including, reliability, time and other such as security, which confirms that our hypothesis is correct. Please refer to the figure below for more detailed information (See Figure 10).

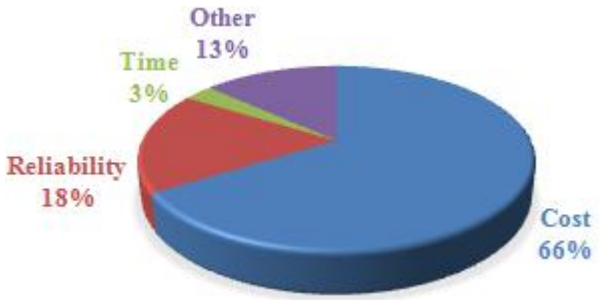

Figure 10-Major Concerns Implementing Smart Home Technology

Now that the paper analyzed some of the major concerns when implementing smart home technology, it is vital for the research to analyze what are some of the outcomes that the research participants would like to get from implementing this technology. Thus, according to the collected data, 68 percent of the survey respondents would like the technology help them to increase their cost saving on utility bills, while 18 percent would like the technology to provide a convenient lifestyle and the other 14 percent would like

to have a remote control and access from anywhere in the world (See Figure 11).

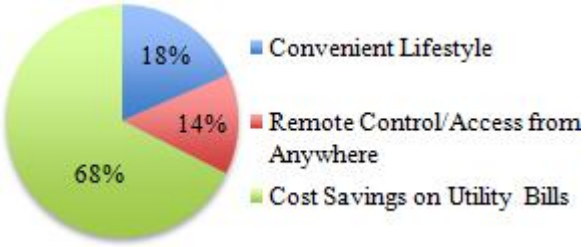

Figure 11-Wanted Outcomes from Smart Home Technology Implementation

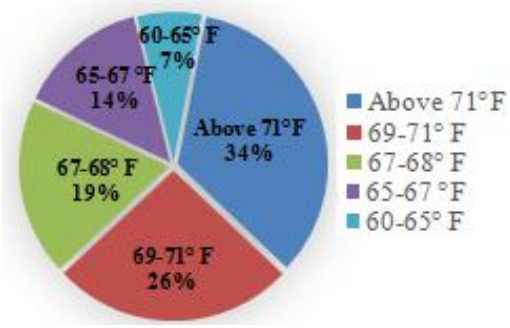

Figure 12-Prefered Set Summer Temperature in Homes

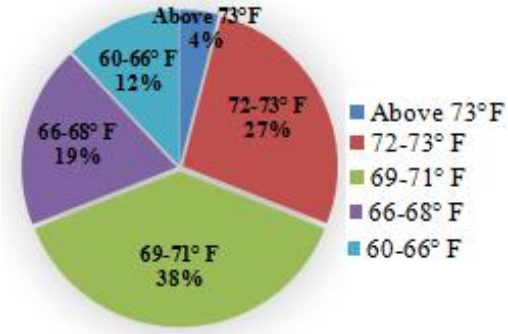

Figure 13-Prefered Set Winter Temperature In Homes

H5: With the increase of outside temperature the preferred indoor temperature should decrease and vice versa.

One of the interesting outcomes that resulted from the study was that the majority of the participants would prefer set temperature of above 71°F in their homes during summer season (see Figure 12). Thus, according to figure 13, that the majority of the respondents would prefer temperature of between 69-71°F during winter season (see Figure 13). These types of result indicate that the individuals are willing to keep their temperature high during the summer and low during the winter in order to keep their utility costs to their affordable level. These types of results indicate the awareness level of people in regards to energy consumption.

V. CONCLUSION

In conclusion, the paper examined the views of Ball State University students, faculty and staff members on smart home technology. Additionally, it determined correlations between different socio-economic characteristics of the participants influencing their views on diverse set of utility cost saving systems. The research methodology employed to attain abovementioned research objectives was comprehensive analysis of peer-reviewed publications. The results of the survey were thoroughly analyzed through statistical analysis and simulations using IBM SPSS Statistics 23 software, Quality web-based survey system and Microsoft Office. The total of 388 individuals participated in taking the web-based survey. The sample size was sufficiently large comparing to the previous studies. The research contained a total of 5 hypotheses (H), which emphasized on critical aspects of the Smart Home Technology. According to the gathered data there was a strong correlation between people who were familiar with the technology they were more likely to implement the system. Therefore, increasing public awareness on the subject matter could boost wide spread adoption of the technology. The survey participants responded “maybe” or “most definitely” to implement Smart Home Technology in disregards to their socio-economic status. Hence, 68 percent of the survey respondents would like the technology help them to increase their cost saving on utility bills, while 18 percent would like the technology to provide a convenient lifestyle and the other 14 percent would like to have a remote control and access from anywhere in the world. However, even though 91 percent of the respondents indicated that they would implement smart home technology in disregards to their current income and socio-economic status, 66 percent of them have specified that when it comes to implementing smart home technology the cost would their number one concern above all other, including, reliability, time and other such as security. Lastly, one of the interesting outcomes of the study showed that the majority of the participants would prefer set temperature of above 71°F during the summer seasons and temperature of between 69-71°F during the winter seasons. These types of results are the indicators of peoples’ awareness in regards to energy consumption. After completing the study, the research teams recommend a further study of investigating capital and running cost of various smart home applications for residential properties.

Furthermore, the team suggests an optimal system and provide recommendations on how residents should choose their system that suits best with their needs.

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