Why Traditional Technology Acceptance Models Won't Work for Future Information Technologies

Carsten Röcker

***Abstract*—**This paper illustrates why existing technology acceptance models are only of limited use for predicting and explaining the adoption of future information and communication technologies. It starts with a general overview over technology adoption processes, and presents several theories for the acceptance as well as adoption of traditional information technologies. This is followed by an overview over the recent developments in the area of information and communication technologies. Based on the arguments elaborated in these sections, it is shown why the factors used to predict adoption in existing systems, will not be sufficient for explaining the adoption of future information and communication technologies.

***Keywords*—**Technology Diffusion, Technology Acceptance Models, Ambient Intelligence, Ubiquitous and Pervasive Computing.

I. Diffusion of Innovations

IN ORDER to understand the importance of technological acceptance when introducing new technologies, it is important to be aware of the different steps of the diffusion process. Diffusion, in the context of innovation research, usually refers to "the process, by which an innovation is communicated through certain channels over time among the members of a social system" [66]. Research related to the diffusion of innovation has a quite long tradition, with first articles being published in the early 1940s (see, e.g., [68]). As new technologies are usually first used for commercial applications, the focus of this section will be on technology adoption in companies. In its easiest form, the diffusion process consists of two stages: adoption and implementation (see Figure 1). The adoption stage includes sub-stages of knowledge acquisition, persuasion and learning, and decision, leading to the actual adoption decision [61]. The process of innovation adoption can happen in different ways, which will be described later in more detail.

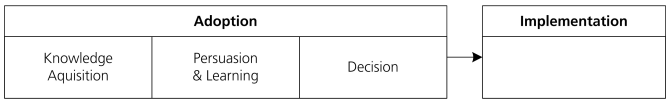

Fig. 1. Different stages of the innovation diffusion process according to Prescott and Conger [61].

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Several factors directly influence the diffusion process. According to Prescott and Conger [61] those factors include the characteristics of the innovation, the social system and the communication channels, which are all interacting over time (see Figure 2).

Fig. 2. Factors affecting the innovation diffusion process according to Prescott and Conger [61].

Within organizations, technology adoption mostly occurs in a two-step process (see, e.g., [43] or [45]). In the first step, the decision to adopt the technology is made on management level and is usually referred to as the 'primary adoption'. The innovation decision is then followed by actual introduction of the technology to the work place, where it has to be adopted by users (secondary adoption).

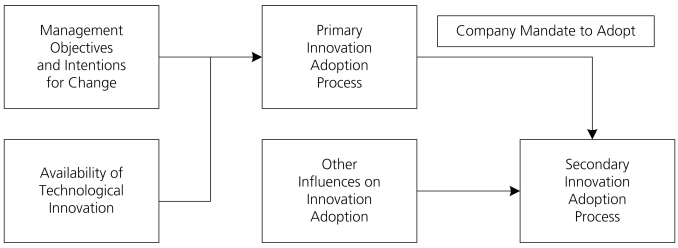

Fig. 3. Process of innovation adoption within organizations [30].

Depending of the adoption decision in the first and second stage, different types of innovation adoption are possible (see Table 1). As shown in the lower left cell of the matrix, the primary adoption decision does not guarantee, that the innovation will actually be implemented or used by the targeted users [30].

TABLE 1: TAXONOMY OF TWO-STAGE INNOVATION ADOPTION TYPES ACCORDING TO GALLIVAN [30].

	Primary Adoption	**No Primary Adoption**
Secondary Adoption	Authority-Based Innovation Adoption	Bottom-Up Adoption
No Secondary Adoption	Adoption, but no Deployment	Non-Adoption

The secondary adoption process can be influenced in different ways. Gallivan [30] distinguishes between three fundamentally different ways, how organizations can ensure secondary adoption: First, the organization can mandate that the innovation is directly adopted by all users. Second, the organization can provide the necessary infrastructure and support for users to adopt the innovation, while allowing it to diffuse voluntarily. Third, the organization can target specific pilot projects within the company, observe the processes and outcomes that unfold and decide, whether to implement the innovation more broadly later on.

Saga and Zmud [69] explored the different stages of IT innovation. Based on their findings they developed a three-stage model, including the steps of acceptance, routinization and infusion. According to this model, acceptance affects use, use affects routinization and routinization finally affects infusion [61]. Hence, it is of particular importance, that technological innovations are accepted in order to enable routinization and infusion in the second and third step.

II. TECHNOLOGY ADOPTION THEORIES

Predicting the adoption and use of information technology has been a key interest since the early days of information systems research [14]. The main goal of technology acceptance theory is, to explore the factors that influence the adoption and diffusion of new technologies throughout a social system [8]. Over the years, several independent theories for the acceptance as well as adoption of information technology have been developed. Most of these models apply to situations, in which individuals can voluntarily choose whether to adopt an innovation or not [30]. Adoption, in this context, refers to the process of choosing a specific innovation or technology (see, e.g., [18]). In the following sections the most prominent theories and models will be briefly outlined.

A. Innovation Diffusion Theory

One of the first theories was the *Innovation Diffusion Theory* developed by Rogers [66]. The Innovation Diffusion Theory sets forth a five-stage model describing the process, by which an innovation is communicated among the members of a social system [10]. Based on his observation of innovation diffusion over nearly three decades, Rogers [67] defined a developed specific innovation characteristics explaining the result of the diffusion process. Barnes and Huff [8] summarize the set of key characteristic as the following:

- *Relative Advantage*
  (the degree, to which the innovation is perceived as being better than the practice it supersedes)
- *Compatibility*
  (the extent, to which adopting the innovation is compatible with what people do)
- *Complexity*
  (the degree, to which an innovation is perceived as relatively difficult to understand and use)
- *Trialability*
  (the degree, to which an innovation may be experimented with on a limited basis, before making an adoption decision)
- *Observability*
  (the degree, to which the results of an innovation are visible to others)

The Innovation Diffusion Theory served as the basis for a variety of other models in the area of technology adoption. One of the better known theories was developed by Moore and Benbasat [59][60]. Based on the original theory of Rogers [66], they developed a survey instrument using eight 'belief scales', which were specific tailored to the adoption and diffusion of information technology.

B. Theory of Reasoned Action (TRA)

Another model, dating back to the same time as the Innovation Diffusion Theory, is the *Theory of Reasoned Action* (TRA) developed by Ajzen and Fishbein (see, e.g., [29] or [6]). TRA is a social psychology model, describing the determinants of consciously intended behaviors [10]. The model focuses on predicting behavioral intention and actual behavior, based on behavioral beliefs and subjective norms [47]. In the context of technology adoption TRA postulates, that actual use of a specific technology is influenced by the user's behavioral usage intention, which in turn depends on the user's attitude towards the use of the technology as well as the subjective norms of using the technology predominant in the user's social environment [8].

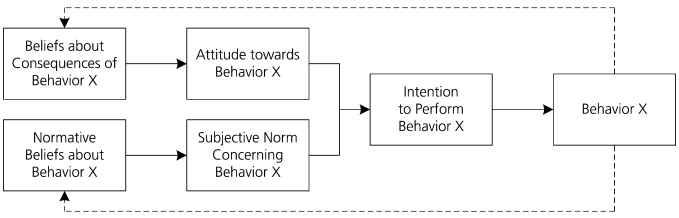

Fig. 4. Theory of Reasoned Action Model according to Mao and Palvia [47].

C. Theory of Planned Behavior (TPB)

Similar to the Innovation Diffusion Theory, the original TRA model was extended by several authors. The most important extension is probably the *Theory of Planned Behavior* (see, e.g., [77] or [48]). The Theory of Planned Behavior (TPB) was developed by Ajzen and Madden [4][5] and is based on Ajzen's previous work on TRA (see above). The TPB model extends the Theory of Reasoned Action by including the variable of 'perceived behavioral control', which measures a person's perception of control over performing a given behavior [62]. As shown in Figure 5, TPB postulates

that the intention to adopt a specific technology is determined by three factors: the user's attitude, his subjective norms and the perceived behavioral control. Each factor, in turn, is generated by a number of beliefs and associated evaluations [10].

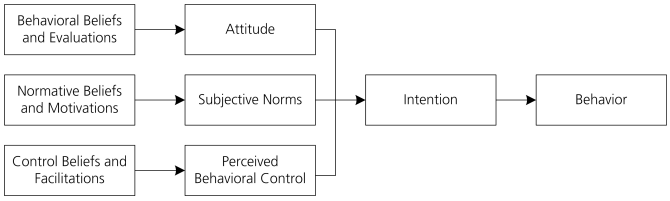

Fig. 5. Theory of Planned Behavior according to Benham and Raymond [10].

The TPB model has been studied by a variety of authors (see, e.g., [15], [36], [40] or [77]), and proved to be reliable in predicting and explaining user behavior in several application areas. Based on the original TPB model, Taylor and Todd [76] extended the Theory of Planned Behavior and created the so-called *decomposed TPB model*. In their model they replaced behavioral, normative and control beliefs and their associated weights with new constructs specific to information systems, that are believed to be important in different usage situations [49].

D. Technology Acceptance Model (TAM)

The *Technology Acceptance Model* (TAM) was developed by Davis (see [23] or [24]) and often cited as the best-established model of IT adoption and use [7]. TAM is a further adaptation of the Theory of Reasoned Action. But while TRA is a general theory of human behavior, TAM was mainly designed for modeling user acceptance in information systems [49]. Similar to the previous theories it is assumed, that users could choose to employ a specific technology based on individual cost-benefit considerations (see [21]).

The Technology Acceptance Model presupposes, that two particular constructs determine the user's acceptance of a technology: *perceived ease-of-use* (PEOU) and *perceived usefulness* (PU). According to the definitions of Davis et al. [24], PEOU refers to "the degree, to which the [...] user expects the target system to be free of effort", while PU describes the individual's "subjective probability, that using a specific application system, will increase his or her job performance within an organizational context".

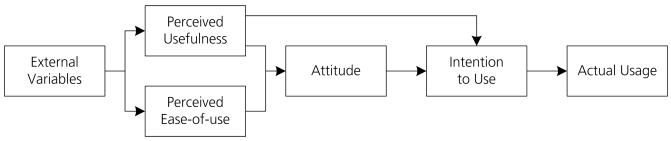

Fig. 6. Original Technology Acceptance Model [24].

As shown in Figure 6, the Technology Acceptance Model suggests, that the user's decision to use a particular system evolves over four stages. Davis el al. [24] believe, that external variables (like individual abilities or situational constraints) indirectly influence technology usage through their impact on PEOU and PU. Both PEOU and PU affect the user's attitude towards the technology, which, in turn, influences the intention to use the technology [49]. As shown in the diagram, there is also a direct impact of perceived usefulness on the user's behavioral intention to use the technology. This is due to the fact, that even if individuals have a negative attitude towards a specific technology, this could be outweighed by a positive belief about the system's usefulness, which should finally lead to a positive usage intention (see [47]).

Over time, the original TAM model was slightly modified in order to incorporate new findings. Testing the original TAM model, several studies found, that attitude did not fully mediate the effect of PU on usage intentions [14]. Therefore, the current version of TAM does no longer include the user's attitude towards the technology (see, e.g., [79] or [83]).

The Technology Acceptance Model has been tested by numerous authors, including Adams et al. [1], Hendrickson et al. [37], Igbaria et al. [38], Riemenschneider et al. [63], Subramanian [74], Szajna [75], Taylor and Todd [76] or Chin and Todd [19]. In most of these studies, the TAM model was able to explain a reasonable amount of variance in the actual use of the technology [7]. An up-to-date review of existing TAM studies and meta analyses can be found in [46] or [42].

Based on these studies, the original TAM model was extended by various authors to incorporate additional variables, that may account for more variance in technology usage [7]. The additional variables included perceived system performance [44], perceived user resources [49], prior experiences with similar technologies [3][76], age and education [3] as well as personal innovativeness [2]. Further extensions of the Technology Acceptance Model were done by Chin and Todd [19], Segars and Grover [70], Venkatesh [80], Venkatesh and Davis [81], Venkatesh and Morris [82] as well as Gefen and Straub [31].

E. Task-Technology Fit Model (TTF)

In contrast to the previous adoption theories, the *Task-Technology Fit Model* (TTF) makes the general assumption that users will choose the technology, which is most appropriate for the task they intend to perform. Based on this assumption, the TTF model postulates that a new technology will only be used, if the provided functionality 'fits' the activity of the user [27][34]. As shown in Figure 7, the basic TTF Model is based on four key constructs: task characteristics, technology functionality, fit between task characteristics and technology functionality, and technology utilization as the outcome variable [73].

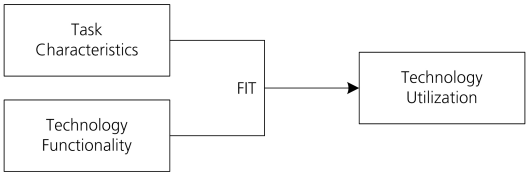

Fig. 7. Basic TTF Model according to Strong et al. [73].

The TTF Model has been used in a variety of different task domains. For more details on the usage of the Task-Technology Fit Model as well as comprehensive examples of TTF evaluations see, e.g., the studies of Goodhue [33][34][35] or Dishaw and Strong [25][26][27][28].

F. General Model of Technology Acceptance

Although both TPB and TAM proved to be quite successful for themselves, each model has its individual advantages over the other. Mathieson et al. [49] did an extensive comparison of both models and found, that in most cases TAM is easier to apply when predicting IS usage, but TPB includes more effects, which may be important in specific situations. Combing the individual strengths of the initial theories led to a new model called the *General Model of Technology Acceptance* (see [8]).

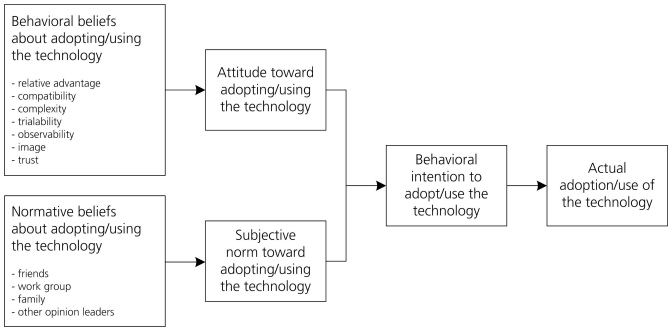

Fig. 8. General Model of Technology Acceptance according to Barnes and Huff [8].

In addition to these models, a variety of other approaches have been developed over the last 20 years. The *Social Cognitive Theory* by Compeau and Higgins [20] or the *Infusion Model* by Cooper and Zmund [22] are only two examples among others. A more recent approach is the *Unified Theory of Acceptance and Use of Technology* (UTAUT) formulated by Venkatesh et al. [83]. UTAUT is a further development of different existing models and is based on four core determinants (performance expectancy, effort expectancy, social influence, and facilitating conditions) and four moderators of the key relationships (experience, voluntariness, gender, and age).

III. Characteristics of Future Information and Communication Technologies

A. The Digital Revolution

The role of computers has dramatically changed within the last decades [65]. The increase in processing power and availability did not only influence the way people use computers, it also gave rise to fundamentally new forms of personal communication and information exchange. Only 30 years ago, companies usually had a single mainframe computer, which cost several millions, needed a whole computing center to be operated, and was jointly used by all employees of the company [51][54]. With smaller and more affordable computers becoming available in the early eighties, the age of personal computing began. Computers became widespread office tools in most companies, and over the years each user was working on his own personal computer.

Today, the initial numerical relation between users and computers has inversed [56]. Each user has a least one personal computer and uses a number of additional micro-processors embedded in everyday objects, like telephones and cars. This age of ubiquitously available computing devices was identified by Weiser [84] already in the early 1990s as the third wave of computing. He envisioned a transition towards calm technologies that recede into the background of our lives and assist us in our everyday activities.

Networking probably brought the most significant change in the usage of personal computers during the last years [8]. Since its introduction in the early 1970s, it changed from an experimental research network, primarily used by computer scientists, to what is known today as the world-wide web and used by billions of users for e-mail communication and web browsing [52][53]. As networking technologies and bandwidth are constantly improving, a variety of new services became available within the last years. After web-based multimedia applications in the 1990s, broadband network appliances became widely available within the last years. And according to studies of large electronic companies [71], the transition to a ubiquitous network society will take place within the next five to seven years. For the future, an even more dramatic shift in the usage of the internet is anticipated. While people today communicate via browsers with machines (web servers), the internet of the future is expected to be used principally for machine-to-machine communication, or rather, object-to-object communication [50].

B. Moore's Law

The ongoing development of new devices and applications is supported by continuous technological progress in the area of micro-electronics as well as by an ongoing decrease in the prices of processors and memory. This trend was already identified by Gordon Moore in the mid-sixties and is today referred to as 'Moore's Law' [58]. In its original form Moore's Law states, that the complexity of integrated circuits doubles every year. In 1975, Moore corrected his initial estimate to a duplication of complexity every two years.

Today, Moore's Law is used in a slightly altered way expressing that the performance of computers doubles every 18 months, while size and price are decreasing [54]. Although Moore's Law is not a law in a scientific sense, its underlying assumption held true with an amazing precision and constancy over the last 30 years [54]. A similar development is also visible in the field of storage components. Over the last years storage capacity doubled approximately every two years, while prices are continuously dropping [55]. Moore's Law is expected to be valid for at least another 10 to 15 years, which means that processors and storage components will become much more powerful, smaller and cheaper in the future, so that there will be an almost unlimited supply of them (see, e.g., [11], [12] or [13]).

C. Towards Smart Objects and Environments

Research in the area of information and communication technology is rapidly progressing, and a variety of new technologies are on the threshold to emerge. Extrapolating the current developments, we soon have to expect work environments, where computers are ubiquitously available in different forms and sizes. The increasing miniaturization of computer technology is expected to result in processors and sensors being integrated into more and more everyday objects, leading to the disappearance of traditional input and output media, such as keyboards, mice and screens [11][12][13]. This coming 'post-PC' era will be characterized by environments, where computers no longer primarily appear in form of a personal computer, and in which "a billion people are interacting with a million E-Businesses through a trillion interconnected intelligent devices" [52]. This vision of *Ambient Intelligence* foresees the integration of a variety of tiny microelectronic processors and sensors into almost all everyday objects, which enables an environment to recognize and respond to the needs of users in an almost invisible way. Ambient Intelligence applications are characterized by a high degree of embeddedness, using computers integrated into the physical environments in order to provide a variety of context-adapted user services. The recent developments in the mobile phone sector are often cited to be a forerunner in this new technological field. Today, smart phones are fully functional computers, equipped with a broad range of additional functionality, such as localization technology, internet connectivity and voice recognition [53].

IV. Short-Comings of Existing Technology Acceptance Models

Over the last two decades, numerous studies about technology acceptance have been conducted in different fields. The technologies and applications being tested include e-mail programs [2][24][41][47][72], internet banking [17], electronic commerce applications [57], word processors [16][24], electronic meeting systems [32] and tools for computer-aided software engineering [85][39]. In most of these studies existing models, like TAM, TRA or TPB, were able to explain and predict the adoption process sufficiently well.

Systems tested in the past, usually consisted of a personal computer with a standard software application and a single user working with this system in a private work situation. In contrast, future information technologies will be designed to continuously support users in technology-enhanced environments by providing a variety of personal and context-adapted services throughout the day. Hence, future technologies will not only break the constraints of time and place, but they will also vary significantly regarding their degree of autonomy. Several authors, like, e.g., Tennenhouse [78] anticipate future environments, in which networked computers proactively anticipate our needs and, sometimes, even take actions on our behalf.

Consequently, factors like ease-of-use, which were used to predict technology adoption for the last 20 years, might not be appropriate anymore. At the same time, new factors, which are not integrated in any of the existing models, might play crucial roles in the adoption decision. For example, a recent study showed that the social situation, in which a context-aware technology is used, significantly influences the acceptance of the system [64]. A similar study by Beier et al. [9] underpins those findings and shows that the acceptance of future information technologies is not determined by usefulness and ease-of-use alone, but is also affected by a variety of other factors. Hence, it is important to identify the factors, which are actually influencing the acceptance of context-aware systems and use this knowledge to adapt existing acceptance model to the characteristics of future information systems.

V. Conclusion

This paper illustrated why existing technology acceptance models are only of limited use for predicting and explaining the adoption of future information and communication technologies. It started with a general overview over technology adoption processes, and presented several theories for the acceptance as well as adoption of traditional information technologies. This was followed by an overview over the recent developments in the area of information and communication technologies. Based on the arguments elaborated in these sections, it was shown why the factors used to predict adoption in existing systems, will not be sufficient for explaining the adoption of future information and communication technologies.

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