Hindawi
Human Behavior and Emerging Technologies
Volume 2022, Article ID 9258317, 15 pages
https://doi.org/10.1155/2022/9258317

Review Article

Theories and Models of Technology Adoption in Agricultural Sector

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Received 4 July 2022; Revised 25 October 2022; Accepted 28 October 2022; Published 29 November 2022

Academic Editor: Zheng Yan

Agriculture is crucial in catering to the increasing demand for food and employment. Thus, adoption of novel technologies is important. Many scientists have developed different theories and models explaining the process of behavioral change relevant to adoption. They are either completely different, similar, or improvements of previously developed models. Therefore, compilation and summarization of these theories and models will support future studies and researchers. Thus, an analysis of literature on technology adoption was conducted. The review was prepared based on literature from various sources spanning around 50 years. The theories and models identified by different studies were compiled and analyzed in this review paper. Many theories and models in agricultural technology adoption such as transtheoretical model, theory of reasoned action, theory of interpersonal behavior, model for innovation-decision process, different versions of technology acceptance model, theory of planned behavior, theory of diffusion of innovation, task-technology fit, technology readiness, unified theory of acceptance and use of technology, expectancy livelihood model, social cognitive theory, and perceived characteristics of innovating theory were compiled. Each theory and model has its own uniqueness, which had explained different aspects of technology adoption process and factors determining the behavioral change. These theories and models included affecting factors such as technological, personal, social, and economical factors. In conclusion, it can be stated that, rather than having a single theory or a model, an integrated and amalgamated form will be more explanatory for technology adoption.

1. Introduction

The contribution of agriculture to gross domestic product of a country is diminishing with growing industrialization [1]. However, it still serves as a major source of income to a majority of the population in the world. Ensuring food safety and increasing production and quality of food are the main concerns worldwide. Therefore, improvement of existing practices is continuously encouraged. New technologies are generated and introduced to the stakeholders through various promotional mechanisms that are worth millions of rupees. Yet the adoption process is lagging behind leaving less technology adoption as a serious challenge. This paper focuses on gathering the available literature on theories and models related to technology adoption that can be applied in the agricultural sector. It is a compilation with a summative evaluation of available theories and models, which are collected through an analysis of literature from numerous sources such as websites, books, journals, and other sources spanning around 50 years. This compilation will support practitioners in technology dissemination and future research on technology adoption and diffusion.

2. Literature Review

2.1. Technology Adoption in Agricultural Sector. Development of agriculture is considered as one of the highly effective strategies to end poverty. This will further boost distribution of wealth among communities while being the top contributor in fulfilling the much increasing demand for food due to population growth. An analysis done in 2016 by World Bank Group found that agriculture serves as the main income source for a major proportion (65%) of the "poor but employed adults" worldwide. Thus, development of agriculture is vital for the growth of the economy of a country. The share of agriculture on global gross domestic product is 4%. However, this contribution might rise even up to around 25% for some countries [1]. Therefore, agriculture has to be continuously developed worldwide.

Technology acts as a key vector for change in a variety of disciplines [2]. Contribution of emerging technologies in developing the food production and improving the quality and safety of food is always looked for by agricultural economists. In the recent past, a considerable development was visible in technological innovations worldwide. Once a technology has been generated, optimizing the awareness and the use of it takes place over a considerably long time. Furthermore, the ultimate goal of generating technology is not only just adoption but could be something much wider and broader. For example, introduction of a new high-yielding paddy variety will have an ultimate goal of increased paddy production or productivity in the country. This can only be achieved by promoting the adoption of the specific technology, which will lead to achieving the ultimate goal. Rather than mere adoption, it will require continuation of usage and spread of usage among a larger community. This will enable to make a visible impact on the community. Thus, the rate of adoption as well as the rate of diffusion will determine the ultimate impact of the technology generated. A vast amount of research has been conducted over time to study the adoption process as well as the diffusion process linked with the type of factors affecting the adoption as well as the rejection of a technology by the end users. Other than agriculture, these studies extend towards many sectors such as information technology, education, agribusiness and entrepreneurship development, medicine, and social sciences [2–4].

Though technological development in agriculture is believed to be a very important path to eliminate poverty by many, and considered as a priority, most developing countries still struggle with low rates of adoption of the introduced novel or improved technologies [5–7]. But adoption of novel technologies lies as a pivotal necessity in developing the agriculture sector. Much emphasis is given to facilitate and ensure adoption of technologies. The technological inventions in agricultural sector coupled with adoption have driven agriculture towards its development [8]. Each day, the population is growing which increases the demand for food. This further aggravates the requirement of new improved technologies in the agricultural sector. Thus, technology adoption is emphasized at high levels [9, 10].

Authors define adoption in different ways. Bonabana-Wabbi [11] had stated that Feder et al. [12] had defined the technology adoption as "a mental process an individual pass from first hearing about an innovation to final utilization of it." Adoption is again defined by Feder et al. [12] as "the integration of an innovation into farmers' normal farming activities over an extended period." Loevinsohn et al. [13] also mention about integration in the definition given, which is "the integration of a new technology into existing practice and is usually proceeded by a period of 'trying' and some degree of adaptation."

Furthermore, adoption is an alteration in the human behavior. Zheng [14], citing the work of other researchers, had mentioned that many variations of human behavior, such as social behavior, entrepreneurial behavior, consumer behavior, and economic behavior, exist. Among them, technological behavior is one of the main human behavioral facets, where the behavioral changes towards introduction of digital technologies are studied. This technological behavior can be useful in explaining the behavioral change in agricultural technology too.

Adoption may vary from person to person and will change over time depending on many factors. Dasgupta [15] had mentioned that these factors can be of three categories which are personal, institutional, and social factors. As continuous development of the technologies takes place over time, there might be many other technologies or a more improved technology is available to suit the requirement and expectations of the end users.

Adoption is classified by Feder et al. [12], into two categories, as individual adoption and aggregate adoption. Each is specified in different contexts. Individual adoption is referred to as the adoption that takes place at the stage of farmer. This is defined as "the degree of use of new technology in long run equilibrium when the farmer has full information about the new technology and its' potential." This implies the technological adoption that takes place and which continues for comparatively a longer period. On the contrary, aggregate adoption is referring to the diffusion of the technology, implied by the definition of "the spread of new technology within a region." Rather than taking one individual, aggregate adoption is referring to a specific area of location or a defined community of people. Rogers [16] describes the diffusion process of a technology as "the process by which an innovation is communicated through certain channels over time among the members of a social system." In collection of all these definitions and comments from various scientists, summery of it is that the adoption of technology is a process that leads to usage of a new technology, and it might spread to other people through the diffusion process.

All these perspectives are facts compiled to three paradigms frequently used in order to classify the adoption behavior and the factors that affect adoption. Melesse [17] had summarized these paradigms introduced by many authors as the innovation-diffusion models, adoption-perception models, and economic constraint models. These paradigms are based on some basic assumptions. The major postulation aligning the innovation-diffusion model is that,

although there are technically appropriate technologies, which are even socially accepted, the adoption is determined by the factors that affect the reaching of information to the relevant clients and the cost involved in searching for information. The second, the adopters' perception paradigm, indicates that the adoption of technological aspects by farmers is decided based on the perceived characteristics of the technology. This further elaborates that, even when farmers are aware of all the details of the technology, they will assess the technology in a different manner than the researchers [18]. Therefore, it is very important to understand the farmers' perceptions towards a specific technology, for development and technology dissemination. The economic constraint model implies that the availability of required inputs will determine the adoption decision making. Some of these inputs are labour, land, availability and access to credit, and other critical inputs. These restrict the flexibility in production and affirm the decision on adopting or nonadopting of the technology introduced [19]. Melesse [17] also mentions that using many paradigms in developing the technology adoption models will enhance the explanatory power of the developed model than using only one paradigm. Further, in the process of decision making, four steps are used. These steps are knowledge or awareness, persuasion, decision, application of the knowledge, and confirmation of usage. The process of adoption takes place over a period of time with a set of communication procedures among members in a comparable society. Additionally, in relation to the characteristics of the invention, relative advantage, compatibility, complexity, trialability, and observability were identified as the most influential aspects of adoption of the respective technology [20].

The author also agrees to all these paradigms, but they seem more useful when used collectively. This collective approach leads to all the factors mentioned in all three paradigms, i.e., the level of information reaching the farmer, perceived effectiveness of the technology to the individual farmer, and all the infrastructure and other capital resources required for the usage of the technology are altogether affecting the adoption process.

3. Theories and Models in Technology Adoption

According to Wunsch [21], a theory can be defined as "plausible explanatory propositions devised to link possible causes to their effects" while a model can be defined as "a schematic representations of reality or of one's view." Many authors have cited as well as described a number of theories and models in adopting the technologies. Sometimes, authors describe the theories with explanatory models as well. Some of these theories and models are discussed below.

3.1. Transtheoretical Model (TTM). The transtheoretical model (TTM) (Figure 1) mentioned by LaMorte [22] was developed by Prochaska and DiClemente in the 1970s to study the changes in health habits of people. It is based on the decision-making ability of an individual showing a process of change based on the individual's intentions. The basic

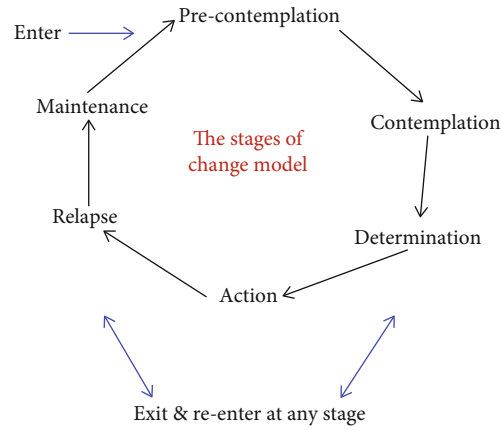

Figure 1: Transtheoretical model [22].

assumption of TTM is that people will not alter their behaviors instantly and conclusively. However, these changes in behavior will occur in a cyclical manner. This is said to be in particular with habitual behaviors. This model explains that each individual will pass six stages of change: precontemplation, contemplation, preparation, action, maintenance of action, and termination of the whole behavior. The originally developed model did not contain termination and it is less used in the process. In order to make the individual to move along these six stages, many different interventions are used. These interventions could be unique to each stage. These different strategies will make sure to lead the individual towards the stage of "maintenance" which is the desired stage of behavioral change [22–24].

3.2. The Theory of Reasoned Action (TRA). Fishbein and Ajzen [25] developed this theory in 1975 and discuss factors that determine behavioral intention of an individual (Figure 2). The "attitude" is defined as the evaluation done by the person on the specific technology. Furthermore, "belief" and "outcome evaluation" are defined as links between the technology and its' characteristic traits. The "subjective norms" are with relevance to how others who are in near surrounding of the individual will feel about the same technology, and how this attitude of others will affect the perception of the individual towards a specific behavioral change. This is commonly used in explaining the behavioral changes in many such as health, education, agriculture, and consumption behavioral studies.

3.3. Theory of Interpersonal Behavior (TIB). The TPB was developed by Triandis in 1977. The TIB (Figure 3) is describing primarily the behavior of an individual towards a novel technology. This model also describes how the personal emotions and social facets will affect the behavioral change. Thus, the TIB discusses similar to TRA and theory of planned behavior (TPB). But TIB has identified the personal habits, facilitating conditions, and affect to upgrade the descriptive ability of the model. Similar to "subjective norms" depicted in theory of reasoned action forming the "intention," TIB had included personal and social factors as affecting the intention of behavior change. The factors are

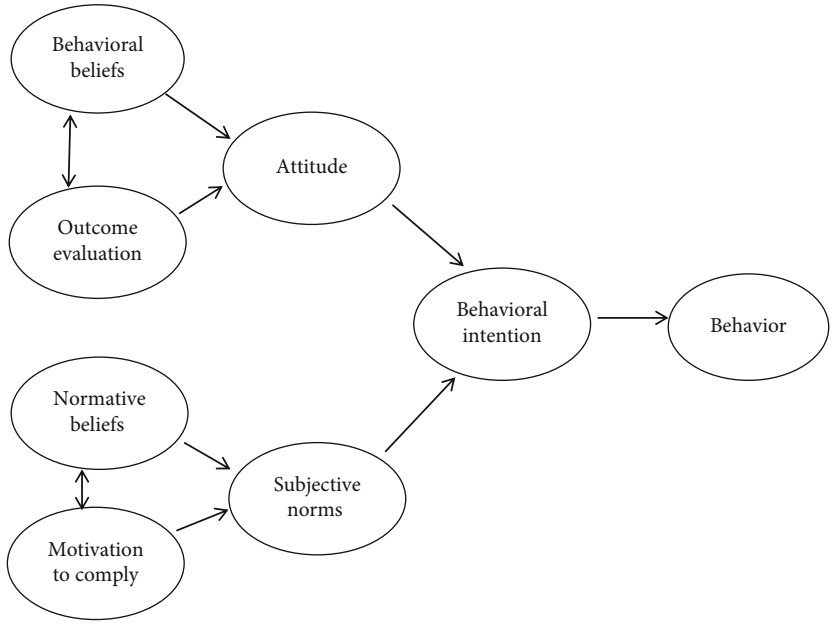

Figure 2: Theory of reasoned action [25].

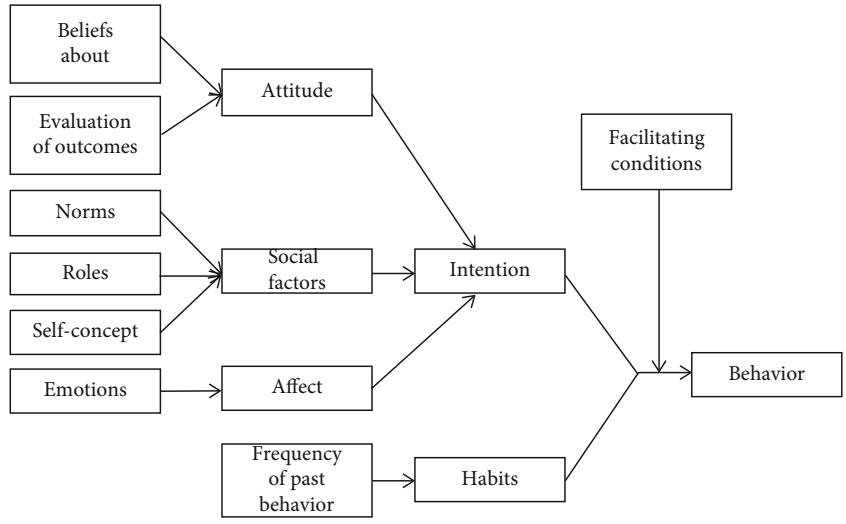

Figure 3: Theory of interpersonal behavior [26, 27].

arranged in three stages. At stage one, individual perceptions and societal influences determining the behavioral change are discussed. The stage two explains the factors such as affect, cognitive abilities, societal factors, and individual conceptions, which affect the targeted specified behavioral change. Thirdly, the intentions towards behavior, conditions in the prevailing situation, and previous experiences were discussed [26, 27].

3.4. A Model for Innovation-Decision Process. Rogers [16] conceptualized the innovation-decision process with five stages speculated in the adoption process. These stages are "Knowledge, persuasion, decision, implementation and confirmation." He had explained that knowledge acquires when a person is made aware of the presence of an innovation and its characteristics as well as on how it works. The individual reaches the persuasion stage upon the development of an attitude respective to the technology. This attitude can be either a positive or a negative one. Decision stage is reached when the individual profoundly conducts certain activities, which will lead to either accept or reject the innovation. The individual reaches the implementation stage when the innovation has been put into practice. Finally, the individual reaches the confirmation stage where the decision has been reinforced by the individual to be the final decision. But this confirmation might not be permanent. If the individual finds any conflicting information on the innovation, the decision might be revoked. The model is given in Figure 4.

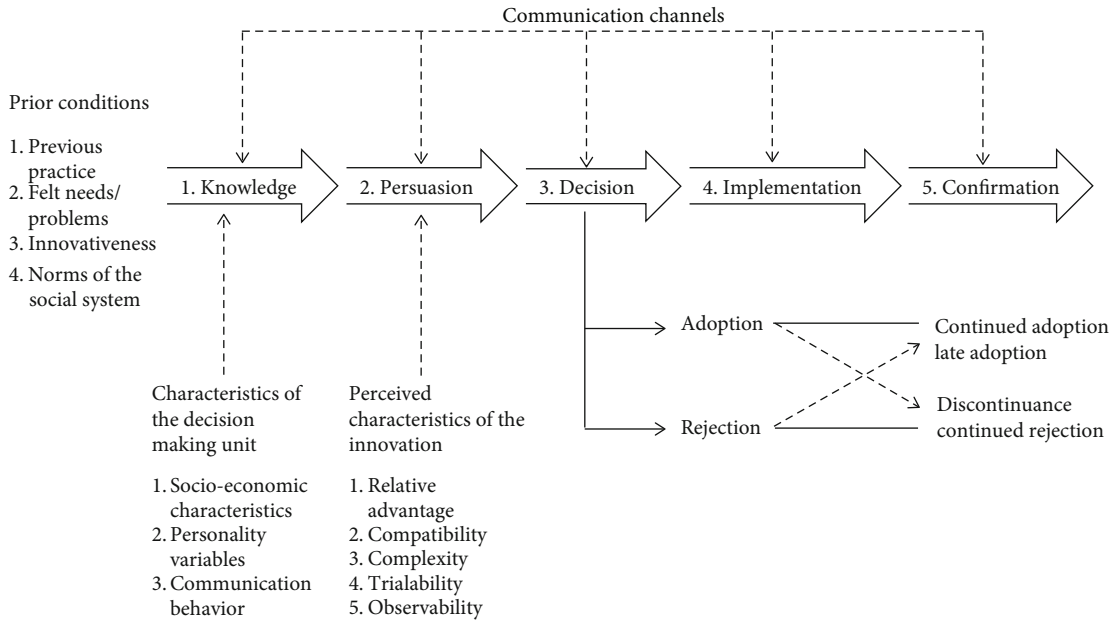

Figure 4: Model for innovation-decision process [16].

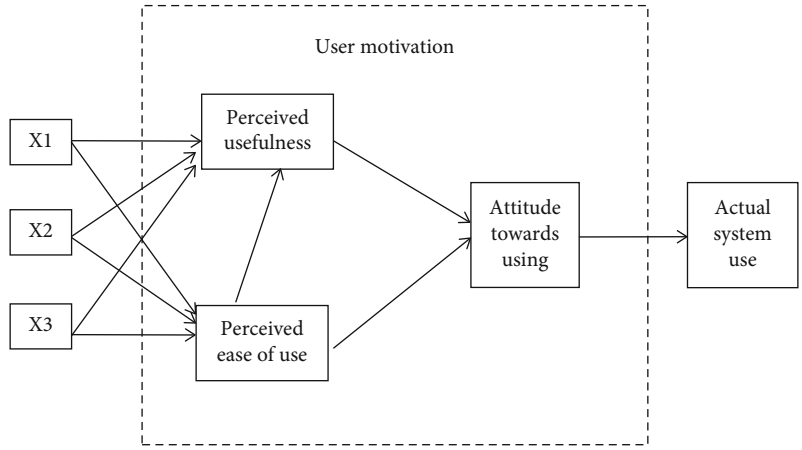

Figure 5: Original technology acceptance model [28].

3.5. Technology Acceptance Model (TAM). This model (Figure 5) was first speculated by Davis in 1985 [28]. This model was especially developed for describing the behavior of an individual towards the information technologies. But this is considered as a further development of theory of reasoned action too. Anyhow, the main concept is based on the characteristics of the technology and acceptance of it.

3.6. First Modified Version of Technology Acceptance Model (TAM). In 1989, Davis et al. had conceptualized the TAM to elaborate the factors affecting acceptance of the use of computers [29]. This further explains the behavior of the user towards a broad range of different computer systems as well as of different users. Unlike in other models, this model is totally based on two factors: "Perceived Usefulness and Perceived Ease of Use." Perceived usefulness describes the probability of using a specified computer technology to facilitate the activities done by the user. The perceived ease of use describes the level of easiness or effortlessness of the technology for the user when using it [30]. This model is depicted in Figure 6.

3.7. Theory of Planned Behavior (TPB). Ajzen had speculated this theory in 1991 [31]. It describes the behavioral intention of an individual as well and is shown in Figure 7. The attitude developed by an individual towards a certain behavior and subjective norms are described to be affecting the intention to use the behavior. Perceived behavioral control is also considered in this model to be a vital factor in determining the behavioral intention. The level of the individual's control

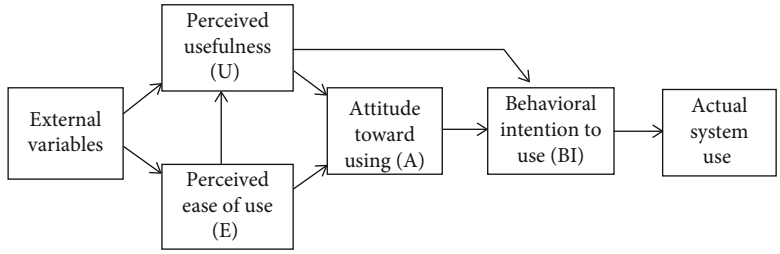

Figure 6: First modified version of technology acceptance model (TAM) [29].

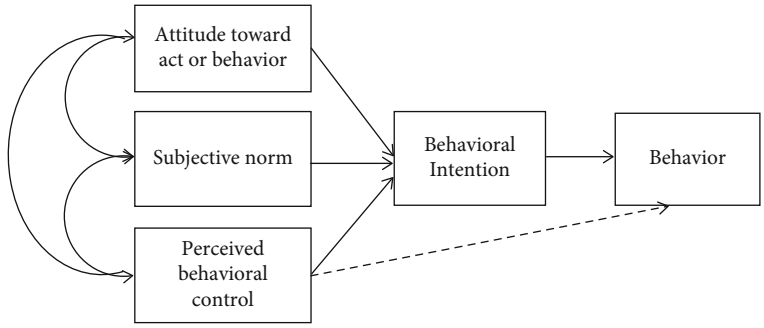

Figure 7: Theory of planned behavior [31].

over the specific behavior is believed to shape the ultimate decision of adopting the behavior. This is commonly used in agricultural, health, and education sector.

3.8. Decomposed Theory of Planned Behavior (DTPB). Taylor and Todd had developed this theory in 1995 [32]. The DTPB is based on three key influences, which affects the behavioral intention and the real scenario of adoption. The key factors of the TPB, which are attitude, subjective norms, and perceived behavioral control, are also included in this model. These factors depicted in TPB are described further and separately indicated at each main factor affecting adoption. The theory is shown in Figure 8. This is widely used in agriculture, marketing, and in educational sectors too.

3.9. Theory of Diffusion of Innovation. Rogers [3] had developed the theory of diffusion of innovation. This theory describes the adoption behavior of an individual and an organization towards an innovation. It discusses about the process through which the information about the new technology is being disseminated towards the members of a society or a social system, via specific channels over a period of time [3]. The theory describes this process by naming several stages, which a person will enter before adoption of a novel technology. These stages were, namely, "understanding, persuasion, decision, implementation, and confirmation." Rogers [3] has described an S-shaped innovation adoption curve for this process as well. Rogers [3] also mentions that this process makes way to group the adopters in to five categories, which are "innovators, early adopters, early majority, late majority and laggards." The S-shaped curve is depicted in Figure 9.

3.10. Task-Technology Fit (TTF). Goodhue and Thompson [33] discuss on the TTF of a technology. This model is depicted in Figure 10. It is assumed that having a "good fit" between the expected task to perform and the new technology introduced will promote the usage of the technology. It is further assumed that this good fit will enhance the impact of the performance. These enhancements will be due to the fact that the new technology is more appropriate in fulfilling the requirements and expectations of the end user. Thus, TTF model is much appropriate to analyze the actual fitness of a task and a technology in relation to the required qualities of the technology. This model is commonly used in information technology sector.

3.11. The Final Version of Technology Acceptance Model. This model was developed by Venkatesh and Davis [34, 35]. The model (Figure 11) describes that there is a strong and direct effect of the two main factors, which are perceived usefulness and perceived ease of use on the behavioral intention of an innovation. This had not considered the construction or effect of the attitude of the user towards the introduced technology. Furthermore, the model states about external factors to affect these two main factors too. This model is used in studies related to computer usage.

3.12. TAM 2. Venkatesh and Davis [36] again had developed the TAM (Figure 8) further on leading to TAM 2 (Figure 12). The TAM 2 had elaborated a much more detailed elucidation why the users had found a specific technology to be beneficial. The model examines three stages in time over the adoption process, namely, "pre-implementation, one month post-implementation and three month post-implementation." The TAM 2 depicts the psychological

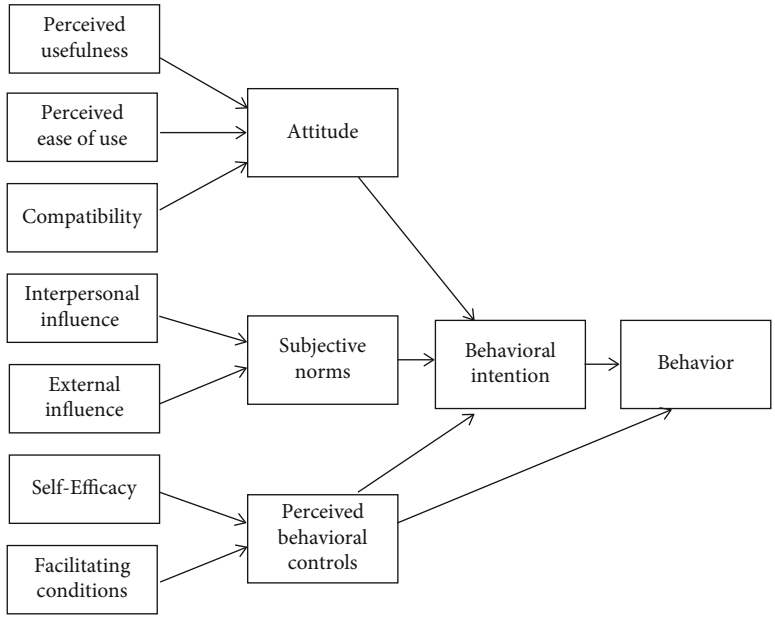

Figure 8: Decomposed theory of planned behavior [32].

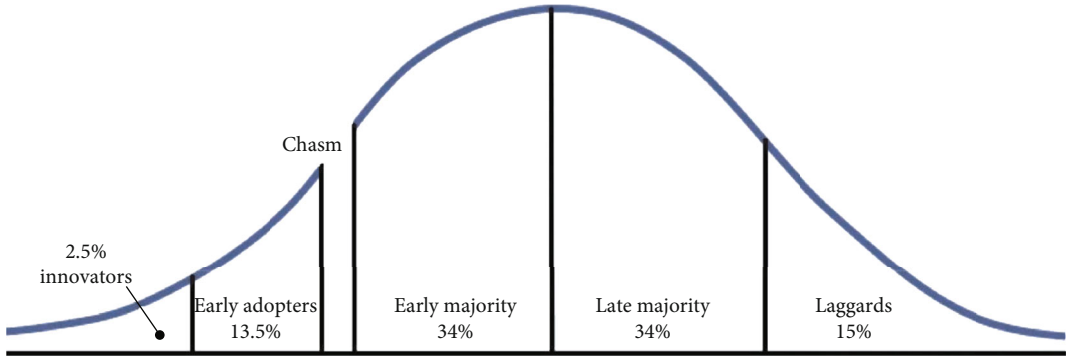

Figure 9: Innovation adoption curve [3].

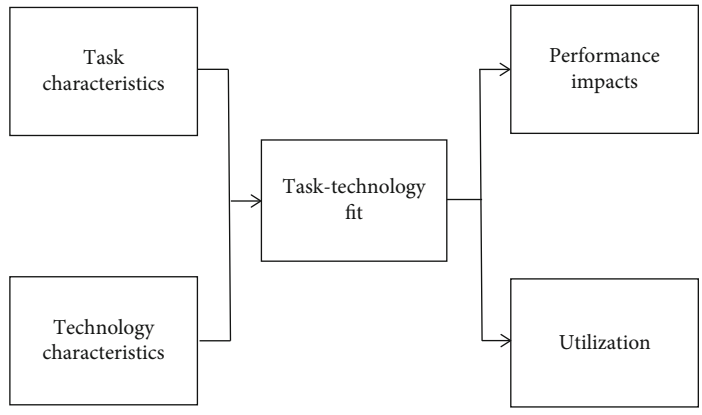

Figure 10: Task-technology fit [33].

evaluation of the expectations of the work and how suitable this new technology is to fulfill these expectations. This stays as the fundamental base in this model. This match between the task to be performed and the usefulness of the technology will shape up the perception developed towards the innovation [37]. Furthermore, TAM 2 had been a better

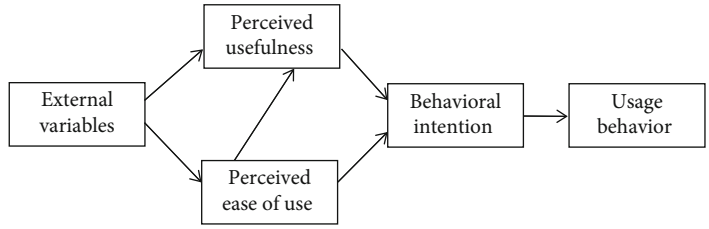

Figure 11: Final version of technology acceptance model (TAM) [34, 35].

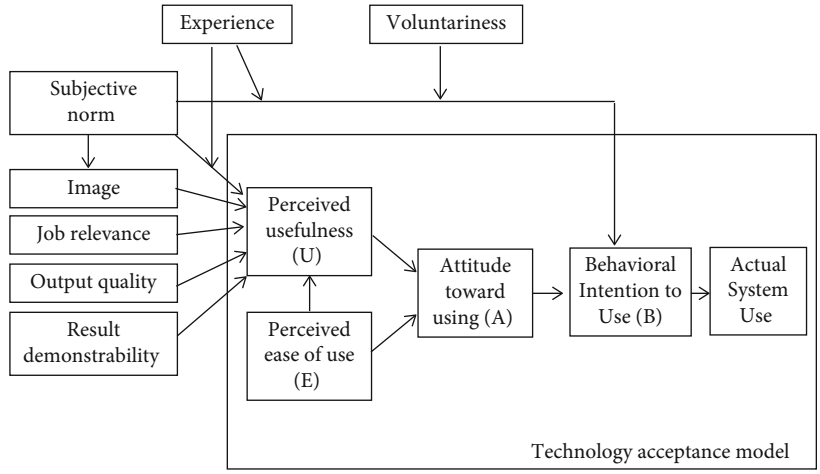

Figure 12: Technology acceptance model (TAM 2) [36].

explanatory model in both voluntary and mandatory environmental conditions.

3.13. Integrated Model of Technology Acceptance (TAM 3). Venkatesh and Bala [37] had further developed the TAM 2 developed by Venkatesh and Davis [36] into the TAM 3. This new model also had used the basics of TAM 2. But it had introduced more factors affecting the perceived ease of use of the technology into focus too. As depicted in Figure 13, the model was used in studying the technology adoption behavior in information technology sector. Venkatesh and Bala [37] had taken individual factors, which differentiate adoption between individuals, the characteristics of the IT system, societal influences, and the supportive conditions to describe the perceived usefulness and perceived ease of use. Furthermore, in TAM 3, experience of the user on the technology is also taken as a determinant of the behavioral change.

3.14. Technology Readiness (TR). Another categorization was done by Parasuraman and Colby [38, 39] to describe the technology adoption. This was developed by taking technology readiness of a person as the base. In this model, Parasuraman and Colby [38, 39] had defined the technology readiness (TR) as "people's propensity to embrace and use new technologies for accomplishing goals in household and at work." This is a similar model as TTF. Furthermore, the model had categorized these users of the introduced technology into five technology readiness categories, namely, "explorers, pioneers, skeptics, paranoids, and laggards." This depicts a comparable scenario to the categories of adopters in the S-shaped adoption curve developed by Rogers [3].

3.15. Unified Theory of Acceptance and Use of Technology (UTAUT). Venkatesh et al. [40] had claimed that they had developed this UTAUT after studying previous theories and models of technology adoption. The UTAUT developed by them is given in Figure 14. The UTAUT describes four main factors affecting the behavioral change of the user. These four are performance expectancy, effort expectancy, social influence, and facilitating conditions. These four depicts the expectations from the technology, perceived ease of use, societal effect, and the facilitating conditions, which are discussed by some other models as well. Furthermore, this model is much used in studies related to information technology.

3.16. Expectancy Livelihood Model (ELM). Petersen and Pedersen [41] introduced this ELM model (Figure 15). The technology adoption and usage of the livelihood approach in livelihood development programs are described in this model. It discusses different concepts in rural development. Vulnerability context given in this model indicates the situation where the targeted groups are living. The model emphasizes the level of vulnerability to risks, shocks, trends, and seasonal changes. The asset pentagon depicting the five

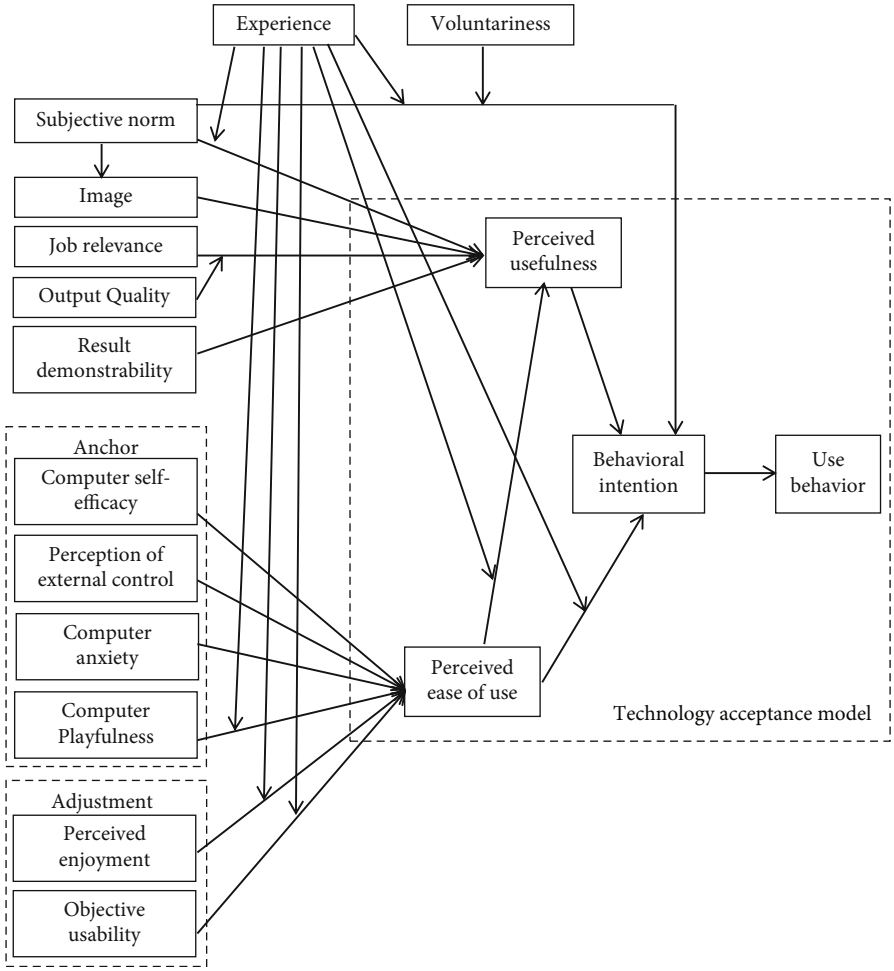

Figure 13: Technology acceptance model (TAM 3) [37].

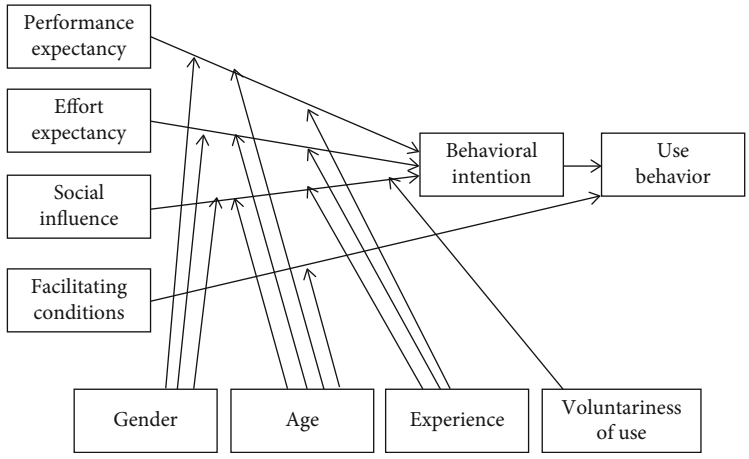

Figure 14: Unified theory of acceptance and use of technology (UTAUT) [40].

capital sources, namely, social, human, natural, financial, and physical capital, is used to evaluate the capital availability of the targeted population. The structures and processors are believed to be affecting the capital sources and the access of it. They are further connected in determining the vulnerability context while moving these people towards livelihood strategies. The capital assets are used to form livelihood strategies to generate the required livelihood outcomes.

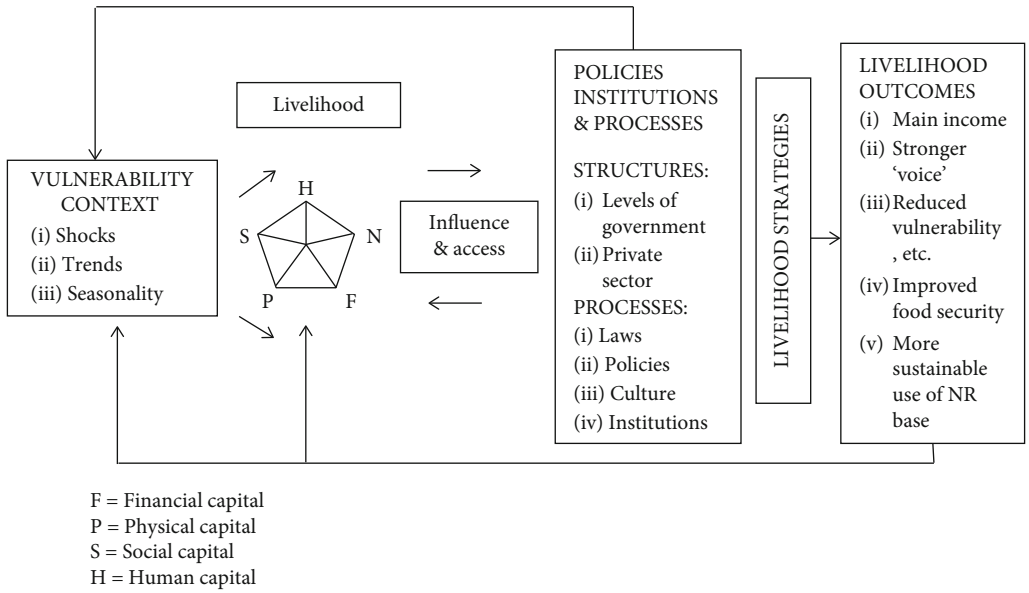

Figure 15: Expectancy livelihood model (ELM) [41].

3.17. Social Cognitive Theory (SCT). The SCT was introduced by Bandura in 1986 [42, 43]. Bandura had taken social psychology as the base in developing this theory. This is used in conducting studies related to rural and health sectors. The SCT described three key factors determining the behavioral change of a person. These three include the present behaviors or habits, mental ability referred as cognitive factors, and the surrounding environment including societal effects. Furthermore, the model describes a bidirectional interaction between these three factors. The behavior In SCT model is mainly concentrated in usage of the technology. This might be similar to the perceived ease of use described in other models. Personal factors included in this model are more related with the personality of the user, cognition, and even the demographic characteristics of the user. The environment described here had included both the physical environment and the societal environment of the user. The bidirectional interaction between the factors shows a continuous impact laid upon each other, which depicts the real scenario (Figure 16).

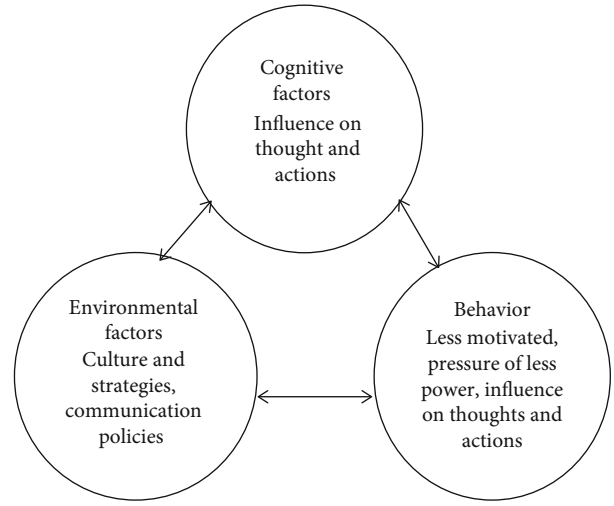

Figure 16: Social cognitive theory [42, 43].

3.18. Perceived Characteristics of Innovating Theory (PCIT). The perceived characteristics of innovating theory developed by Chen et al. [44] have extended the diffusion of innovation model (Figure 17) by defining three additional characters, namely, voluntariness, image, and behavior. The observability by the user would determine the intention to adopt. The observability constitutes of two subcharacteristics, namely, visibility and result demonstrability. The model describes that the perception of voluntariness influences the behavior. This perception of voluntariness is affecting the actual behavior than the voluntariness itself. Chen et al. [44] also had mentioned that when the technology is more demonstrable, it will facilitate the rate of adoption to increase rapidly.

3.19. Compatibility UTAUT (C-UTAUT). The different compatibility beliefs introduced by Karahanna et al. [45] and UTAUT model which was developed by Venkatesh et al. [40] were integrated together by Bouten in 2008 [46, 47] to develop this C-UTAUT model. The compatibility beliefs are taken as compatibility with preferred work style, compatibility with existing work practices, compatibility with prior experience, and compatibility with values. Furthermore, this model focuses on obtaining a thorough analysis on which ways that the cognition portion of the UTAUT model is shaped by recognizing and evaluating the new limitations.

3.20. The Basic Model of Human Behavior with Technologies. Zheng in 2020 [14] explains that all these different models

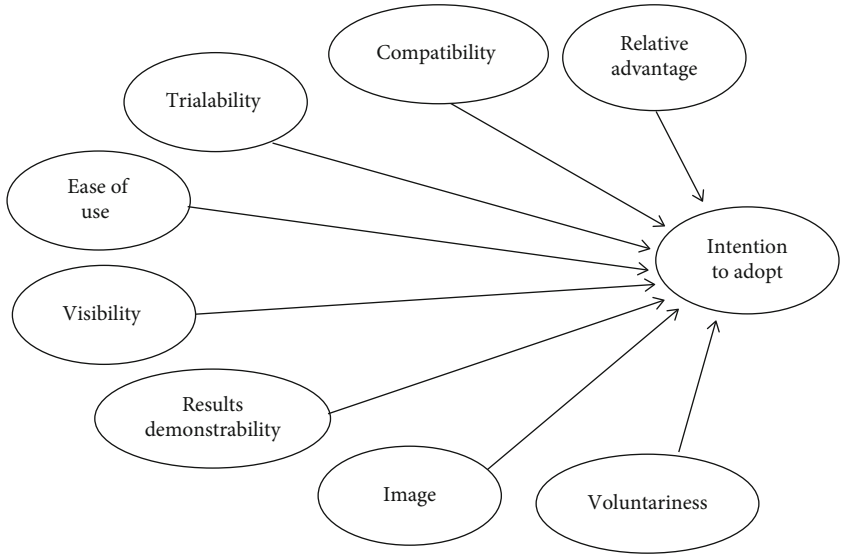

Figure 17: Perceived characteristics of innovating theory [44].

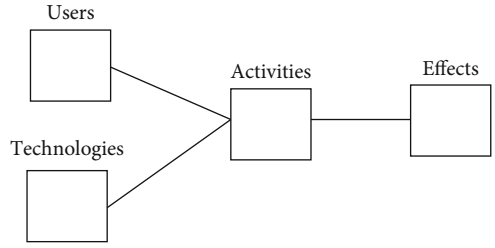

Figure 18: The basic model of human behavior with technologies [14].

can be fitted into one simplified model and that is the basic model of human behavior with technologies. This basic model elaborates four basic elements as users, technologies, activities, and effects (Figure 18). Zheng [14] had given many examples in his study for proving this phenomenon. Zheng has used digital technologies such as internet usage as an example. All factors related to the users of the technology are indicated under "Users," while all factors related to technologies are included under "Technologies". The activities or processes, which are required to make the desired outcome, are included under "Activities." The outcome or the effect of these activities is indicated under "Effect."

4. Discussion

There are a number of theories and models developed by many authors as described above. These theories have been evolved over time considering different factors. The factors varied depending on the objectives and the context of developing it. There are numerous similarities among those theories and models while some are extensions of the already established theories and models.

Many of these theories and models discuss adoption and the factors affecting it but not much on continuation of the adoption process. Adoption might take place after several attempts, but long-term continuation is also expected to follow adoption to improve the practices conducted by the stakeholders.

In the transtheoretical model, the termination of the required habit that needs to be changed is considered while maintenance of it is also discussed. Although this is widely used in medical research, its application in agriculture is very limited. But the model only describes about the personal attributes and the process within a person. It does not concern on the external factors such as social contacts associated with each stage of behavioral change.

In the theory of reasoned action also, factors affecting the behavioral change are taken into consideration. Additionally, personal as well as social factors are taken into consideration unlike the TTM. In TAM, the factors affecting the user motivation are not defined. Therefore, no clear indication is given of the factors affecting the perceived traits. This might lead to difficulties in determining the factors. But, simultaneously, it is kept open to include any factor that deem fit for the situation. The first modified version of the TAM indicates that the belief of an individual regarding a system might get affected by many other external variables. A final version of TAM was also developed. Attitudinal factors are also included when perceived attributes are discussed. Perceived usefulness and perceived ease of use are directly related with characters of the technology introduced and the task that has to be performed by using it. Additionally, when the term "Perceived" is used it is always related to personal attributes of the users. However, no other limiting factors such as economic constraints are taken into consideration. TAM 2 was then developed. In TAM 2, the technology-related factors and its effect on personal characters are also discussed. No social factors or other resources required for use of the technology are considered. This model is better for usage of ICT systems introduced to organizations. TAM 3 is introduced to IT systems. It is compatible with similar other factors when the system is introduced and all resources are physically present for usage.

This will deviate in agricultural technology adoption where the resources required have to be acquired by the user him/herself. But it would be compatible when the resources are already available and the practice is the question. This situation is similar to cases when subsidy programs are implemented.

TPB is commonly used in agricultural technology adoption studies. It considers attitude, subjective norms, and perceived behavioral control, which will lead to the willingness to adoption. The decomposed TPB describes the factors affecting all these three factors. The decomposed TPB gives a better explanation than TPB.

It is accepted that the technology adoption is directly related to the fact of the task-technology fit but is not alone responsible in technology adoption. TTF model discussed this relation. This model can be used to assess the technology-related factors that affect the adoption of the technology in focus. However, in other previous models, task-technology fit has also been considered in attitude. Therefore, in considering a total scenario of technology adoption, other models have better analyzing power than TTF.

Theory of TR is highly beneficial for an organization in order to understand the market segments of the customers for the new technology and then further plan and execute the marketing strategies. Further, it is beneficial to understand the stakeholders in extension and technology transfer for effective dissemination of technology to ensure adoption. This is a similar categorization as theory of diffusion of innovation. The categories of this theory are innovators, early adopters, early majority, late majority, and laggards. These theories explain the types of clients or the technology receivers in adoption process.

Perceived characteristics of innovating theory also describes the factors related to the technology and the ability to perceive the characters of it in determining whether to adopt or not. Although it does not discuss on the other factors such as personal and social, it gives better description on the technology characteristics in a different way to affect the decision-making process of technology adoption.

The model UTAUT tends to discuss a more reasonable scenario in technology adoption. It has captured the technology task fit, the social effects, and even the resource availability in facilitating conditions. Comparatively, this model has a better explanatory power than other models and theories.

Most of the technological advancement in agricultural sector is to introduce technologies either to ease the current practices, improve final quality of product, or as a livelihood development opportunity. But in all other theories and models, technology adoption is taken as the final objective and not much on the purpose of technology adoption. However, in expectancy livelihood model, a different scenario is discussed. It takes the technology adoption as a livelihood development opportunity. It describes about the capital sources, namely, financial, physical, social, human, and natural capital. All these capital sources have captured the social factors including the environment and the personal characteristics. Therefore, this model has a better explanatory power of the agricultural sector and the technology adoption with reference to livelihood development approach.

The social cognitive theory describes the effect of personal and environment on behavior. Furthermore, it describes on the interactions between these factors and the behavior itself. The author also agrees to the fact that in our social and environmental system, every factor is linked with each other. Therefore, this model depicts the interactions better than other models.

Rogers's model of stages in the innovation-decision process, although developed earlier than most models and theories discussed above, has the characteristics the others also have discussed. The personal characteristics, previous conditions of the individual, and perceived characteristics of the technology are also discussed with the factors of continuation, discontinuation, and even adoption at a later stage. Therefore, this also has a proper explanation of the scenario of adoption process. In most models, the process ceases at the level of technology adoption. However, in order to develop the agricultural sector and the livelihood of the people involved in it, continuation of use of the adopted technologies is highly essential. Therefore, including the situation after adoption is very useful.

Continuation of adding more and more factors will increase the explanatory power of a model. However, it will increase the complexity of the model too. Zheng's basic model had combined and compressed all these factors into four elements. All factors related to the user and the technology can be included under the elements of "user" and "technology," respectively. The factors related to activities such as obtaining knowledge and conducting trials can be categorized under the element of "activities." However, this model does not show the effect of social or environmental factors. It can be argued that these are related to all the basic elements of user, technology, and activities. This model also elaborates on the effect of the process, where this effect could be the technology adoption and the outcomes of the adoption as well. The outcomes might give an idea on the continuation or discontinuation of the adoption. This model has drastically reduced the complexity of many models and explains in a much simplified manner, which is a better characteristic. It has the capacity to fit any model into this basic model and simplify them. The author likes to suggest that it can be improved by adding an "environment" element.

Thus, in summarizing all these theories and models, the following categories of factors are affecting the adoption of technology.

(1) Factors related to technology

(2) Factors related to personal attributes

(3) Social factors

(4) Economic factors

It is understood that the technology is first being aware to the user. The personal characters of the user him/herself such as age and prior experience might affect this knowledge gain. The socioeconomic characteristics such as connections with peers and institutional influences will also affect the knowledge. Communication is another factor affecting the

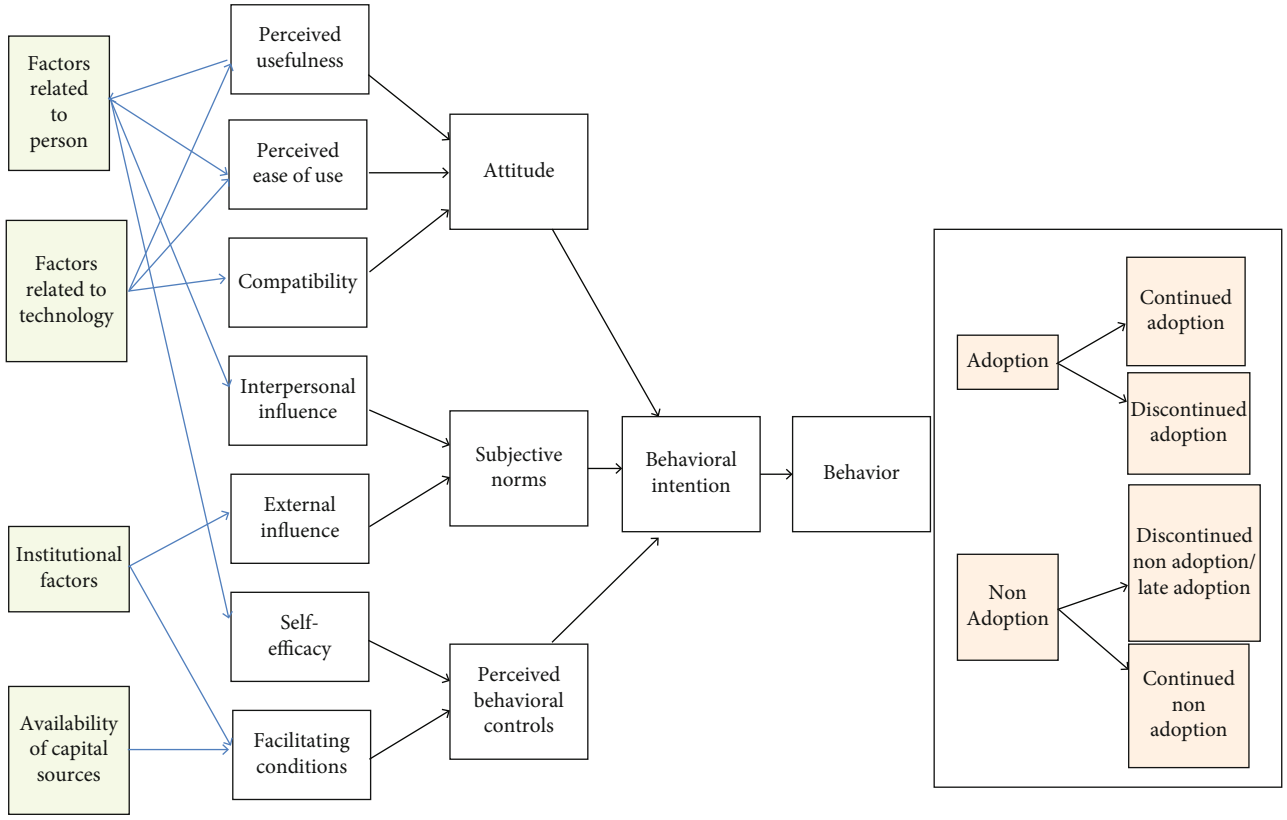

Figure 19: A collective approach model on technology adoption.

knowledge. Communication includes personal communication aspects as well as the information-receiving process.

After receiving the knowledge, the person will evaluate the information and will be persuaded to make a decision to adopt or reject it. Characters of novel technology such as relative advantage, complexity, compatibility, divisibility, and trialability will affect the decision. Furthermore, social issues such as norms and beliefs tend to affect it. Then, the availability of capital sources, which are physical capital, social capital, natural capital, financial capital, and human capital, will affect the decision of adoption or rejection of the technology. Once the decision is taken, it will go through a stage of continuation or discontinuation of the use of technology. Capital availability will again effect here. The issue of later adoption should also be taken into consideration.

Therefore, a collective approach (Figure 19) of all the literature reviewed is proposed to describe the technology adoption in agriculture sector. Thus, it can be concluded that many scientists have introduced various theories and models to describe the technology adoption in a variety of fields, some of them are either discrete, overlapping, or combinations of different models. Therefore, a separate model with all facts being considered can be developed to suit the agricultural technology adoption, which includes the factors related to personal, technology, social, and economic. The process should include the steps in awareness, evaluation, decision making, and actual adoption. If need to oversee the whole and actual scenario of technology adoption, the continuation and discontinuation of adoption as well as late adoption are required to be paid much attention. Rather than mere adoption, continuation will be the most crucial in developing the agricultural sector.

Data Availability

Because this is a review article, all data obtained are through published sources.

Conflicts of Interest

All authors have no conflict of interest.

Authors' Contributions

All authors have approved the manuscript.

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