A Literature Review of the Adoption of Internet of Things: Directions for Future Work

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Abstract
Internet of Things (IoT) is a technology that is changing the way of doing everything. Empirical studies focused on the technical aspect of this technology while studies related to the behavioural approach are limited. Among the empirical studies, there is no agreement on the predictors of IoT adoption by users. Therefore, the purpose of this study is to review and analyze the literature systematically to find the status of IoT adoption and the predictors that affect the adoption. To achieve this purpose, a systematic literature review is conducted to identify the related articles. Three filtering processes are deployed to refine the selected articles. This has resulted in reviewing 22 articles between 2016-2020. A frequency analysis was conducted. The findings of the 22 articles indicate that the number of articles pertaining to IoT is increasing with majority of the studies were conducted in Asian countries in smart devices, healthcare, consumers, and smart home IoT. The majority of the reviewed studies are quantitative with the technology acceptance model (TAM) is the dominant model. The important predictors of IoT adoption include ease of use, usefulness, perceived risk, social influence, privacy, attitude, security, compatibility, and trust. More qualitative and mixed-method studies are needed in IoT adoption, and more studies are needed in the adoption of IoT smart homes in developing countries

1. Introduction

Internet of Things (IoT) is a revolutionized technology that is changing all aspects of life and work. It was introduced in 1999 when the term for the first time has been mentioned by Kevin Ashton [1]. IoT is a method of communication between machines where machines communicate with each other without human intervention [2]. The applications of the IoT has expanded to include all aspect of security, manufacturing, medical institutions, consumers, smart home and healthcare [3], [4]. It is expected by 2025 that the number of device that each human will have will account to 9 making the total used devices of IoT account to almost 75 billion [5].

Studies in IoT focuses on identifying and solving the security and privacy challenge. Researchers indicated that the technical studies that focuses on sensors, networking, scalability, and actuators outperforms the studies that investigated the behaviour of users [2], [3], [6]. For this reason, there is a limited studies on IoT adoption and usage by user. Nevertheless, previous studies do not agree on a set of factors that can be consider as the ultimate predictors of IoT adoption. Previous studies also has no universal agreement on what theory can better suit or predict the IoT adoption. For example, some researchers have used the technology acceptance model (TAM) e.g., [7]–[9] while other considered the unified theory of acceptance and use of technology (UTAUT) e.g., [1], [10].

To solve this contradiction and lack of information regarding the predictors and the theories of IoT as well as to identify the area, countries, sectors, and number of publications, this study aims to review the literature to understand the status of IoT and provide a direction for future work. Therefore, this study aims to systematically review the literature pertaining to the adoption of IoT by individual (user). The coming sections discusses the research methodology, summary of the reviewed studies, findings, discussion and the direction of future works as well as the limitation and conclusion. However, the studies that investigated the adoption of IoT is still limited. In addition, IoT still has no known theory to explain the behaviour of users of IoT. Further, it is not known to what extend the IoT is deployed and in what country or sector the IoT is used.

2.   Research Methodology

This study full under the quantitative study as it aims to review, integrate and consolidate the view of the literature using secondary data approach by extracting articles and presenting the gauged view of the literature. This study is a systematic review study. To extract the related articles, keywords such as IoT, IoT adoption, IoT usage, IoT intention to use, Internet of Things as well as a combination of these words. Articles are extracted from three reliable databases that include the Web of Science (WoS), IEEE, and Science Direct. As a result, 153 articles were extracted. The inclusion criteria are the articles must be from reliable source, in English and investigate the adoption of IoT by individuals. Articles that are not in English or investigate the technical aspect of IoT by organizations were excluded. Three screenings were conducted to filter the articles. In the first screening the duplicated and outdated articles (less than 2015) were removed to have a recent view of the trend in IoT adoption. This has resulted in removing 103 articles. The second screening include the reading of abstract. As a result, a total of 15 articles were removed. Making the final number of articles is 35. The third screening include full reading of the article, and this has resulted in removing 13 articles. The articles that have been reviewed in this study include 22 articles. Figure 1 presents the process of selecting the related articles.
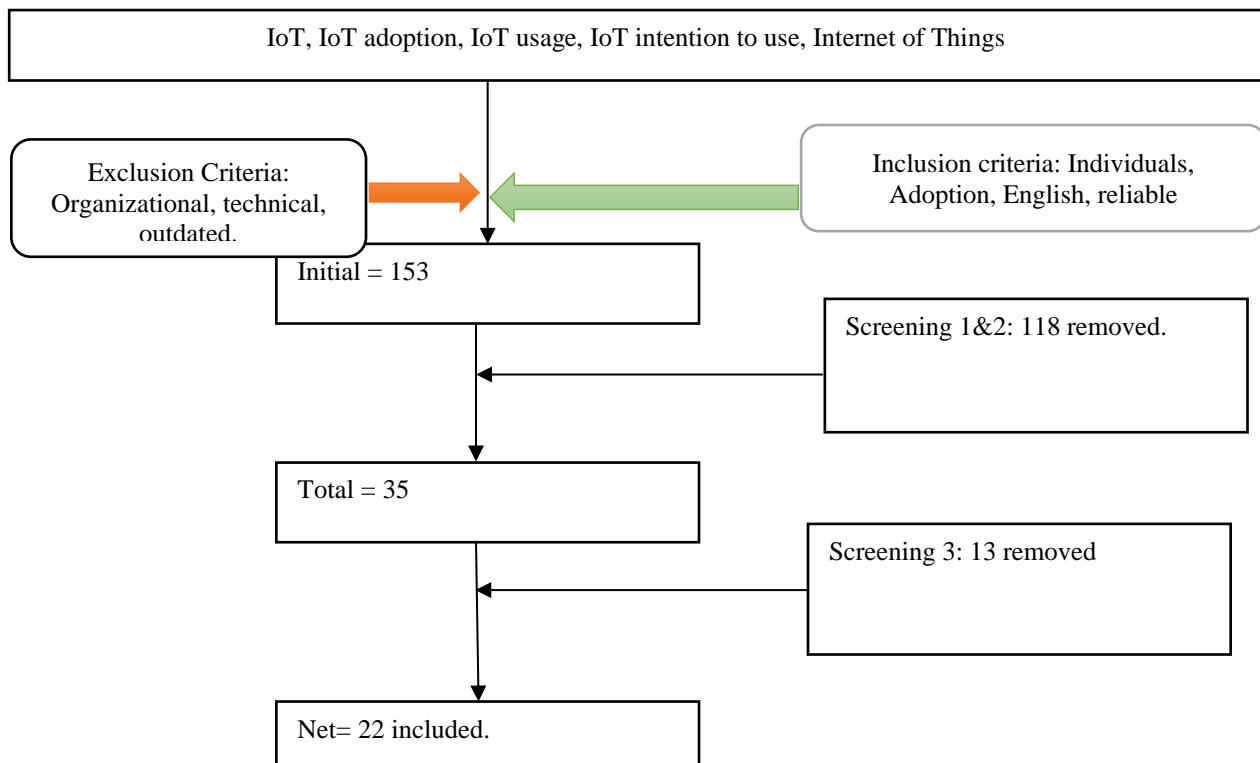

Figure 1: Process of Selecting the Related Articles

3.   Summary of Reviewed Studies

A total of 22 articles were reviewed in depth and summarized to understand the findings of previous studies. The reviewed articles can be divided, based on the theoretical adoption theory, into several categories. Majority of reviewed articles focused on the use of TAM as the main adoption theory. TAM was used in the study of [8] to examine the adoption of smart watch. In a smart home study, [9] in China examined the intention to use IoT smart homes. The author deployed TAM model. Similarly, TAM has been used in several other studies such as [11] and [12] in India and [13] in Turley who examined the healthcare using TAM, [14] who examined the smart device in Netherland, [15] and [16] who investigated the consumers' adoption of IoT in Saudi Arabia and Taiwan respectively, [17] who examined the smart locker in Taiwan,

Other models and theories were used slightly in the literature. For example, the information system success (IS success) was used in few studies. In the study of [6], the IS success was deployed to examine the adoption of IoT healthcare. Similarly, in the study of [18], the IS success model also was used to examine the adoption of IoT wearable devices. UTAUT was used in the study of [1] to predict the adoption of IoT by young user in Poland.

The trend in the literature either to combine two or more theories or to not use theories in explaining the adoption of IoT. Those who deployed more than one theory such as [10] who deployed the UTAUT and health believe model (HBM) were used to examine the IoT healthcare adoption. In the study of [11], three theories were combined that include the TAM, theory of reasoned action (TRA) and TPB.

The study of [13] examined the adoption of IoT by healthcare in Turkey. The study utilized the TAM, innovation diffusion theory (IDT), technological innovativeness, and protection motivation theory. IDT and behavioural reasoning theory (BRT) were also combined in the study of [19] to examine the IoT based healthcare wearable devices.

A high number of studies did not deploy any theory and it is mostly related to the exploratory nature of the studies. Privacy, security, trust and cost were among the most important variables in several studies [5], [20]–[25], reviewed studies also highlighted the role of knowledge management [26]. In the following sections, the findings of this study is discussed.

4. Findings

A frequency analysis was conducted to describe the findings of this study. The findings are presented as follows:

4.1 Profile of Articles

In this section, the profile of the article is discussed. This includes the year of publication, country and industry, approach, adoption theory, sample size, and analytical tools.

4.1.1 Year of Publication

A total of 22 articles were reviewed in this study. Interest in IoT has increased over years with number of articles increasingly steadily during 2016-2018. Article in 2019 were less than previous years and this could be due to the exclusion criteria. Number of articles in 2020 has increased indicating that the IoT is getting attention. Figure 2 shows the year of the publication of the reviewed articles.
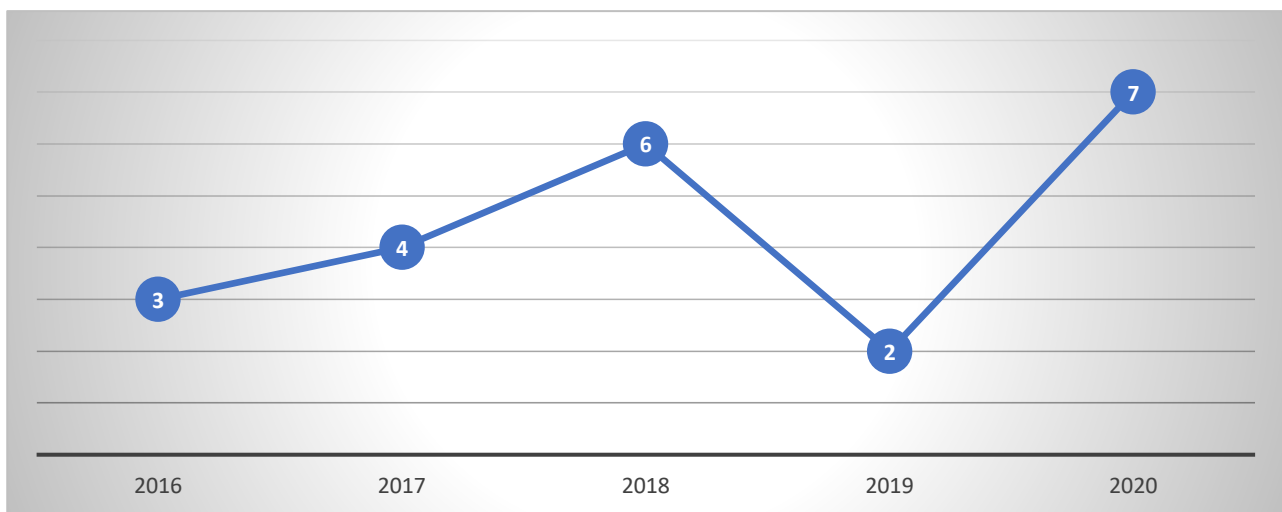

Figure 2: Year of Publication

4.1.2 Country and Industry

Figure 3 shows the country of the studies. It can be seen that 23% of the articles were conducted in South Korea followed by 14% in India, 9% in China, and 9% in Taiwan. Other countries ranged between 4-5%.
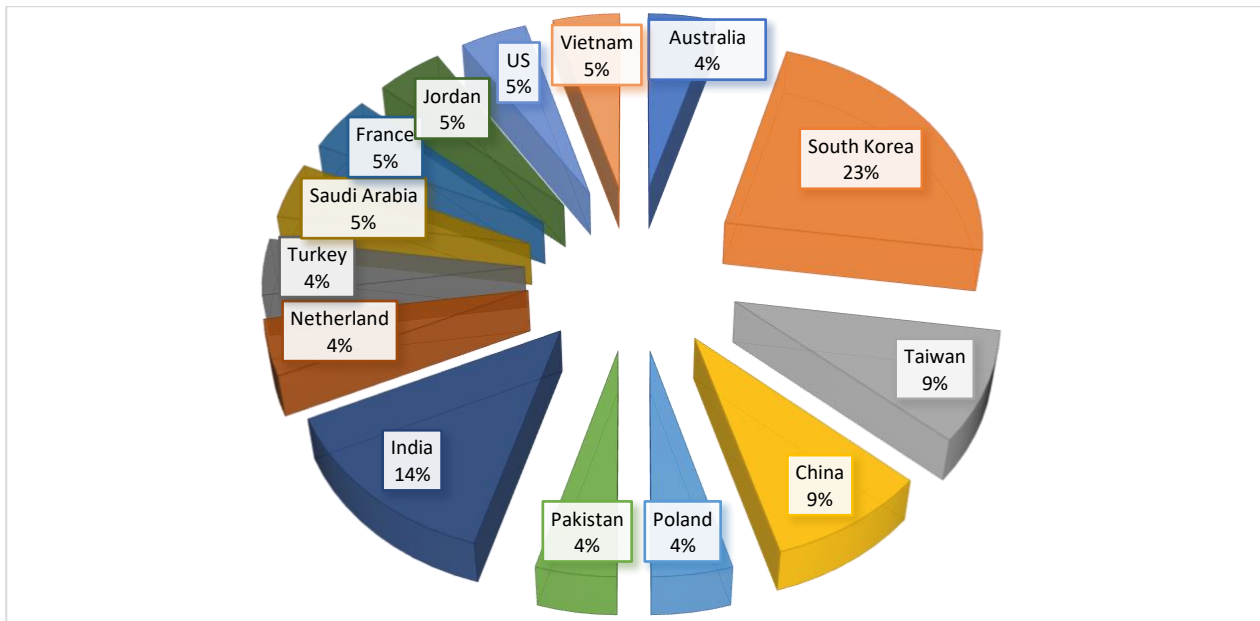
Figure 3: Countries of the Studies

For industries, Figure 4 shows the industries where the studies has been conducted. It can be seen that smart devices is the centre of attention of previous studies with 36%, 23% in consumer and 23% in healthcare while 18% in Smart Home.
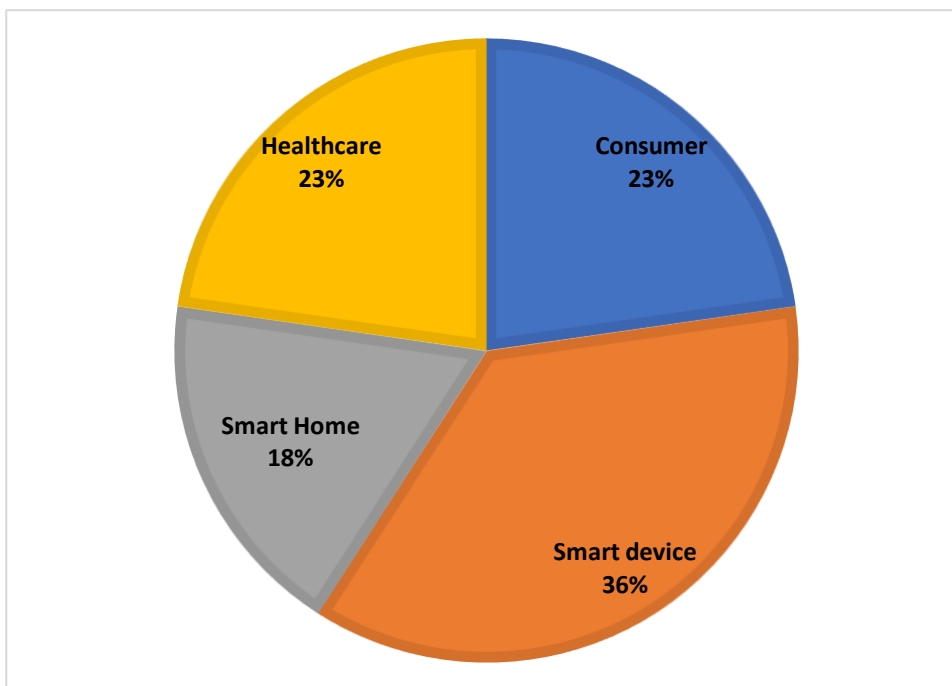

Figure 4: Industries of the Reviewed Studies

4.1.3   *Approach of Reviewed Studies*

The reviewed studies included two main approaches. The first approach is the quantitative study which accounted to 86% of the reviewed articles. The second approach is a mixed method which include quantitative and qualitative studies and accounted to 14% of the reviewed articles. Figure 5 shows the approach of the reviewed studies.
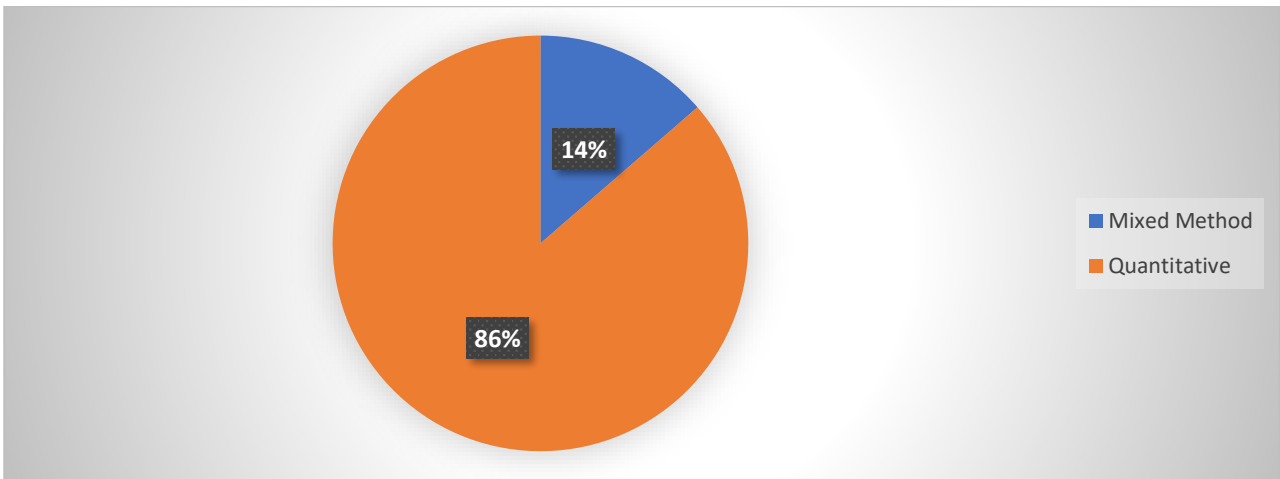
Figure 5: Approach of the Reviewed Studies

4.1.4 Adoption Theory

Several theories has been used in the reviewed studies. Some studies included only one theory while other combined more than one theories to develop the research model. Figure 6 shows that majority of studies has used the theory of TAM followed by IS success and UTAUT. Large number of articles has no theories.
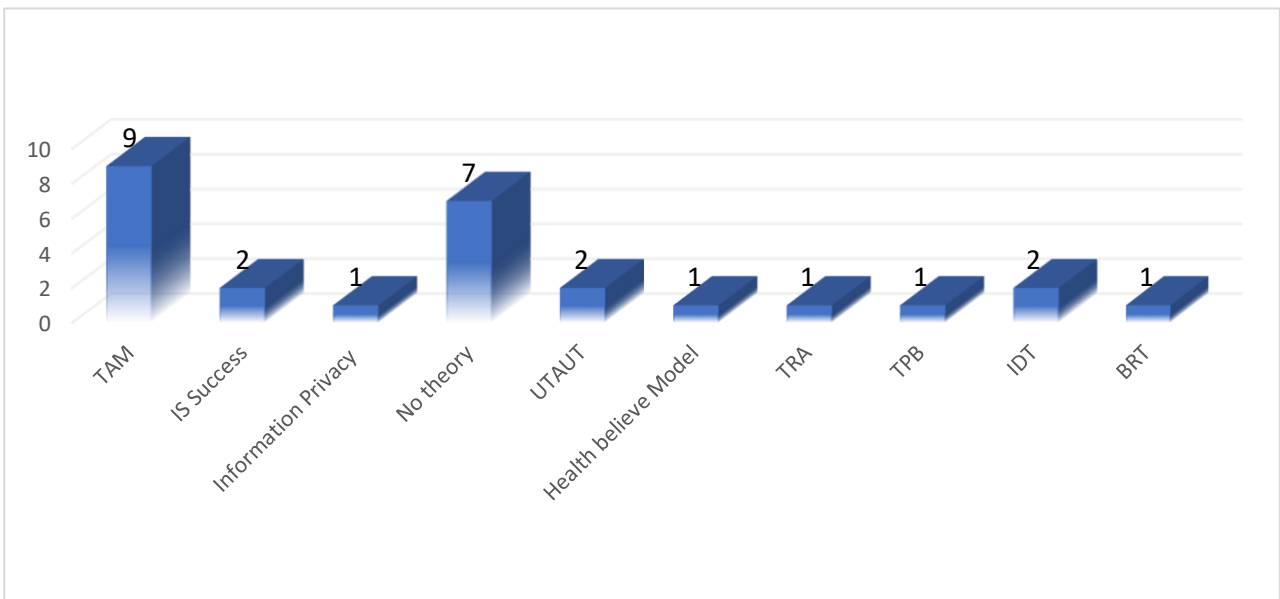

Figure 6: Adoption Theories

4.1.5 Sample Size

The quantitative studies collected data using a questionnaire. The sample size ranged between 40 respondents and 1356 respondents with a mean of 458 respondents. Figure 7 shows the sample size of previous studies.
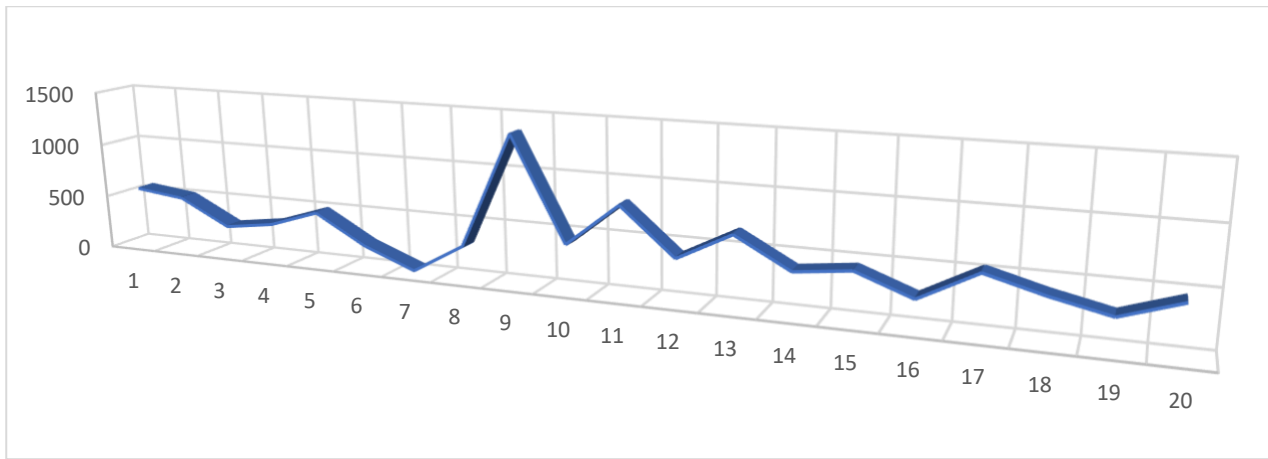
Figure 7: Sample Size

4.1.6 Analytical tools

The analytical tools of previous studies are given in Figure 8. AMOS and Partial Least Square (PLS) were widely used in the quantitative studies. For the mixed method studies, it was analysed using content analysis.
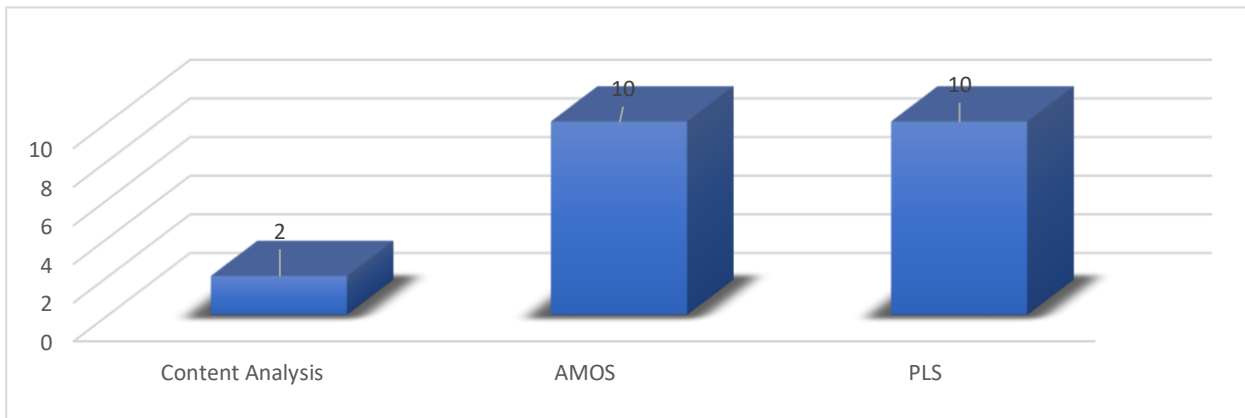

Figure 8: Analytical tools

4.2 Predictor of IoT adoption

To identify the most important predictors of IoT in all sectors, a frequency analysis was conducted on the variables that are included in the previous studies. Figure 9 shows the most important and frequent variables. The Figure shows that the variables of TAM such as the ease of use and usefulness were widely deployed and considered as important variables. This is followed by the perceived risk which is a variable that can explain the concern of the respondents regarding the use of IoT. Additional factors that express the concern of the respondents is the privacy and security. These variables are important to determine the adoption of IoT by respondents. The frequency analysis also showed that the variables of attitude from TAM and TPB is a critical variable for the adoption of IoT. Social influence from UTAUT is also an important predictor of IoT. Lastly, trust and compatibility is critical variable. Trust comes from the social exchange theory and from the context of adopting IoT while the compatibility comes from the IDT theory. Figure 9 shows the most important predictors.
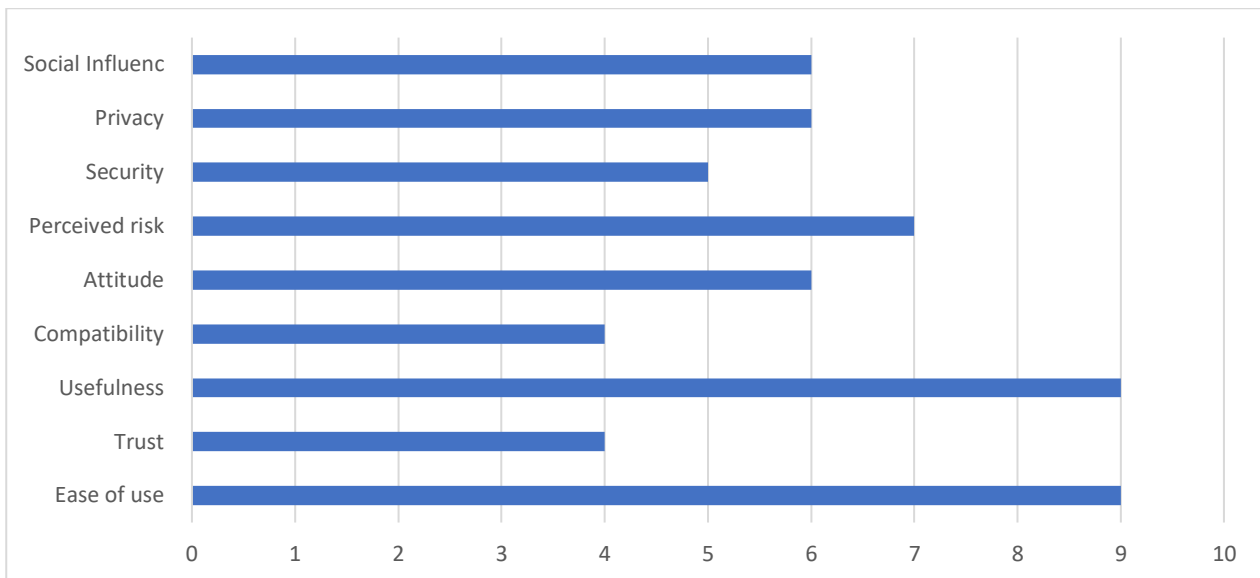
Figure 9: Important Predictors of IoT

5. Discussion

This paper reviewed the literature related to the adoption of IoT by individual users. The study conducted a systematic literature review. A total of 22 articles were reviewed. The findings showed that the number of articles is gradually increasing during the last five years. Against the view of most empirical studies, the number of articles in Asia rather than Europe or America is increasing and more than half of the articles were conducted in South Korea, India, China, and Taiwan [3], [27] The findings showed that the users of smart devices were the largest target group followed by healthcare and consumers. Smart homes received less attention despite the growing in the market of this segment. Majority of the studies are quantitative while few studies have been conducted using mixed method. In line with the findings of previous studies, TAM dominated the adoption theories [28] followed by studies with no theory which reflect the fact that IoT is still theoretically emerging and there is no one theory can be used as the ultimate predictors of IoT adoption.

The predictors of IoT adoption were mainly related to TAM and its variable the ease of use and usefulness. Usefulness reflects the benefits that can be gained from using the IoT while the ease of use denotes to the easiness of using the IoT such as the physical and mental effort that are needed to use the IoT [29]. Predictors also include the social influence which the effect of others such as relatives, friends, experts on the decision of individual to use the IoT [30] [31]. Variables that reflect the concerns of individual in term of using IoT such as the risk, privacy, trust, and security are critical and used in some studies. These variables are not part of UTAUT or TAM and studies recommended to add these contextual predictors in the IoT adoption [4], [15], [22], [32], [33]. In addition, from the IDT, the compatibility of IoT with existing system is important for the adoption of this technology by individual.

6. Conclusion, Limitation, and Future Work

This study reviewed the literature and identified the predictors and the area of future works. However, this study has limitations that includes the number of the articles that are included in this study. The number is based on the inclusion and exclusion criteria and can to large extend provide an overview of the trend in the literature. Only three databases included in this study due to the notion that these databases include most of the articles of IoT. As a way forward and based on the findings of this study, it is suggested for future studies to examine the adoption of IoT in other developing countries. The IoT is currently being used in most of countries while previous studies were conducted either in developed countries or in Asian countries such as South Korea, India, china, and Taiwan. Future studies are suggested to examine the adoption of Smart Home IoT this is because this segment received less attention compared with smart devices, healthcare, and consumers.

More mixed method studies are needed. The literature is confirmatory in nature with few exploratory studies conducted on IoT. Interview or focus group approach can be used to identify the predictors of IoT within a certain area. For example, in smart home, experts can be interview to understand the predictors of using IoT. In quantitative studies, future research are advised to combine more than one theory and to deploy other models. Future studies are recommended to examine the use of social exchange theory, UTAUT, and technology-organization-environment. Other theories such as TPB and IDT can be combined also to increase the explanatory power of predicting the IoT. This study identify a set of predictors to be the most important factors of adopting IoT. However, future work can examine these predictors in an empirical studies. Other variables can be included such as the IT knowledge because it is essential for using the IoT to have an

adequate knowledge of the technology. Decision makers can benefit from this study by understanding the most critical factors that lead to more adoption of IoT by individual users.

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