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Validating IOT and Block Chain Adoption for Home Automation and Block less Solution for Robust Penetration

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Abstract: *The motivation behind this comprehensive study is twofold, i.e. validation of UTAUT2 for both potential and actual users of IOT as well as proposing the incorporation of blockchain 3.0 (IOTA) and challenges as novel constructs in UTAUT2. This study helps academicians and practitioners understand the antecedents of IOT adoption and underpins the core areas that need attention to foster adoption. The study incorporates 750 plus responses from both actual and potential users of IOT from the entire Pakistan. Three hundred fifty actual users and 400 plus potential users participated in the study and analyzed using Smart PLS. Performance expectancy, facilitating conditions, price value, and challenges were strong predictors of usage. However, effort expectancy was a strong predictor of actual user adoption, and IOTA was a significant predictor in the case of potential user adoption. The study of the IOT market in Pakistan is pivotal owing to its enormous potential and interest in IOT manufacturers. Our study serves as a useful guide for practitioners in the allocation of marketing budgets and designing of IOT products. This study expands the extant UTAUT2 by incorporating novel variables relevant to the upcoming decade.*

Key Words: Determinants of Smart Home, IOTA, Home Automation, Adoption of IOT, Unified Theory of Acceptance and Use of Technology 2 (UTAUT2), Use Behavior

Introduction

Industrial advancements prompted unprecedented growth in the manufacturing of future technologies, paving the way for the 4th Industrial Revolution. Origination of these high-tech advances stems from multiple disciplines not limited to AI cloud/fog computing, BPM, cyber-physical systems, and Enterprise architecture, but particularly IOT and blockchain (Xu et al., 2018). The use of these automation technologies has not only revolutionized the manufacturing sector but has also created a strong footprint in the services sector. In the manufacturing sector, since a firm does not work in isolation, it works as an integral part of the entire supply chain where closer coordination between upstream and downstream activities becomes pivotal; these technologies play the role of enablers in achieving efficient and responsive supply chain management. The role of IOT has become especially pivotal in achieving automation because it shifts these coordination activities from humans to things (Ben-Daya et al., 2019). IoT is capable of transforming existing processes because it allows objects to gather and process data without the intervention of humans (Arfi et al., 2021).

Home automation refers to governing smart devices remotely by the use of certain applications (Alam et al., 2020). It helps us obtain robust control over digital possessions, thereby regulating our day-to-day tasks in an efficient manner (Navin, 2021). By leveraging this technology, one can add additional comforts to one's everyday life (Gladence et al., 2020). A study of the literature reveals that controlling these devices is pretty simple and easy as they can be easily controlled via an app, voice, gestures and text (Hamdan et al., 2019). Therefore, in the present scenario, the possibility of replacing human input with machines is on the rise (Singh et al., 2019).

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Literature Review

Performance Expectancy

It encompasses the expectation that buying a certain technology will help in the performance of tasks(Anna Sołtysik-Piorunkiewicz et al., 2021). It is associated with the attainment of objectives at work and is concerned with ameliorating job performance. However, the performance of the job may differ for a variety of use cases. For smart homes, it may be associated with the attainment of efficient and improved control of devices. In education, it may be related to improved content delivery. In health, it may be related to remote monitoring and quick execution of tasks. The role of P.E. in the final purchase is well established in extant literature (Ryu et al., 2021). It is linked with the accomplishment of job-specific tasks. The influence of this variable can't be undermined as underpinned by extant literature (Hung et al., 2019).

H1: *Performance expectancy positively influences Use behavior*

Effort Expectancy

It encompasses the comfort level associated with the usage of technology (Onaolapo et al., 2018). The ability to handle a specific technology differs from consumer to consumer and technology to technology owing to their varying background of education, income and past experience with such technologies (Hung et al., 2019). The extant literature solicits that amelioration in the level of ease can result in amelioration in its adoption. This variable, along with P.E., is considered a major driver of adoption for many of the technology-related products. Effort expectancy entails both perceived as well as real complications in technology usage (Wei et al., 2021).

H2: *Effort expectancy positively influences Use behaviour*

Social Influence

This variable takes into account the desire to purchase a technology due to his circle (Abbad, 2021). Hence, it encompasses the peer pressure as well as the family pressure (Alghazi et al., 2021). The family pressure persists and is paramount because family members are among the first and closest people to influence a person (Jadil et al., 2021). Literature regarding the conspicuous role of S.I. in final selection exists (Arfi et al., 2021). Past studies have confirmed the positive role of S.I. and adoption (Myeong-Jun Park & Joono Lee, 2021).

H3: *Social influence positively affects Use behavior*

Facilitating Conditions

It is mainly concerned with the presence of soft and hard infrastructure to support the use of technology(Dwivedi et al., 2019). It also refers to availability of needed support in case of difficulty/emergency(Altalhi, 2021). Hence it is the belief of an individual that he can seek support in smooth usage of technology(Patil et al., 2020).

H4: *Facilitating conditions positively influence Use behavior*

Hedonic Motivation

It entails the scope and magnitude of happiness associated with the use of technology (Gunasinghe et al., 2019). It depicts the perceived pleasure that user love due to innovative solution (Chao, 2019). The innovation seekers are among the first people who tend to embrace a technology prior to general public (Nur et al., 2021). UTAUT2 include this variable because it is usually concerned with the consumer purchases (Khechine et al., 2020).

H5: *Hedonic Motivation positively influences Use behavior*

Price Value

It is the monetary tradeoff for using a solution (Yeo et al., 2017). Consumers are mostly rational in their choices of goods and prefer those goods that give them value for money (that offer more benefits compared to the cost that the consumer is paying). This variable has a significant impact, particularly in those societies which are income-sensitive.

H6: *Price value positively influences Use behavior*

Block Chain 3.0 (IOTA)

IOTA is a DLT (distributed ledger technology) based on Tangle, which is intended to facilitate an M2M economy and communication without fees (Bhandary et al., 2020). The usage of DAG adds robustness to its speed by allowing each transaction to be recorded as soon as it is performed (Raschendorfer et al., 2019). This feature is different from block architecture, where a block consists of a bundle of transactions, and the entire bundle undergoes mining. DAG (direct acyclic graph) speeds up the scalability, and it also adds privacy through the use of MAM (masked authenticated messaging) protocol (Alsboui et al., 2020). The scalability is inherent because as soon as the number of devices in the network grows, the speed of the network also grows, which is quite the opposite compared to previous architectures, where the network gets slow as more users join the network.

The difference in scalability is that every device in DAG is capable of mining existing transactions. Therefore, as soon as the new devices join the network, the speed of performing POW (proof of work) of existing transactions also accelerates (Iqbal & Idrees, 2022). Nowadays, a variety of accelerators are being used to accelerate POW and curl functions, which are likely to boost POW abilities by 2100 times (Korotkyi & Sachov, 2019). The DAG can also serve as an energy trading platform in addition to POW performance (Park et al., 2019).

H7: *IOTA tangle concatenation with IOT positively influence Use behavior*

Challenges in IOT adoption

Despite having numerous benefits, some pitfalls in the adoption of IOT also exist. These encompass the availability of hardware and technical support for smooth operations, authentication and authorization, privacy and security of data, cost of cloud services, compatibility issues (release of matter 1.0 standard has resolved this issue now), and DDOS, etc. The variety and intensity of challenges are subject to the use cases, i.e. medical, agri-sector, logistics, home, city, industry, etc. The most common challenge that existed among multiple use cases was privacy, which can get compromised as a result of an attack (Haque et al., 2020). The challenges that users are anticipated to face are related to the speed of the blockchain network, the cost of mining, and the scale of the network.

H8: *Challenges in adoption has a negative influence on Use behavior*

Use Behavior

It refers to the actual rate of recurrence of a certain solution (Venkatesh et al., 2012). It is directly influenced by B.I., and hence, it is inferred by many studies that influencing B.I. can lead to actual usage. In-home automation leads to the purchase and acquisition of smart appliances, gateways, microcontrollers and actuators.

Figure 1

Original UTAUT2

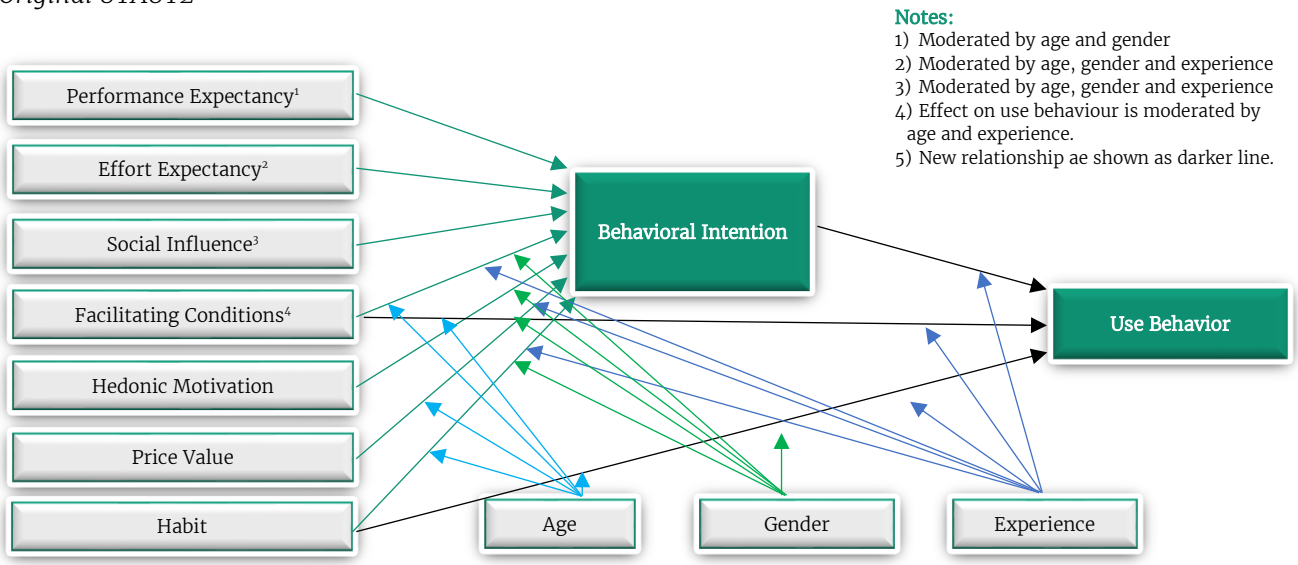
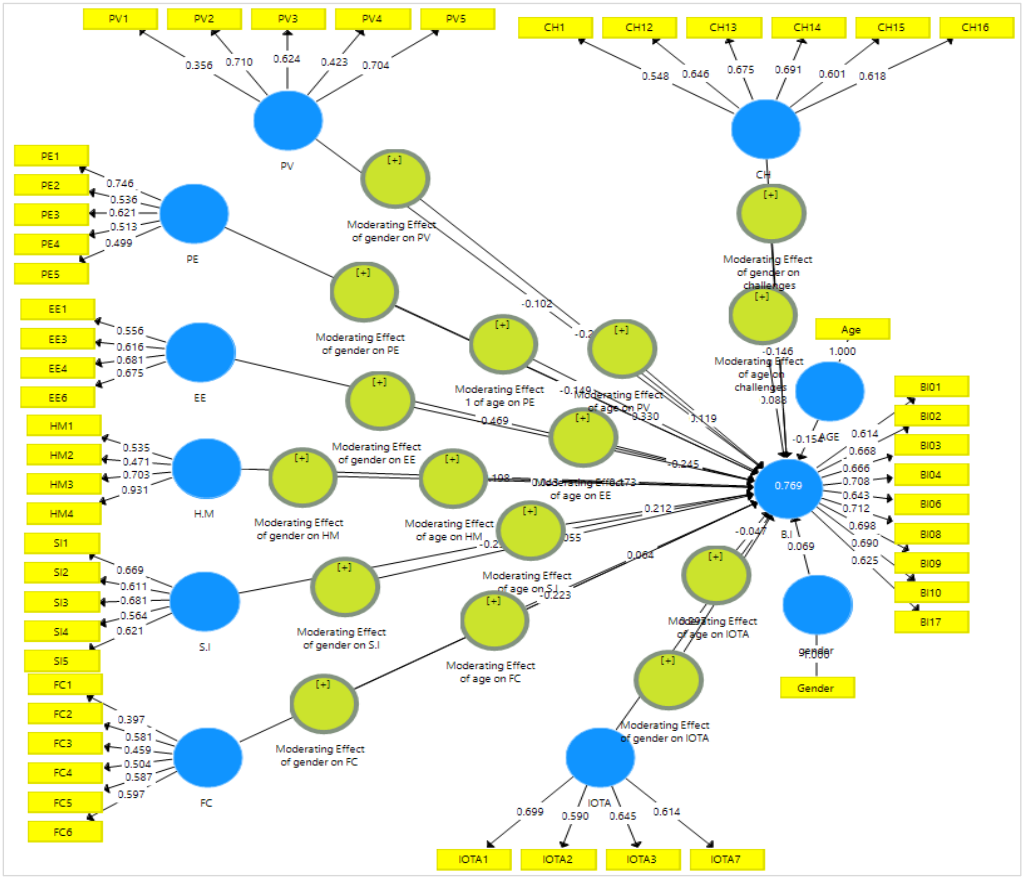


Figure 2

Proposed Extended Moel with IOTA and Challenges as Construct



Note: P.E= (Performance Expectancy). E.E= (Effort Expectancy). H.M= (Hedonic Motivation). S.I= (Social Influence). F.C= (Facilitating conditions). P.V= (Price Value). U.B= (Behavioral Intention). CH= (Challenges in IOT adoption)

Methodology

This research extracts P.E, E.E, H.M, S.I, F.C, and P.V from (Venkatesh et al., 2012), IOTA from (Garg et al., 2020) and challenges from (Janssen et al., 2019.). In order to ensure impartiality and true representation, data was collected from all the main cities of Pakistan by hiring people from those cities. Punjab, being the most populous province, was the prime target, and the rest of the provinces were given representation according to their percentage of the total population. The minimum criteria to qualify as a respondent was a rudimentary understanding of IOT as well as blockchain in the collection of data for potential users. However, for gathering data related to actual users, the minimum criteria were different. In order to qualify as a participant, one needs to be an actual user of at least one of the IoT products.

The survey was employed as a data-gathering tool due to its ability to be quantifiable and efficient mode. During the pilot study, a self-employed survey was presented to the participants owing to its vantage over an electronic survey. Self-employed surveys are important when you try to avail immediate feedback from the participants coupled with a higher response percentage, but it comes at the cost of time as you have to follow the availability of the participant and surrounding environment matters also during data collection. Once feedback was received from the participants during the pilot study, the rest of the study employed an electronic version of the survey for gathering data. This approach also has merit as it enables one to approach a large audience within a short span of time. However, this approach has demerits as well because the audience needs to be well educated in order to be the respondent as well, and it can compromise the response rate.

The study included responses from 750 respondents, of which 400 plus were future prospects while 350 plus were actual users. The duration of approaching the relevant audience for both of these data sets

was approximately one year. Both of the genders were encouraged to participate. The unit of analysis entailed different income and age groups with varying degrees of educational background. Respondents were allowed to avail as much time as they required to submit their survey. It was further ensured that their queries were addressed arising during the time of participation. The obtained data was analyzed using PLS because of its merits over other software. To ensure data triangulation, Cronbach alpha was checked at different levels using different software, i.e. Amos, Spss, etc., along with PLS.

Results

The evaluation of the unit of analysis depicts that it encompasses largely males, who constitute up to 69.6%, and females, who constitute up to 30.4%, with varying backgrounds of education, age, income, and occupation.

Measurement Model

The composite reliability for both data sets (potential and actual users) was above 0.7, which depicts a reasonable reliability value. Moreover, the AVE for both sets was above 0.5, depicting construct validity. Discriminant validity was established via the Fornell-Larcker method. HTMT values were found below 0.85, which is considered a threshold (Henseler et al., 2015). VIF values were also below three, which is considered a threshold. Hence, the measurement model met the thresholds for all these values (Sarstedt et al., 2017).

Table1

Convergent Validity

	Cronbach's alpha	Composite reliability (rho_a)	Composite reliability (rho_c)	Average Variance Extracted (AVE)
CH	0.837	0.839	0.817	0.573
EE	0.704	0.717	0.705	0.542
FC	0.788	0.807	0.768	0.525
HM	0.71	0.75	0.718	0.568
PE	0.71	0.713	0.692	0.524
PV	0.731	0.758	0.739	0.537
SI	0.702	0.741	0.691	0.574
UB01	0.794	0.8	0.792	0.593

Table2

HTMT Values

	Age	CH	EE	FC	Gender	HM	PE	PV	Qualification	SI	UB01
Age											
CH	0.086										
EE	0.024	0.364									
FC	0.101	0.383	0.631								
Gender	0.085	0.066	0.053	0.061							
HM	0.054	0.296	0.657	0.686	0.037						
PE	0.137	0.397	0.793	0.542	0.142	0.542					
PV	0.143	0.276	0.321	0.615	0.034	0.403	0.363				
Qualification	0.332	0.099	0.076	0.094	0.021	0.061	0.090	0.045			
SI	0.098	0.194	0.617	0.723	0.102	0.665	0.629	0.558	0.046		
UB01	0.102	0.386	0.467	0.323	0.055	0.253	0.293	0.540	0.054	0.346	

Structural Model

The R^2 value is 0.544 in the case of actual users, which shows that the model is a strong predictor of adoption behavior. The addition of two novel constructs, i.e. IOTA and Challenges, enhances the predicting ability of the model even further up to 0.769. This means that the model is an even better explainer of behavior compared to the existing model of UTAUT2. In the case of actual users, price, performance, effort expectancy, and facilitating conditions were found to be extremely significant predictors. Meanwhile, H.M., gender, and age were found to be the weakest predictors, and S.I. was found to have a moderating impact. The data set pertaining to the potential user's performance expectancy, social influence, facilitating conditions, price value, IOTA construct, and challenges in IOT adoption were the predictors of usage intention.

Table 3

R^2 before Incorporating Novel Constructs in UTAUT2

	R-Square	R-Square Adjusted
UB01	0.544	0.523

Table 4

R^2, after Incorporating Novel Constructs

	R-Square	R-Square Adjusted
B.I	0.77	0.75

Table5

Model Fit Summary

	Saturated Model	Estimated Model
SRMR	0.073	0.073
d_ULS	5.718	5.724
D_G	1.156	1.156
Chi-square	1,995.608	1,996.954
NFI	0.577	0.576

Table 6

Hypotheses Results

	Variable	Actual users	Potential users	Supported/not supported
H1	P.E	Strong	Moderate	Supported
H2	E.E	Strong	Weak	Supported
H3	S.I	Weak	Weak	Supported
H4	F.C	Strong	Moderate	Supported
H5	H.M	Weak	Statistically insignificant	Not Supported
H6	P.V	Strong	Moderate	Supported
H7	IOTA	N.A	Moderate	Supported
H8	Challenges	Strong	Moderate	Supported
H9	Age and Gender	Weak	Weak	Supported

Discussion

This study focused on analyzing the antecedents of embracing IOT for both prospects and actual IOT users in Pakistan (a country with enormous penetration of cell phones) having biometrically verified users (Iqbal et al., 2021).

Robinson estimates that by the year 2025, consumers in Pakistan will have access to 3.8 million IOT connections, and COVID-19 played a pivotal role in societal transformation, where people started to rely more on technology. Therefore, it fosters the adoption of new technologies that are energy-efficient and

eco-friendly (Umair et al., 2021). The current study seeks to extend extant (utaut2) by incorporating novel constructs, i.e. IOTA and challenges, for a better explanation of antecedents of adoption. The results depict that Performance expectancy (P.E.), facilitating conditions (F.C.), price value (P.V), and challenges were moderate to strong predictors of usage; however, effort expectancy was only found to be a strong predictor in actual user adoption, and IOTA was found significant predictor in the case of potential user's adoption. However, social influence, hedonic motivation, and the moderating role of age and gender were found to be weak predictors of IOT adoption in both studies.

Conclusion

Industry 4.0 is capable of transforming the everyday lives of individuals apart from its commercial applications. The conglomerate of these emerging technologies will pave the way for the amelioration of existing use cases along with the development of novel applications in different domains, i.e. health, agri sector, homes, automobiles, education etc., the diffusion of IOT will not only change the way we live but will uncover a plethora of opportunities for social science researchers in predicting the future behaviors of users. This well-conceived and well-investigated study aims to help marketers and IOT dealers delight their prospects in an improvised manner. The author anticipates that present touch points will be replaced with novel ones where IOT will take the lead in the transformation of society (Brous et al., 2020).

Managerial Implication

This study will serve as a vantage for companies that are planning to associate themselves in IOT related supply chain. It will also serve the marketers and users because it will guide the marketers to know exactly the areas of importance that consumers really value and that play a decisive role in purchase decision. Consumers on the other hand will get the benefit of exactly getting the product that they require.

In this way, firms will gain insights into the antecedents of embracing IOT and will be able to preserve precious monetary and time resources that can delight their users. This research validates that P.E, P.V, and F.C Challenges are relatively more significant variables that may result in the embracing of IOT for smart homes. However, with the growing adoption of smart objects, where machines will behave as economic agents, IOTA will also play a decisive role in the adoption process.

Pakistan is a country known for its robust penetration of biometrically verified users and IOT for home automation will ease their everyday tasks. Inclusion of block chain and crypto processor within the micro controller will enhance the capability of transforming those smart devices into economic agent. The block less architecture of Tangle will transform mobiles into POW processing machines unlike its predecessors i.e. BIT Coin and Ethereum.

Limitations and Future Directions

Although the current study tried to approach a reasonable sample from different cities in Pakistan, more and more representation can add rigour to our research. Furthermore, the participants of our study were mostly males and were young people. In order to reduce this limitation, females and elderly people can also be encouraged to improve the generalizability. With the chances of increased automation in the near future, machines are likely to become economic agents instead of humans. DAO's and Daps can play a decisive role in years to come. Moreover, with enhanced penetration of blockchain, scalability can become a serious issue. Though IOT tangle has built an algorithm to manage this scalability problem yet, surging influx can push for diminishing processing time. This may lead to the development of hardware accelerators with POW-performing capabilities in Nano-seconds.

Advancements in chips, the development of crypto engines, and clusters of accelerators can become the major areas of interest for contemporary research. Another important arena that may seek the attention of researchers is handling the vulnerabilities of the Curl hashing function due to the emergence of quantum technology.

Quantum computers, owing to their robust computational capabilities, can decrypt present-day encrypted documents/transactions. Hence, securing and ameliorating the Curl hashing function can secure IOTA as a platform to serve the future exchange of money and other valuable resources, i.e. energy (Korotkyi & Sachov, 2019).

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