Decision Model for the Features of a Smart House

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1. Introduction

Smart house is one of the best solutions today in the market because it helps users to manage their activities by using special programs to automate electronic home devices [1]. The smart house began in the twenty century by inventing home appliances. The vacuum cleaner was the first to invent and after that followed to sewing machine, food processors, refrigerator, and washing machine. In 1939, popular mechanics magazine helped users to know the modern technology and think about the future from describing modern cocking device. After that in 1966, the first home computer ECHO IV was invented [2]. When people know the importance of these modern appliances, the demand is increased on these appliances, and that led to more research and more development in smart house. Nearly 2000, smart house began to develop quickly because different kinds of technology started to emerge together that help technology to spread and user began to demand of smart product. In 2013, Microsoft showed in the market a lab of thing to help researchers to discover different kinds of smart house appliance [3]. Today, smart house uses many applications such as remote mobile control, control lighting, manage video surveillance, etc.

As the demand of smart appliances increased and with a variety of smart products in the market that do many tasks and make everything in the house easy to use, and that confuse the users and make it difficult for them to choose the right products that they really need inside their smart houses. Hierarchical decision model (HDM) is one of the technique that help users to take the right decision easily in choosing what features that they need. So we made more researches on each feature to have more information and understand each feature and how it effects on smart house work. We used pairwise comparison to evaluate each feature from experts who answered our survey. The decision of the features of a smart house is a complicated process because many experts have many ideas and different opinions.

In this paper, we reached the preference features through applying pairwise comparison to decision making. We used a simple tool which is helping to recognize the features of smart house. HDM is used to simplify a large number of options.

2. Literature Review

Smart houses become very popular in the recent years because the demand of the appliances is increased, and more information needs to pass these challenges and make it easy to use. Smart houses consider one of the best standard systems because it connected with smart devices to give awareness and intelligent, so it can supply the best service to users. Smart house made for making the life more convenient, comfort, intelligence, energy efficiency, and security [4].

http://www.micropcrepair.com/control-4/

Smart house systems consist of smart appliances, and these appliances have smart card and the frame of the smart card contains sensor, digital meter, micro controller, and LAN card. The sensor is the device that gives the consumption power and determines current status. Digital meter explain the consumed unit of electric and cost. Micro controller is managing equipment that runs the flow of the electric. LAN card is linking equipment having Ethernet port that use to join together smart meter and smart card through twisted pair cable [5].

Users' use technology for installing smart home communication, and they need Z-Wave, X10, Insteon and ZigBee to implement the technology. Z-Wave is the fastest way to send the message that comes from using a Source Routing Algorithm. X10 participates short radio frequency that enables activation between transmitter and device. Insteon is similar to electrical line, and the user may have an interface and at the same time using a wireless network to support more flexibility for placing instrument. ZigBee explains the mesh networking concept since the signal comes from the transmitter zig zag similar to bees searching for the best way to the receiver. Many examples about implementing these technologies in the home such as Cameras, video door phone provides more than a doorbell, Door handles can open with scanned fingerprints, Audio systems distribute the music, Channel modulators take any video signal, and Remote controls [6].

A lot of applications today apply in smart house, and researchers and industrial try to make all appliances participated in the smart house by making network of appliances which is connected together when they see the benefit from that, and users today is more willing to make all instrument inside and outside the home work under the system of the smart house and take the advantage from that such as smart house will give you notification what going on and security system can make to supply an immense amount of support in an emergency. Smart house also supports senior people who don't have ability to manage their activities without taking support from other people such as it alarm them to take medicine without remind from others, alarm the hospital if the user fell and track how much they was eating. Smart houses help seniors who are forgetting to do their job like turn off the stove if the cook is ready. Also, Smart house can assist senior people through using intelligence appliance that helps to leave nurse and doing their activities alone because these intelligent interfaces observe their movements and learn to understand their habits. If these appliances notice any strange behavior from them, it will send an alarm to medical facilities because smart house supplies with artificial intelligence that will notice any dangerous message and transfer this alarm to medical emergency immediately [6].
Users need to build smart house as they see the demand of electricity become very high and power plant cannot supply all electricity when they need it. Although houses don't have a big effect on electricity consumption, but if we have millions of houses how to solve this problem. In addition, the cost of electricity increased quickly in the last few decades. All of these factors contributed to use smart grid, Users begin to use automated metering infrastructure in the house smart meters up to the individual appliance through supplying enough real time information to end-user related to decision on electricity consumption. Smart house architectures help to reduce carbon emission, depend on renewable energy such as wind turbine, solar panel, and reduce the electricity bill because in the architecture contain a set of sensors and actuators to

measure and control electricity consumption. So users need to make a connection between smart house and smart grid with the support of (ICT) that lead to distribute electricity with more efficient and cost effective way [7].

Smart houses are beneficial to people who is working for a long time. With increasing difficulties in the life and sometime the requirement to live comfortably become very expensive, people work hard to gain their financial aims and personal, and that lead to people become stressed and unwilling to do anything when they finished their work and returned to their home. Many researchers have found that people who work with stress lead to health problems. Smart house is the best solution to this problem and using the automated light system has a big effect to minimize the stress. It has the capacity to manage lighting condition automatically. Many appliances used today to automate electronic and light control such as Savant lighting control, Demo Eazy system, InelliSwitch and Green Room System. These appliances with some electronics companies like Panasonic and Samsung manage their home devices. The system Eye 2H, an intelligent system is the solution that describes the process and facial expression to discover human expression to manage electronic and lighting equipment in their home [8].
Although all of these benefits from the application of smart house, many people don't have ability to use it because it is very expensive compared with smart product, and it needs more work to make it adaptable to what you need, and the costs reached will not be expectable [9]. Also, smart houses don't have a wireless system that works perfectly because sometime wireless signal interrupt with other electronic products that lead to stop working together as the work becomes very complex when adding more appliance in the system [10]. Smart houses also have limitation, and it doesn't have ability to manage large equipment together in the system, and some instruments go out the system because there are specific to the number of sensors [11][12]. Also, smart home is modern technology, and users can manage their appliance through iPhone, iPod, etc. because it is easy to use through touch (fingerprint), but if these instruments lost that lead to make your home exposure to steal from others because from these instruments thieves can control the safety of their home [9].

3. Methodology

A Hierarchical Decision Model (HDM) is a systematic approach or a conceptual tool that is used to help a decision maker to apply a rational decision. It is broke a big complex decision problem down into simple sub problems, and after that gives a way to consolidating all straightforward arrangements into a thorough result. It is also efficient for decreasing bias by constraining decision maker to consider the diverse criteria involved in the choice autonomously. These autonomous estimations are made through pairwise comparisons; each element have compared with every other element to select its relative weight, and checked for consistency. A substantial set of examinations is exceptionally reliable when component weights remain relatively comparative when compared with the others.

Those procedures for creating an HDM need a couple essential steps. Those to start with step will be with select the main criteria. This set about criteria ought to be restricted to the practically impactful set from claiming important qualities acknowledged previously, making the choice. Every component in the situated sub-criteria that point a chance to be broken down under constituent sets of sub-criteria, alternately a set from claiming quantitative qualities that speak to those go of substantial qualities for the individuals criteria. Following the model may be developed, people dubbed likewise ‘experts’ address the model toward giving work to weights about relative importance for each of the qualitative also quantitative criteria similarly as they would contrasted with their companions. Components during each level are the main contrasted with different components In that same level [13].

Over acknowledging attributes, we main examined every last one of separate approaches Smart House might make sorted and measured. There were an astonishing amount about accessible criteria, and we rapidly decided that we might need on farthest point the extension of the model should a little situated of key qualities. Despite the fact that An that's only the tip of the iceberg complete suited for criteria might empower us will judge the middle of refined nuances from claiming individual’s preferences, we controlled that these contrasts might a chance to be overwhelmed toward the all the more significant criteria, making our model unnecessarily intricate without moving forward those choice.

This might have been an restricting variable when creating our model, as a portion of the features initially acknowledged were not accessible for constantly on features of smart house decisions. Comprehending that model might have been reasonably direct much appreciated to PCM programming [13] provided by the Portland State University ETM department [14]. The model might have been optimized toward setting more level what's more upper limits of safety,

convenient, environment, and intelligent, what is more restricting determination of the four practically prevalent alternatives on preferred features of smart house. Once those model might have been complete, it might have been uploaded of the HDM software, important criteria and qualities were associated, and the URL might have been given to the less group will address.

Features of Smart House were committed to determine that relative importance for each criterion. The point when we apply this examination we dependably the opinion of the experts. In this case, people are our experts because they are involved in the selection of the real features, which they prefer in their home smart future. This principal venture is with create a questionnaire on be given of the masters. That point the correlations are gone through those “PCM” programming project. Finally, the relative weight of every paradigm will be assessed should observe its imperativeness.

Our ultimate goal quantifies both subjective what's more goal estimation for every characteristic of the alternatives. This venture evaluates every elective in light of its qualities (or attributes) for those admirations to the relative vitality of the destination of the model. The utility bend is constructed by the experts In light of their individual inclination. A questionnaire might have been formed to catching those experts’ assumption in place to develop those utility curves.

4. Problem Definition

Deciding to buy a house is an essential financial decision people made during their lifetime. They take in their considerations many factors such as the cost, neighborhood, schools around and the house's design. People take long time to find the design they want for their own dream home. One option is buying a smart house. There are many benefits in having a smart house, but the most benefit is fitting the contemporary lifestyle. However, buying a smart house with its all features could be a very expensive and out of budget for middle-class people [16]. Therefore, people are willing to give up some features in order to buy affordable smart house.

The goal of this project is to determine the most favorable features that people desire in smart houses. In other words, this project proposes a typical smart house that is affordable for most middle-class individuals.

5. Identification of Objectives and Features

In this project, the mission is to determine the most favorable features in a smart house. To satisfy this mission, there are four objectives, which are safety, convenience, environment, and intelligence. Under each objective, there are several goals to fulfill each objective.

The first objective is safety. Because of the rise number of crime on nowadays including robbery and theft [17], people want a strong security system that keeps their families inside the house safe. Now, there are many devices or systems in the market can be used for safety purpose. This category contains devices for entrance security, fire alarm, children monitors, and surveillance. The second objective is convenience. There are many devices or systems to make people easier. These devices can be divided into four categories: lighting, Wi-Fi, Disparities' Assistance, and Entertainment. The third objective is environment. In this objective, there are many devices that help to reduce environmental damages. These devices can be divided into three categories, which are sprinkling, solar energy, and trash recycles. The last one is intelligence. This objective helps people living in a house where they can take benefit of the current advances in technology. HAVC, motorized drapes, appliances, and smart faucet are devices that fulfill the intelligence objective [18].

The following table summarizes the features and their definitions [6] [19].

Safety	
Entrance	Devices are installed on entrances, such as camera and sensors, to identify comers and protect home form breaking in.
Fire/CO gas alarm	Devices are installed inside the home to detect the presence of fire or carbon monoxide.
Children monitor	Devices are installed inside children's room to monitor them and notify the parents if there is something unusual happened.
Surveillance	Devices are installed inside the house to observer the unusual moves.
Convenience	
Lighting	Sensors are installed inside the house to switch the light on and off depending on the presence of people in the place.
WiFi	This item helps to setup the equipment and you can control it by IOS or Android device. And you control the equipment from anywhere in the world. Also, it becomes easily to control wall switches, lamp, and

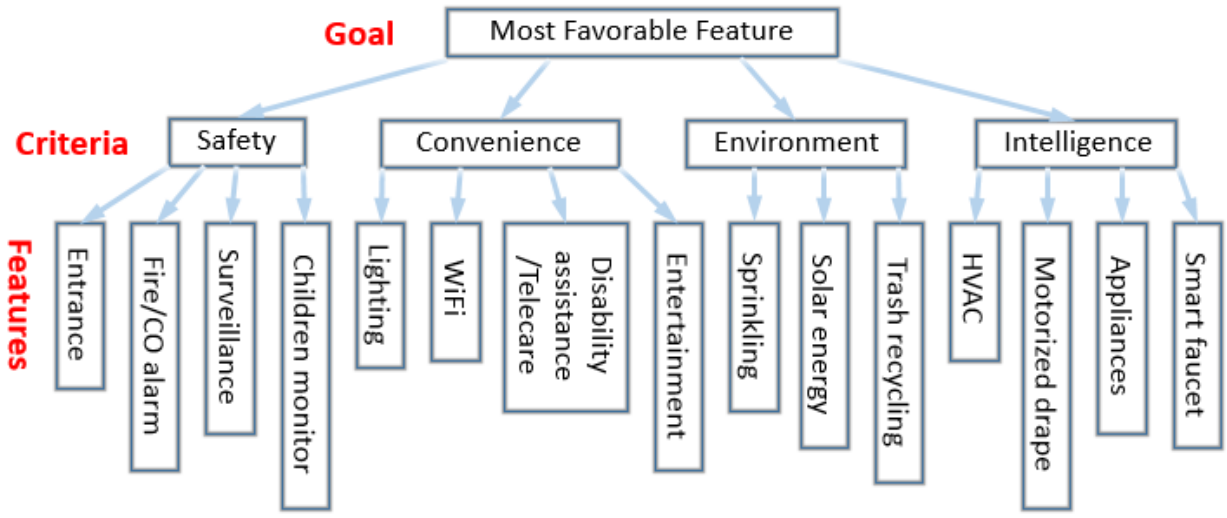
	garage door.
Disability assistance / Telecare	Disability assistance/Telecare: this item help doctor to see senior who are disabilities by implanted device, and also it helps senior for activities of daily living assist devices for eating and drinking.
Entertainment	Distribute music from one location throughout your entire home with a whole-home distribution system, and control speaker volume in each room individually or all at the same time
Environment	
Sprinkling	This smart sprinkler controller optimizes watering schedules based on soil moisture and weather predictions.
Solar energy	Solar power is the best possible way save energy. You can cover an especially large portion of your energy needs and gain greater independence, for example from rising energy costs.
Trash recycling	A Sensor Recycling Trash System helps keep garbage and recycling materials separate.
Intelligence	
HVAC	A Heating, Ventilation, and Air-Conditioning (HVAC) system to help maintain good indoor air quality through adequate ventilation with filtration and provide thermal comfort.
Motorized drape	Press a button on your wireless wall switch or hand-held remote control and the motorized curtains open smoothly and quietly
Appliances	A domestic device or piece of equipment designed to perform a specific task, such as electrical and gas appliances
Smart faucet	The faucet is equipped with smart and intelligent features and programmable through simple touch to preset the ideal temperature of water and control the usage, making it an environmentally responsible.

6. Implementation and Result

7.1 Data Gathering

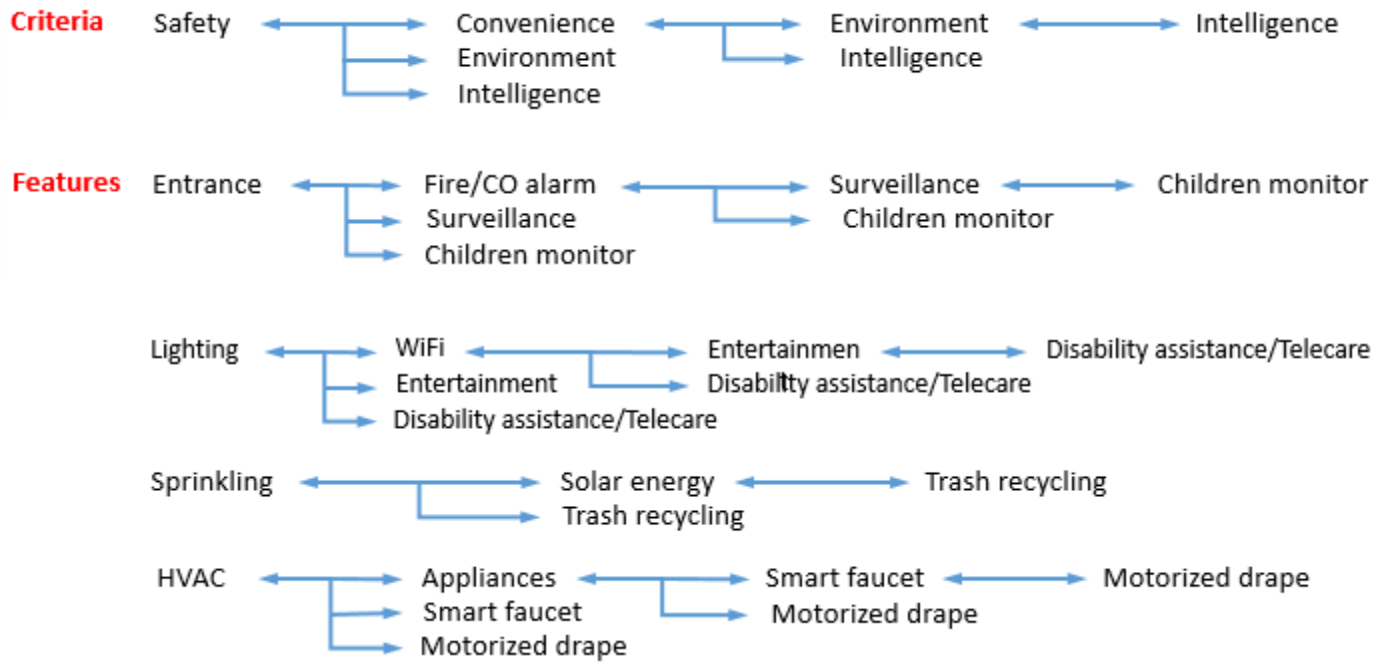
A questionnaire (refer to Appendix A) had been used to collect the expert opinions for relative importance of each level in hierarchical decision model (HDM). The features of a smart house are defined literally with supplementary pictures as a consistent reference for expert panel when they respond the survey. There are four criteria which are considered to be most concerned by a potential smart house buyer, safety, convenience, environment, and intelligence. For every criterion, several representative features are listed. Though not all features of a smart house are included, this module provides a compressive assessment to demonstrate a feasible method in deciding the most favorable features which can be employed to accelerate the flourish of the smart house market.

Figure 1. The hierarchical decision model diagram for selecting the most favorable feature of a smart house



These features were compared with a pairwise comparison method (PCM) in a three level hierarchical decision model. The questionnaire was developed for the survey. Its result was based on the decision model and input from the expert panel. The expert allocates a total of 100 points to the two elements in the proportion of their relative importance to the immediately upper level in the HDM diagram.

Figure 2. The mechanism of expert questionnaire with the pairwise comparison method



7.2 Outcome Analysis

The relative importance rating (weight) of each feature contributes to the most favorable smart house then be calculated. Though the expert panel members may not have expertise in all the features listed in the questionnaire, they are treated as potential buyers of the smart house. Among 18 survey enquiries, 15 experts had completed and submitted their respondence. The result of the comparison is quite concordant and the disagreement is only 0.04. Meanwhile, the individual inconsistencies of expert panel are distributed over an acceptable range from 0.00 to 0.08.

The outcome analysis demonstrates a human essential demand for the living safety beyond other criteria. As to the feature level, there is no a prominent item among them. The fire/CO gas alarm and children monitor are somewhat with higher weight than the others. It should be contributed by the safety concerns.

Table 1. Overall view of the weights for the criteria and features

Goal, Criteria, and Feature	Weight (Criterion to Goal)	Weight (Feature to Criterion)	Final Weight (Feature to Goal)
The most Favorable Feature			
Safety	0.40		
Entrance		0.21	0.08
Fire/CO gas alarm		0.34	0.14
Surveillance		0.19	0.08
Children monitor		0.25	0.10
Convenience	0.20		
Lighting		0.21	0.04
WiFi		0.34	0.07
Disability assistance / Telecare		0.22	0.04
Entertainment		0.23	0.05
Environment	0.16		
Sprinkling		0.30	0.05
Solar energy		0.29	0.05
Trash recycling		0.41	0.06
Intelligence	0.24		
HVAC		0.27	0.07
Motorized drapes		0.20	0.05
Appliances		0.29	0.07
Smart faucet		0.24	0.06
Disagreement		0.04	

A numerical analysis of the preferences among different customer segments was also made base on the characteristics of expert panel to identify their influence on decision making. These characteristics are

- Gender
- Matrimony -- married or single
- Kid -- with or without kid (less than 18 years old)
- Estate -- own or lease a house
- Age -- 20~30, 31~40, 41~50, over 50
- Education – high school, undergraduate, master, PhD
- Nationality

In the study, we analyze one characteristic at a time. The conjunction among characteristics such as a married man with kids are not discussed in this paper. Neither the psychological factors behind the results, i.e. why experts made their choices while doing the comparison.

Table 2 and 3 and Chart 1, an analyzing the input from experts shows there is no divergence in the demand for safety from people of different characteristics. The safety objective is either the first choice or the second one for all experts

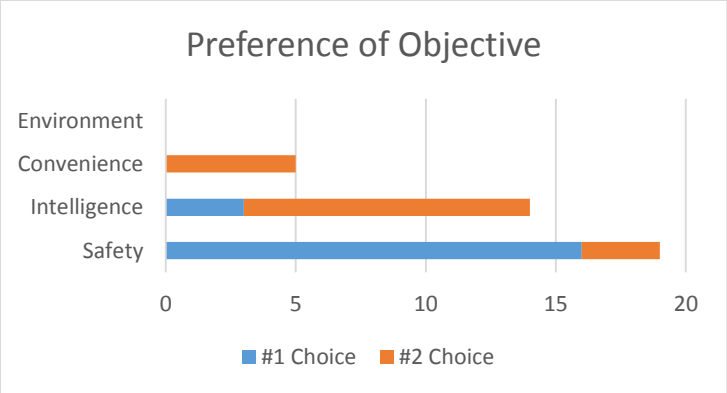
Table 2. The preference of objective for different characteristics of expert

Characteristic of Expert		Preference of Objective	
		#1 Choice	#2 Choice
Gender	Female	Safety	Intelligence
	Male	Safety	Intelligence
Matrimony	Single	Intelligence	Safety
	Married	Safety	Intelligence
Kid	w/o kid	Safety	Intelligence
	with kid	Safety	Intelligence
Estate	Lease	Safety	Intelligence
	Own	Intelligence	Safety
Age	21~30	Safety	Intelligence
	31~40	Safety	Convenience
	41~50	Safety	Intelligence
	51~	Safety	Convenience
Education	PhD	Safety	Convenience
	Master	Safety	Intelligence
	Bachelor	Safety	Intelligence
Nationality	China	Safety	Convenience
	Iraq	Safety	Convenience
	Saudi	Intelligence	Safety
	Taiwan	Safety	Intelligence

Table 3. The choice of objective made by experts

Preference of Objective		
	#1 Choice	#2 Choice
Safety	16	3
Intelligence	3	11
Convenience	0	5
Environment	0	0

Chart 1. The choice of objective made by experts



This result reveals the preference of potential consumers clearly. People expect smart house can provide them a safer home and other fuzzy functions should only build on it. They willing to pay more for safety features while within a limited budget. As its name, people are also looking forward to the intelligence that a smart house to possess. The safety and intelligence represent almost 85% of requirement from customers.

In order to deeper understand the consumers' prospect from feature aspect, we dissected data of features and refer them to each characteristic of experts. As expect, the features in safety objective were counted mostly as the top choice. Experts of almost every characteristic regard Fire/CO gas alarm as their highest priority. And the other safety features share a major portion the rest attention as shown in Table 4 and 5 and Chart 2.

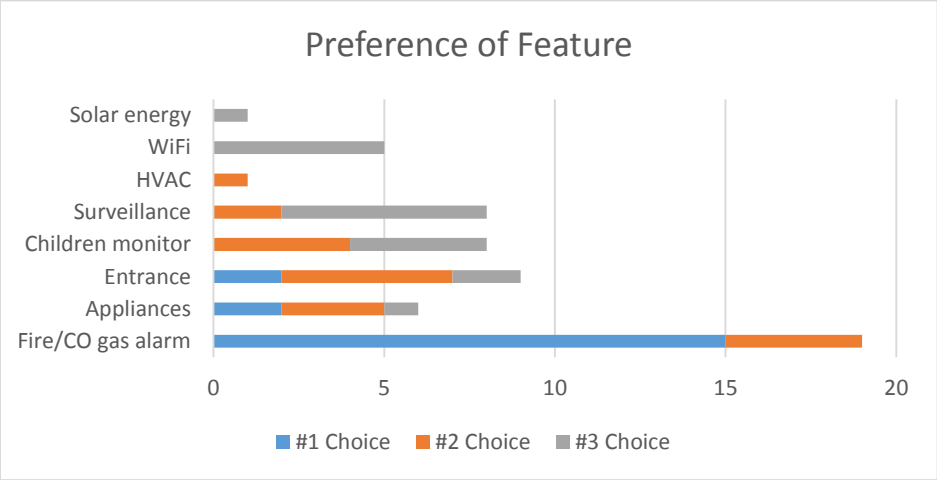
Table 4. The preference of feature for different characteristics of expert

Characteristic of Expert		Preference of Feature		
		#1 Choice	#2 Choice	#3 Choice
Gender	Female	Entrance	Fire/CO gas alarm	Surveillance
	Male	Fire/CO gas alarm	Children monitor	Entrance
Matrimony	Single	Fire/CO gas alarm	Appliances	WiFi
	Married	Fire/CO gas alarm	Entrance	Surveillance
Kid	w/o kid	Fire/CO gas alarm	Appliances	WiFi
	with kid	Fire/CO gas alarm	Entrance	Children monitor
Estate	Lease	Fire/CO gas alarm	Entrance	Surveillance
	Own	Appliances	Fire/CO gas alarm	WiFi
Age	21~30	Fire/CO gas alarm	Appliances	Children monitor
	31~40	Fire/CO gas alarm	HVAC	Solar energy
	41~50	Fire/CO gas alarm	Children monitor	Entrance
	51~	Fire/CO gas alarm	Entrance	Surveillance
Education	PhD	Fire/CO gas alarm	Surveillance	Children monitor
	Master	Fire/CO gas alarm	Children monitor	WiFi
	Bachelor	Fire/CO gas alarm	Entrance	Appliances
Nationality	China	Fire/CO gas alarm	Surveillance	Children monitor
	Iraq	Fire/CO gas alarm	Children monitor	Surveillance
	Saudi	Appliances	Fire/CO gas alarm	WiFi
	Taiwan	Entrance	Fire/CO gas alarm	Surveillance

Table 5. The choice of feature made by experts

Preference of Feature			
	#1 Choice	#2 Choice	#3 Choice
Fire/CO gas alarm	15	4	0
Appliances	2	3	1
Entrance	2	5	2
Children monitor	0	4	4
Surveillance	0	2	6
HVAC	0	1	0
WiFi	0	0	5
Solar energy	0	0	1

Chart 2. The choice of feature made by experts



Nevertheless, if we segregate those safety features, the outcome presents a diverse preference in other features. Table 6 and 7 and Chart 3 demonstrate a noticeable conclusion. Although the demand for WiFi is higher than the others, but it does not stand out in the first choice. More experts take appliances as their most concerned item then.

People expects a smart house can provide an advanced protection from detecting and reacting automatically to a possible mishap. The Fire/CO gas alarm system has already been a standard feature in a modern house. However by connecting it with the intelligent appliances, once a fire alert is detected, system can command the source facility to take preventive actions, such as shut down the furnace or turn down the stove.

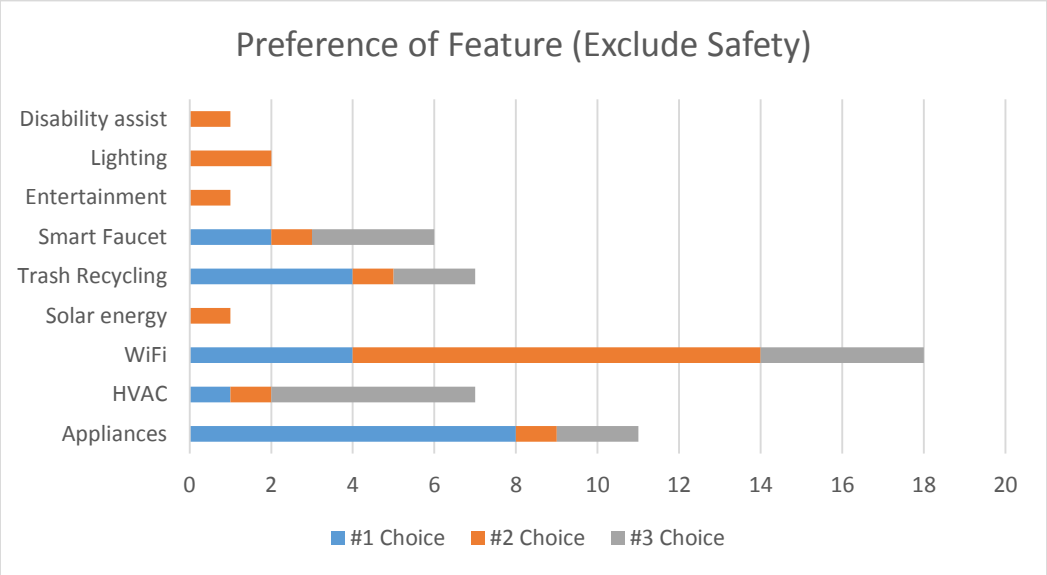
Table 6. The preference of feature (exclude safety objective) for different characteristics of expert

Characteristic of Expert		Preference of Feature (Exclude Safety Objective)		
		#1 Choice	#2 Choice	#3 Choice
Gender	Female	Appliances	WiFi	Smart Faucet
	Male	Appliances	WiFi	Trash Recycling
Matrimony	Single	Appliances	WiFi	Motorized drapes
	Married	WiFi	Appliances	Trash Recycling
Kid	w/o kid	Appliances	WiFi	HVAC
	with kid	Trash Recycling	WiFi	Smart Faucet
Estate	Lease	Trash Recycling	WiFi	Smart Faucet
	Own	Appliances	WiFi	HVAC
Age	21~30	Appliances	WiFi	HVAC
	31~40	HVAC	Solar energy	WiFi
	41~50	Trash Recycling	Smart Faucet	Appliances
	51~	WiFi	Entertainment	Sprinkling
Education	PhD	Smart Faucet	Lighting	WiFi
	Master	WiFi	Trash Recycling	Motorized drapes
	Bachelor	Appliances	WiFi	HVAC
Nationality	China	Smart Faucet	Lighting	WiFi
	Iraq	Trash Recycling	Disability assistance / T	WiFi
	Saudi	Appliances	WiFi	HVAC
	Taiwan	WiFi	HVAC	Appliances

Table 7. The choice of feature (exclude safety objective) made by experts

Preference of Feature (Exclude Safety)			
	#1 Choice	#2 Choice	#3 Choice
Appliances	8	1	2
HVAC	1	1	5
WiFi	4	10	4
Solar energy	0	1	0
Trash Recycling	4	1	2
Smart Faucet	2	1	3
Entertainment	0	1	0
Lighting	0	2	0
Disability assist	0	1	0

Chart 3. The choice of feature (exclude safety objective) made by experts



The calculated features' weight for different characteristics of expert are listed in Appendix B.

7. Conclusion:

The smart house is a highly customized merchandise. How to catch the favorite features of potential customers is always the top challenge for the service providers. A customers' preferences of the smart house have been summarized from analysis in this research. The smart house constructors, investors or component developers can make their business decision based on this information

- People expect smart house can provide them a safer home
- Integrate intelligent facilities to generate a more comfortable living space
- WiFi is an essential demand for people interest in a smart house

Also the outcome of this report will be helpful in understanding the inclination of customers of specific characteristics if the businessmen try to concentrate on a target market. It will help developers to focus more on things that are really important rather than wasting precious resources on something that is perceived irrelevant by customers.

8.1 Limitations

When we made our survey, we chose people who are highly educated such as bachelor, master, Ph.D., because smart house is new in the market and to answer our survey, they must have big background that help us to receive more accurate answers because if we send message to anyone, we cannot take accurate information compared with high educated people. As our project not famous in the market, we sent clarifications to each feature with our survey to make it clear when they answer it. Also, we chose international students because we will obtain variety in answers and opinions.

As we mention in the introduction the demand of smart products increased nearly in 2000 and after that time the company's update and launched new products in the market every year, so users become unwilling to old product editions. Also, we collect our information from the survey; each one has preferring particular features.

The cost of smart house is different from one to another so we didn't put it in consideration because the variety of smart product and for the same feature many models and brands of the company and what is the more willing in the market and what is the less important. All these factors for ten weeks work project lead to inaccurate information so we ignore the cost for these reasons.

8.2 Future Works

There are many features that can be considered in building Smart House so we must add more features in the hierarchy to obtain more information and to prevent any bias that can happen. We divided the objective to four parts: safety, convenience, environment, and intelligence we ignore saving energy and put solar energy under environment, but we must put saving energy as an objective and put inside it many features like thermostat, lighting, shading, celling fan, and solar energy.

Also, we see the final weight is 0.4 for safety, 0.25 intelligence, 0.20 convenience, and 0.15 environment. If we compare the result between safety and convenience, we see a big differences so we need more convenience analyze to see if there is any difference or change.

As we mention in the beginning, we collect our survey from international students and highly graduated and they are nearly the same age and we see our survey focus on safety while convenience in the third rank, so in the future, researchers must focus on making the survey and ask the senior people as we notice in literature review senior people prefer convenience more than safety.

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Appendix

Appendix A. The questionnaire in survey form used to gather experts' opinion

Compare these objectives with respect to their contribution to the mission

		Total 100 points				Total 100 points		
Objectives	Safety			Convenience	Convenience			Environment
	Safety			Environment	Convenience			Intelligence
	Safety			Intelligence	Environment			Intelligence

Compare these features with respect to their contribution to the objective – safety

Features of Safety	Entrance			Fire/CO alarm	Fire/CO alarm			Surveillance
	Entrance			Surveillance	Fire/CO alarm			Children monitor
	Entrance			Children monitor	Surveillance			Children monitor

Compare these features with respect to their contribution to the objective – convenience

Features of Convenience	Lighting			WiFi	WiFi			Disability assistance/Telecare
	Lighting			Disability assistance/Telecare	WiFi			Entertainment
	Lighting			Entertainment	Disability assistance/Telecare			Entertainment

Compare these features with respect to their contribution to the objective – environment

Features of Environment	Sprinkling			Solar energy	Solar energy			Trash recycling
	Sprinkling			Trash recycling				

Compare these features with respect to their contribution to the objective – intelligence

Features of Intelligence	HVAC			Motorized drape	Motorized drape			Appliances
	HVAC			Appliances	Motorized drape			Smart faucet
	HVAC			Smart faucet	Appliances			Smart faucet

Appendix B. The features' weight for different characteristics of expert

Mission, Objective, and Feature	Female	Male	Difference
The most Favorable Feature	Average		
Safety	0.3980	0.4000	0.0020
Entrance	0.1203	0.0784	0.0419
Fire/CO gas alarm	0.1076	0.1482	0.0406
Surveillance	0.0964	0.0774	0.0190
Children monitor	0.0736	0.0960	0.0224
Convenience	0.1860	0.2110	0.0250
Lighting	0.0360	0.0388	0.0028
WiFi	0.0834	0.0745	0.0089
Disability assistance / Telecare	0.0366	0.0416	0.0050
Entertainment	0.0300	0.0561	0.0261
Environment	0.1100	0.1600	0.0500
Sprinkling	0.0272	0.0419	0.0147
Solar energy	0.0465	0.0509	0.0044
Trash recycling	0.0363	0.0673	0.0310
Intelligence	0.3060	0.2290	0.0770
HVAC	0.0667	0.0621	0.0046
Motorized drapes	0.0744	0.0409	0.0336
Appliances	0.0868	0.0759	0.0109
Smart faucet	0.0781	0.0501	0.0280

Mission, Objective, and Feature	Single	Married	Difference
The most Favorable Feature	Average		
Safety	0.3250	0.4264	0.1014
Entrance	0.0441	0.1100	0.0659
Fire/CO gas alarm	0.1390	0.1331	0.0059
Surveillance	0.0439	0.0982	0.0543
Children monitor	0.0980	0.0851	0.0129
Convenience	0.2100	0.2000	0.0100
Lighting	0.0266	0.0419	0.0153
WiFi	0.1028	0.0683	0.0345
Disability assistance / Telecare	0.0350	0.0417	0.0068
Entertainment	0.0457	0.0481	0.0024
Environment	0.1000	0.1591	0.0591
Sprinkling	0.0300	0.0395	0.0095
Solar energy	0.0253	0.0582	0.0330
Trash recycling	0.0448	0.0614	0.0166
Intelligence	0.3650	0.2145	0.1505
HVAC	0.0852	0.0558	0.0294
Motorized drapes	0.0863	0.0396	0.0466
Appliances	0.1290	0.0615	0.0674
Smart faucet	0.0646	0.0575	0.0070

Mission, Objective, and Feature	w/o kid	with kid	Difference
The most Favorable Feature	Average		
Safety	0.3880	0.4050	0.0170
Entrance	0.0788	0.0992	0.0204
Fire/CO gas alarm	0.1496	0.1272	0.0224
Surveillance	0.0748	0.0882	0.0134
Children monitor	0.0848	0.0904	0.0056
Convenience	0.2000	0.2040	0.0040
Lighting	0.0238	0.0448	0.0210
WiFi	0.1008	0.0658	0.0350
Disability assistance / Telecare	0.0369	0.0414	0.0045
Entertainment	0.0384	0.0519	0.0135
Environment	0.0920	0.1690	0.0770
Sprinkling	0.0260	0.0424	0.0164
Solar energy	0.0272	0.0606	0.0334
Trash recycling	0.0388	0.0660	0.0272
Intelligence	0.3200	0.2220	0.0980
HVAC	0.0738	0.0586	0.0152
Motorized drapes	0.0718	0.0422	0.0296
Appliances	0.1205	0.0590	0.0615
Smart faucet	0.0539	0.0622	0.0083

Mission, Objective, and Feature	Lease	Own	Difference
The most Favorable Feature	Average		
Safety	0.4260	0.3460	0.0800
Entrance	0.0926	0.0920	0.0006
Fire/CO gas alarm	0.1503	0.1034	0.0469
Surveillance	0.0917	0.0677	0.0240
Children monitor	0.0914	0.0828	0.0086
Convenience	0.2010	0.2060	0.0050
Lighting	0.0414	0.0307	0.0108
WiFi	0.0678	0.0968	0.0290
Disability assistance / Telecare	0.0450	0.0298	0.0152
Entertainment	0.0468	0.0487	0.0020
Environment	0.1660	0.0980	0.0680
Sprinkling	0.0365	0.0378	0.0013
Solar energy	0.0571	0.0341	0.0230
Trash recycling	0.0724	0.0261	0.0463
Intelligence	0.2070	0.3500	0.1430
HVAC	0.0510	0.0890	0.0381
Motorized drapes	0.0407	0.0747	0.0340
Appliances	0.0569	0.1248	0.0679
Smart faucet	0.0584	0.0615	0.0031

Mission, Objective, and Feature	21~30	31~40	41~50	51~	Difference
The most Favorable Feature	Average				
Safety	0.3900	0.3300	0.4100	0.4600	0.1300
Entrance	0.0825	0.0825	0.0986	0.1326	0.0501
Fire/CO gas alarm	0.1430	0.0990	0.1134	0.1470	0.0480
Surveillance	0.0781	0.0660	0.0944	0.1017	0.0357
Children monitor	0.0863	0.0825	0.1037	0.0787	0.0250
Convenience	0.2000	0.2500	0.1667	0.2450	0.0833
Lighting	0.0256	0.0700	0.0575	0.0473	0.0444
WiFi	0.0828	0.0800	0.0552	0.0856	0.0304
Disability assistance / Telecare	0.0438	0.0350	0.0228	0.0507	0.0279
Entertainment	0.0478	0.0650	0.0311	0.0614	0.0339
Environment	0.1244	0.2000	0.1800	0.1450	0.0756
Sprinkling	0.0276	0.0660	0.0395	0.0609	0.0384
Solar energy	0.0429	0.0840	0.0586	0.0479	0.0411
Trash recycling	0.0540	0.0500	0.0819	0.0363	0.0457
Intelligence	0.2856	0.2200	0.2433	0.1500	0.1356
HVAC	0.0661	0.0924	0.0555	0.0504	0.0420
Motorized drapes	0.0607	0.0374	0.0483	0.0261	0.0346
Appliances	0.0959	0.0374	0.0686	0.0432	0.0585
Smart faucet	0.0628	0.0528	0.0709	0.0303	0.0406

Mission, Objective, and Feature	PhD	Master	Bachelor	Difference
The most Favorable Feature	Average			
Safety	0.3900	0.3957	0.4067	0.0167
Entrance	0.0788	0.0757	0.1164	0.0406
Fire/CO gas alarm	0.1170	0.1554	0.1164	0.0389
Surveillance	0.1053	0.0790	0.0821	0.0263
Children monitor	0.0889	0.0856	0.0918	0.0062
Convenience	0.2200	0.2057	0.1933	0.0267
Lighting	0.0671	0.0321	0.0348	0.0350
WiFi	0.0652	0.0822	0.0761	0.0170
Disability assistance / Telecare	0.0303	0.0468	0.0352	0.0165
Entertainment	0.0575	0.0447	0.0473	0.0128
Environment	0.1750	0.1643	0.1083	0.0667
Sprinkling	0.0546	0.0399	0.0277	0.0270
Solar energy	0.0620	0.0600	0.0330	0.0290
Trash recycling	0.0585	0.0644	0.0477	0.0167
Intelligence	0.2150	0.2343	0.2917	0.0767
HVAC	0.0488	0.0611	0.0716	0.0228
Motorized drapes	0.0418	0.0617	0.0443	0.0199
Appliances	0.0493	0.0599	0.1125	0.0632
Smart faucet	0.0752	0.0515	0.0634	0.0237

Mission, Objective, and Feature	C	I	S	T	Difference
The most Favorable Feature	Average				
Safety	0.3900	0.4680	0.3317	0.4400	0.1363
Entrance	0.0788	0.0861	0.0837	0.1478	0.0690
Fire/CO gas alarm	0.1170	0.1825	0.1050	0.1217	0.0775
Surveillance	0.1053	0.0941	0.0637	0.0963	0.0417
Children monitor	0.0889	0.1052	0.0793	0.0743	0.0309
Convenience	0.2200	0.1920	0.2083	0.1950	0.0280
Lighting	0.0671	0.0292	0.0369	0.0329	0.0379
WiFi	0.0652	0.0612	0.0935	0.0825	0.0323
Disability assistance / Telecare	0.0303	0.0625	0.0229	0.0443	0.0397
Entertainment	0.0575	0.0391	0.0551	0.0354	0.0222
Environment	0.1750	0.1720	0.1150	0.1250	0.0600
Sprinkling	0.0546	0.0347	0.0299	0.0460	0.0247
Solar energy	0.0620	0.0587	0.0410	0.0393	0.0227
Trash recycling	0.0585	0.0786	0.0441	0.0398	0.0388
Intelligence	0.2150	0.1680	0.3450	0.2400	0.1770
HVAC	0.0488	0.0405	0.0842	0.0747	0.0437
Motorized drapes	0.0418	0.0434	0.0660	0.0423	0.0242
Appliances	0.0493	0.0482	0.1179	0.0729	0.0697
Smart faucet	0.0752	0.0359	0.0769	0.0501	0.0410