RESEARCH ARTICLE

Factors Affecting the Adoption Intention of New Electronic Authentication Services: A Convergent Model Approach of VAM, PMT, and TPB

EUNCHAN KIM[ID][1] **AND YEUNWOONG KYUNG**[ID][2]

[1]Department of Intelligence and Information, Seoul National University, Gwanak-gu, Seoul 08826, Republic of Korea

[2]Division of Information and Communication Engineering, Kongju National University, Cheonan, Chungcheongnam-do 31080, Republic of Korea

Corresponding author: Yeunwoong Kyung (ywkyung@kongju.ac.kr)

ABSTRACT This study empirically analyzes factors affecting the adoption and recommendation intentions for next-generation electronic authentication services based on a convergent model of the value-based adoption model (VAM), protection motivation theory (PMT), and theory of planned behavior (TPB). As a result of the analyses, perceived benefits and perceived sacrifices (based on the VAM), perceived threats (based on the PMT), and adoption motives (based on the TPB) are found to significantly impact the adoption and recommendation intentions. The verification results demonstrate that all factors (and sub-factors) — perceived benefits (perceived usefulness and enjoyment), perceived sacrifices (technicality and perceived fee), perceived threats (perceived susceptibility and severity), and adoption motives (adoption attitude, subjective norm, and perceived behavior control) — have a significant effect on adoption intentions. Further, all variables and sub-factors, except for technicality in perceived sacrifice, have a significant effect on recommendation intentions. This study provides theoretical and practical guidelines that are helpful for future development, dissemination, and promotion strategies of new electronic authentication technologies demanded and expected by most financial consumers. At the same time, it verifies the validity and rationality of the convergent model based on the three theories, thereby presenting an in-depth and expanded methodology for theoretical model application.

INDEX TERMS Adoption intention, electronic certification services, protection motivation theory, recommendation intention, theory of planned behavior, value-based adoption model.

I. INTRODUCTION

A. THE NEEDS AND PERSPECTIVE OF THE STUDY

Competition in the domestic electronic authentication service market has accelerated since the Digital Signature Act was revised in May 2020 to abolish the monopoly status of accredited certificates. Accredited certificates, which were the representative method of digital authentication in Korea until 2020, were guaranteed a superior position in the domestic market based on the Digital Signature Act of 1999. Hence, they were used extensively and exclusively in all fields that required digital authentica-

The associate editor coordinating the review of this manuscript and approving it for publication was Zheng Yan[ID].

tion and signatures, such as online and mobile banking and e-government [1]. However, controversies continued over certificate leaks, security issues (such as Active-X), and the limit of support to specific platforms. Accordingly, security tokens, non-Active-X methods, and browser certificates were proposed as countermeasures; however, they too were not free from similar controversies or problems. While the accredited certificates do not fully satisfy users' requirements or the essential elements of digital security, the Digital Signature Act was amended in 2020 to abolish the monopoly status of accredited certificates after the Ministerial Meeting on Regulatory Reform in 2014 and the continuous collection of opinions from various fields [2].

Due to the abolition of exclusively accredited certificates, next-generation electronic authentication services equipped with new technologies are being competitively researched, developed, and released. The next-generation electronic authentication service is divided into two types — fast identity online (FIDO), based on biometric technology; and decentralized identifier (DID), using blockchain-based decentralization technology. Neither service has a clear competitive advantage over the other. However, from the point of view of improving service quality and improving user experience (UX) through fair competition and the pluralistic and diversified development of future technologies, it is desirable to ensure that various technologies and services continue to compete openly and horizontally rather than a specific method having a monopoly. This will enable the smooth performance and maintenance of two-way communications and co-creation between developers, suppliers, and users.

This study is aware of this problem and hence, uses empirical investigation to analyze and clarify the variables that affect general users' adoption and recommendation intentions for the next-generation electronic authentication service. We attempt to examine which factors are prioritized by users in the process of newly selecting and adopting next-generation electronic authentication services such that they can be trusted and used for a long time in the future. This is in the context of replacing the accredited certificate, which has either been used habitually for a long time in the past, or because there was no alternative. At a time when technologies or services in a specific field are being extensively replaced, or important innovations are in progress, examining the factors that affect users' intentions to adopt, change or continue using new technologies and services in the future will provide meaningful insights for their development direction and strategy. Analyzing factors that affecting the adoption and recommendation intentions, it is possible to reconfirm areas where existing technologies and services do not satisfy users, and use this information to comprehensively and reflectively review the development direction of new technologies.

This study uses theories that explain the process of judging, deciding and executing new selections or planned behaviors to logically and scientifically identify the factors that affecting the adoption and recommendation intentions for new technologies or next-generation services. These results have important strategic significance. First, this study references and employs the value-based adoption model (VAM) — a theory related to the adoption or continued use of new technologies — in the context of adopting next-generation electronic authentication services. The VAM not only includes the perceived benefits or benefits that users get from new technologies, but also includes the perceived sacrifices, i.e., the time, effort, technicalities, and financial costs required for the adoption and use of new technologies. It is thus, regarded as a balanced analysis model that proposes to analyze the effect on adoption and uses intentions

from various angles by equally verifying the positive and negative factors of new technologies [3]. Using the VAM as an analysis tool, this study aims to analyze and prove the factors that affect users' adoption and recommendation intentions for the next-generation electronic authentication service. Users who are dissatisfied with the service quality of the existing electronic certificates will approach the next-generation electronic authentication service with an open attitude, carefully considering the perceived benefits and sacrifices from its adoption. Given these predictions, the VAM is judged to be a useful option as the grounded theory of the study.

Second, users who perceive the security vulnerabilities and personal information leakages in the existing electronic certificate systems as serious threats will genuinely consider switching to or adopting the next-generation electronic authentication service. Regarding this path, the protection motivation theory (PMT) can be referenced. PMT is a theory that states that individuals who perceive actual and potential threats surrounding them take active protective actions against them [4]. PMT can provide a valid basis for explaining the behavior of users who newly adopt next-generation electronic authentication services as an active protective action based on their perceived threat to the current electronic authentication technology and service.

In the process of selecting and adopting new technologies and services, most users go through a process of careful consideration and rational judgment, rather than making a sudden or impulsive decision. The theory of planned behavior (TPB) — a theory that explains this planned and rational behavior — is used as another analytical framework for this study. Users preparing and planning to utilize the next-generation technology instead of the current authentication service will maintain a reasonable attitude toward the new technology, appropriately refer to the social perceptions and reactions of the surrounding people, and make important decisions while voluntarily controlling their attitude and behavior. As such, [5] explains people's planned behavior with three factors — rational attitude, awareness of social norms, and perceived behavior control. Thus, it can be a valid basis to explain the internal and psychological characteristics of users who make such important decisions, such as the adoption of new technologies.

By utilizing three theories — VAM (analyzes psychological and attitude variables related to the adoption of new technologies), PMT (identifies the causes and processes of actions in response to current perceived threats), and TPB (analyzes the process of performing prepared and planned behaviors in advance in a convergent and composite manner) — this study aims to build theoretical and practical guidelines for the proliferation, commercialization, and popularization of next-generation electronic authentication services. So far, research related to next-generation electronic authentication services has not matured due to the topic being very contemporary, and because a small number of studies have solely focused on analyzing and forecasting technical and industrial

characteristics, advantages, or market trends. As a result, very few studies have been conducted to specifically analyze the psychological, behavioral, and social variables that affect the perceptions, attitudes, and behaviors of individuals who will be the main users of the new technology. Further, as the next-generation electronic authentication service is yet to be popularized and disseminated, the need to analyze users' perceptions and attitudes about it has not been so demanding. This has made it difficult to find directly related studies. However, in order to realize the qualitative development and high performance of electronic authentication services and systems, it is necessary to proactively induce and promote the adoption and recommendation intentions of next-generation technologies to individual users. Based on this awareness of this problem and the need for research, this study aims to provide theoretical and practical guidelines that can help with disseminating next-generation electronic authentication services. This is done by providing a theoretical basis to analyze the various factors that affect how users perceive and adopt the value of next-generation electronic authentication services.

B. PURPOSE OF THE STUDY

Given the above problem definition, this study sets the following objectives. First, we demonstrate the effect of the perceived benefits and sacrifice (independent variables based on the VAM) on the dependent variables (adoption and recommendation intentions). Through this, the theoretical rationality of the VAM is demonstrated and practical strategies are explored to inspire the adoption of new technologies. Second, we prove the effect of perceived threats (independent variable derived from PMT) on the dependent variables (adoption and recommendation intentions). Through this, we prove the validity of the PMT and explore practical strategies for users to protect themselves while overcoming the perceived threat of current electronic authentication. Third, we demonstrate the effect of adoption motivation (independent variable proposed from the TPB) on the adoption and recommendation intentions. Through this, the rationality and validity of the TPB are proven, while the rational behavior model and detailed process of users for adopting new technologies are verified.

C. CONTRIBUTION OF THE STUDY

The contribution of this study is as follows. 1) Research was conducted and verified based on an extended convergence model among multiple theories on the variables that affect the intention to accept and recommend new electronic authentication technologies. 2) Comparing previous studies on the electronic authentication services, a more sophisticated methodology was presented by deepening and expanding the design or scope of the study, away from research that grafted and utilized only one theme, theory, or model. 3) Provides effective practical guidelines that require efforts to improve usefulness, enjoyment, and satisfaction while reducing technical complexity for new electronic authentication users.

II. BACKGROUND
A. NEXT-GENERATION ELECTRONIC AUTHENTICATION SERVICE
1) TECHNICAL STATUS OF NEXT-GENERATION ELECTRONIC AUTHENTICATION SERVICES

The representative types of next-generation electronic authentication services that have emerged after the abolition of the monopoly status of accredited certificates include biometric-based FIDO and blockchain-based DID [2]. FIDO is a technology that performs personal authentication quickly, conveniently, and securely by using biometric (face, fingerprint, iris, etc.) recognition technology alone, without an ID and password, in an online and mobile environment. In recent years, biometric information technology that digitizes behavioral characteristics, such as intrinsic behavior, is also being studied [6].

In December 2014, several global companies such as Samsung Electronics, Google, and Microsoft announced the "International Certification Technology Standard FIDO 1.0", which is an international and standard authentication system for biometrics. Such standardized authentication is an essential prerequisite for the commercialization and dissemination of biometric technology. With this system in place, cutting-edge technologies, such as supplying smartphones equipped with biometric sensors, ensuring secure zones including Trust Zone and public key infrastructure (PKI), which guarantees the identity of transaction parties, can be combined to create the foundation to solve the existing problems. It is on the basis of this potential that the commercialization of FIDO technology has accelerated [7]. Global companies, such as Google, Microsoft, Visa, PayPal, RSA, Intel, and Samsung have participated and led the entire development process with the FIDO Alliance. With the international standardization and specifications of FIDO technology as a future alternative to accredited certificates in Korea, it has been incorporated into mainstream services with KB Kookmin Bank and Shinhan Bank leading the new technology market. The spread of smartphones with biometric sensors has accelerated this trend. However, since standardized FIDO can only be authenticated in a mobile environment using protocols such as universal authentication framework (UAF) and universal 2nd factor (U2F), it has the disadvantage of being difficult to use universally in various environments including the web via personal computers (PC). Recognizing this problem, the FIDO Alliance started a standardization called FIDO2 to make it widely usable in various browsers and operating systems without platform restrictions. This effort was realized in 2019 [8]. In Korea, as the standardization of FIDO2 continues, the technology has been quickly accepted and now accounts for 3% of all certified products. Despite expecting the success of FIDO2 in the market, it has not achieved the expected results due to the culture of local users, who are not familiar with the payment of separate tokens at an individual's own expense. The effect that paying the individual expense has on the promotion of the next-generation electronic authentication

service will be verified through the effect of the perceived sacrifice on adoption intention during the empirical analysis process of this study.

Next, due to various personal information leakage accidents, the perception that centrally controlled personal information is a target of digital attacks, such as hacking, is spreading. That is why the digital self-sovereign identity (SSI) concept has been developed, wherein the digital self-identity verification method and scope of disclosure are directly managed by the individual [9]. DID, which is a new type of authentication technology, has developed from this; it is a blockchain technology combined with and applied to the field of electronic authentication. Today, blockchain is widely known as a virtual currency to the general public; however, it is essentially a new technology that dramatically improves the shortcomings of the centralized data management method by distributing and managing the transaction ledger using a consensus algorithm based on cryptographic technology [10]. The decentralized characteristics of blockchains have become the basis for systematically realizing the needs and demands of users who want to manage their own information. Unlike the existing method (accredited certificate, etc.) that collectively stores personal electronic information in a central server of an external institution, DID stores and manages identity information in a distributed manner across personal digital and mobile devices. Thus, it has the advantage of users being able to exercise complete management and control over individual self-information [11]. Due to this, damage cause by personal information leakage in the centralized system is fundamentally prevented, Further, the situation can be prevented wherein personal information is arbitrarily used and shared without the consent of the person concerned. However, for personal identification information to be trusted, the trust of the information issuer must also be secured in advance. Therefore, a separate trust authority is required to verify the decentralized personal identity information. In Korea, existing identity verification systems, such as accredited certificates and smartphones are responsible for this. As a result, existing identity verification methods may be additionally employed to adopt the new authentication technologies. Despite these problems, a number of consortiums are being created to dominate the global DID market, which has high growth potential. These include the DID Alliance, My ID Alliance, and Initial Consortium, which are competing in Korea.

2) NEW CERTIFICATION SERVICES AND PROSPECTS

After the exclusive status of accredited certificates was abolished in Korea in 2014, various private certification services have been introduced competitively; these include the Kakao Bank certificate, which is followed by KB mobile certificate in the bank industry; open pass in the stock industry; PASS app, which is a common service in telecommunication providers; and simplified certification services based on web standards [11]. The details are as follows.

First, Kakao Bank opened the second Internet-only bank in Korea in 2017, and launched a private authentication service to maximize secure transactions and user convenience. It tried to strengthen security by unifying the redundant installation methods of complex security modules (keyboard security, firewall, PKI, etc.) used in accredited certificates and replacing them with their proprietary method, called the mobile protection area storage. Additionally, in order to change the complicated authentication-related UX to an intuitive UX, new technologies such as biometric authentication and personal identification number (PIN) were applied to maximize customer convenience. Kakao Bank's innovative method of enhancing customer convenience, while maintaining security, was benchmarked in the process of introducing private certificates by many companies. Kakao Bank recommends a one-person-one-device policy to increase security and convenience, while providing new authentication services only in the Kakao Bank app.

In 2019, KB Kookmin Bank launched the service of "KB mobile certificate" — a private authentication system that improved the inconvenience of accredited certificates [12]. The main features of KB mobile certificates are the simplification of the initial issuance process, secure storage of the certificate, and convenient and diverse authentication methods, including biometric authentication and simple passwords. In particular, they solved the inconvenience of an accredited certificate requiring to be renewed every year, by improving the certificate so that it can be used continuously, except when it is discarded by a user or has not been used for a long time. It can also be used for electronic services, such as year-end tax returns and electronic civil documents, where accredited certificates were required. The KB mobile certificate works only in the Kookmin Bank app and does not work in general environments, such as PCs and browsers.

In 2019, AhnLab and Koscom launched the Open Pass service, which combined Koscom's integrated authentication function with AhnLab V3 Mobile Plus 2.0 [13]. By integrating the authentication function into the app, which is running on 28 million mobile devices, it reduced the burden of an additional installation for individual users. Convenient authentication methods, such as the secure storage of certificates, biometric authentication, and simple passwords, are also provided. Unlike other private authentication methods, the duplicate use of public certificates is allowed. An authentication service is available through the app even if a PC does not contain the certificate.

PASS, a joint authentication service of the three domestic telecommunication service providers, was also launched and its market share is increasing. In 2018, three telecommunication service providers developed and released an app-based private certificate, PASS, by integrating the authentication services they had previously operated — SK Telecom's T authentication, KT's KT authentication, and LG U+'s U+ authentication [14]. It uses a method that protects the certificate using white-box

cryptography (WBC), thereby providing more convenient authentication methods such as biometric authentication and simple passwords.

With the abolition of the monopoly status of accredited certificates, various types of next-generation electronic authentication services have been launched and are now competing. Most of them focus on the mobile web, instead of the PC web, to develop and supply services. However, the importance or value of the PC web should not be ignored. As of 2019, in the context of internet banking performance, mobile banking use accounts for 61.9% in terms of the number of transactions, and 13.1% in terms of the transaction amounts [15]. PC web banking accounts for 38.1% in terms of the number of transactions, and 86.9% in terms of transaction amount. Referring to this, it is clear that a private authentication service with high versatility and compatibility is essential, regardless of the PC or mobile environment. Considering this demand, domestic companies such as YettieSoft and HancomWITH have developed and provided a web-based general-purpose private authentication service that does not distinguish between PC and mobile. Such an open and multi-faceted approach is needed continuously in the field of next-generation electronic authentication services.

So far, we have reviewed the status of next-generation electronic authentication service technologies and their market prospects. Based on this background understanding, this study uses various theoretical models to derive the psychological, attitudinal, and behavioral variables that affect the adoption intention of individual users. This forms the basis for the dissemination and promotion of next-generation electronic authentication services as a new technology of the future. By verifying the influencing relationship between them, this study suggests the desirable direction of development for next-generation electronic authentication service technologies.

B. VAM AND RELATED VARIABLES

1) MEANING AND CHARACTERISTICS OF VAM

To empirically analyze the factors affecting individual users' adoption and recommendation intentions for next-generation electronic authentication services, this study reviews the value-based acceptance model (VAM), a valid analytical theory on the acceptance and continuous use of new technologies. A number of theories have been proposed since the late 20th century, from the viewpoint of behavioral science, to identify the factors affecting the acceptance and continued use of new technologies, tools, and equipment [16], [17], [18]. The representative theories include 1) Moore and Benbasat's innovation diffusion theory [19], 2) Fishbein and Ajzen's theory of reasoned action (TRA) [20], 3) Compeau, Higgins's social cognitive theory [21], 4) Ajzen and Fishbein's TPB [22], and 5) Davis's technology acceptance model [23]. They derive the various factors that can influence users' acceptance and use of new technologies and tools from different viewpoints.

However, previous studies that have used the above theories alone to analyze the behavior of users who accept and use new technologies, unilaterally focus on the side that new technologies or tools provide positive effects such as perceived benefits or advantages to users [24]. In reality, the positive and negative sides coexist in the outcome obtained from the acceptance and use of new technologies and tools. It is necessary to measure these two sides fairly [25], [26]. Hence, not only should the positive effects, such as benefits and advantages from the adoption of new technologies, be considered, but also the factors that must be abandoned and sacrificed for technology adoption [27].

The theoretical model proposed to respond to this need is the VAM — a balanced analytical model that considers both the perceived benefits as well as sacrifices that can be obtained from the acceptance and use of new technologies [3]. Sacrifices comprehensively include time, effort, technical difficulties, financial costs, loss of opportunity costs, psychological burden, and personal risk [28].

From this point of view, the adoption intention of new technology refers to the combination of perceived benefits that users can obtain by purchasing, accepting, and using new technologies or next-generation services, and perceived sacrifices (time, effort, opportunity cost, financial cost, personal risk, and psychological burden) [29], [30]. This is the analytical strength and effect of the VAM.

2) DISCUSSION ON RELATED VARIABLES AND PREVIOUS STUDIES

Given this perspective, the variables that affect the intention to adopt new technologies are composed of the "perceived benefit" and "perceived sacrifice" in the VAM model. The dependent variables of this model are the users' "Perceived value" and "adoption intention" for the new technology, while the independent variables that affect them are their "perceived benefits" and "perceived sacrifices". "perceived benefit" is composed of two sub-factors — "perceived usefulness" and "perceived enjoyment", while "perceived sacrifice" is composed of two sub-factors — "technicality" and "perceived fee" [31]. Perceived usefulness refers to the degree to which a new technology is utilized in the user's daily life or work, thereby increasing life and work efficiency; enjoyment refers to the degree of pleasure, joy, and satisfaction that the user feels while using the new technology [3], [32]. Technicality refers to the degree of mental and physical effort and the perceived difficulty required for users to acquire and use new technologies fairly well. The perceived fee widely refers to various fees that should be spent to adopt new technologies, such as the financial cost, time and effort, opportunity cost, psychological burden or stress, and personal risk [3], [25].

As mentioned above, there are many previous studies that suggest that the perceived benefits provided by a specific new technology or next-generation service, and the sacrifices to be made for it, work in a balanced and complex way and

significantly affect the acceptance and continuous use of the new technology or service. First, Rhee et al. [33] used VAM to prove that the perceived benefits and sacrifices of cloud computing services have a significant effect on the adoption intentions of companies. Similarly, Jo et al. [34] demonstrated that the perceived benefits and sacrifices of newly released real estate brokerage mobile apps have a significant effect on the acceptance and continued use intentions. Next, Kim and Lee [25] have empirically reported that the perceived benefits and sacrifices of food service delivery services have a significant effect on the adoption intention. Also, Kim [31] proved that the perceived benefits and sacrifices of internet of things (IoT)-based smart home services have a positive effect on the adoption intention.

Furthermore, the following similar studies have been conducted in multiple contexts: augmented reality (AR) technology by Oh [35], analyzing the effect of perceived benefits and sacrifices of AR on adoption intention; a study by Belisari et al. [36] exploring the positive and negative influences of electronic procurement solution; a study by Yu [37] demonstrating the effect of perceived benefits and sacrifices of self-customization services on their adoption intention; a study by Yoon et al. [24] demonstrating the effect of perceived benefits and sacrifices of smartphone vaccines on adoption intentions; and a study by Lee [38] on the effect of the perceived benefits and risks of convenience store lunch boxes on their recommendation intention.

Combining the discussions of the previous studies, this study selects "perceived benefit" and "perceived sacrifice" as the independent variables for this study. "perceived benefit" is defined as the degree to which individual users expect and perceive various benefits, usefulness, and enjoyment by accepting next-generation electronic authentication services in line with the objective of this study. Thus, perceived usefulness and perceived enjoyment are selected as the sub-factors. Additionally, "perceived sacrifice" is defined as the degree to which individual users perceive and hesitate about the sacrifices of effort, difficulty, cost, and time to accept next-generation electronic authentication services. Technicality and the perceived fee are selected as the sub-factors. The effect that the perceived benefits and sacrifices, and each associated sub-factor extracted from the VAM has on adoption and recommendation intentions, will be verified through the empirical analysis of this study. It is in the interest of companies or institutions to confirm that the perceived benefits and sacrifices of new technologies and services not only significantly affect the intention to switch to and accept new technologies, but also the recommendation intentions. Thus, not only promoting acceptance and change intentions immediately after launching new technologies, but also inducing and promoting recommendation intentions and following in-depth and active intentions (continuous use intention, brand loyalty, etc.), will become a greater driving force for the growth and development of a company or institution. Considering this extended effect, this study uses VAM to analyze and investigate the effects of perceived benefits

and sacrifices of next-generation electronic authentication services on adoption and recommendation intentions.

C. PMT AND RELATED VARIABLES
1) MEANING AND CHARACTERISTICS OF PMT
Protection motivation theory (PMT) is a theory advocated to explain people's attitudes, behavioral changes, and risk management and self-protection behaviors caused by potential threats [4]. The PMT, first proposed by Rogers [4], is composed of "perceived susceptibility" — the degree to which a person believes that a negative event or catastrophe is likely to be caused by a surrounding vulnerable environment — and "perceived severity" — the degree to which a person perceives the risk of a specific threat or catastrophe seriously [39]. This can also be understood as the perception of vulnerability to disasters or negative events, and the perception of the severity of risks or hazards [40]. Perceived threat is a concept that integrates the concepts of perceived susceptibility and perceived severity. PMT focuses on analyzing the process by which perceived threats to dangerous disasters, events, and contingencies lead to voluntary protective and preventive actions [41].

PMT was originally proposed and utilized for research in health-related fields. Previous studies based on PMT have progressed to identify how the perceived susceptibility and severity effects the overcoming of diseases or healthcare behavior, particularly when the threatening signs caused by diseases such as swine flu, middle east respiratory syndrome (MERS), and acquired immune deficiency syndrome (AIDS), and negative habits such as smoking and drinking, are encountered [40], [41]. However, cyber privacy infringement, defamation, cyber-attacks, and information security problems are frequent and have intensified due to the recent rapid development of the Internet and mobile devices. As a result, the perceived threats to the unstable and vulnerable cyber world have increased the self-defense and protection by users to such an extent that studies are actively being attempted to use PMT to explain the effect these threats have on coping behavior [42], [43]. As these issues are also related to the subject of this study, we will look into them below.

2) DISCUSSION ON RELATED VARIABLES AND PREVIOUS STUDIES
First, Kim et al. [42] proved that the perception of susceptibility and severity of information infringement affects the privacy protection behaviors of social networking service users. According to Park et al. [43], the perceived susceptibility to the Internet environment affects the technical protection behavior for personal information, general attention behavior, and use of security products, whereas the perceived severity has a significant effect only on general attention behavior. According to Kim et al. [44], the higher the perceived threat to personal information exposure, the higher the intention to act to protect personal rights. Choi et al. [45] have verified that the perceived threat of amblyopia patients

affects their intention to accept wearable devices for vision correction [43].

When summarizing the above previous studies, it can be seen that the perceived threat (susceptibility, severity) of a potential disaster, catastrophe, or negative event induces active steps of protection by users. This protective behavior also includes adopting and using technologies and tools that help defend against or prevent an event or disaster of concern. Therefore, this study predicts that the perceived threat to the current electronic authentication technology will have a significant effect on the adoption intention of next-generation electronic authentication services. Based on these logical predictions, this study selects the perceived threat as the third independent variable. It is operationally defined as the degree to which individual users perceive a serious threat due to security vulnerabilities, and the severity of threat caused in an individual's daily living and social networks by the current electronic authentication services and related systems. Additionally, the perceived susceptibility and severity are selected as the sub-factors of perceived threat. Based on this, this study empirically investigates the effect of perceived threats on the adoption and recommendation intentions of next-generation electronic authentication services.

D. TPB AND RELATED VARIABLES

1) MEANING AND CHARACTERISTICS OF TPB

The theory of planned behavior (TPB) was advocated by Ajzen [5], which is a theory evolved from the theory of reasoned action (TRA). The TRA pays attention to "attitude", which is related to personal and internal attributes, and "subjective norm", which is related to social and environmental influences, as factors that affect human social and cultural behaviors [46]. Attitude refers to the positive or negative perceptions or judgments about a specific behavior, while subjective norm refers to the degree to which an individual respects the opinions and evaluations of others who are important to them, and makes them a criterion or principle for personal behavior [47]. The TPB adds "perceived behavior control" — the belief that we can control and manage the behaviors we need in the present and in the future. This makes the theory useful for rational and scientific explanations and interpretations of judgments, decisions, and action processes surrounding human behavior [48].

2) DISCUSSION ON RELATED VARIABLES AND PREVIOUS STUDIES

Based on the above explanation, TPB demonstrates its strength when predicting various online and offline cultural and social behaviors, and understanding their intentions [48], [49]. In this regard, Chang et al. [50] have demonstrated the effects of attitudes, subjective norms, and perceived behavior control of Korean university students on their intention to download illegal online content. Rhee et al. [51] have used TPB to demonstrate that attitudes and perceived

behavior control of users in their 20s have a significant effect on their intent to adopt artificial intelligence products. Joo et al. [52] has reported that the attitudes and perceived behavior control proposed by the TPB have a significant effect on smartphone usage intentions. Kim et al. [53] has proved that the subjective norm of the TPB has a significant effect on the intention of individuals to accept hacking technology. Um [47] has reported the effect of attitudes, subjective norms, and perceived behavior controls on the sustained use of sports wearable devices, based on a fusion model of the post-acceptance model (PAM) and TPB.

On the other hand, Lee et al. [49] and Joo et al. [52] have found that the various behavioral intentions of humans can be explained more deeply through an extended analytical model that combines different theories and models, such as the TPB and the technology acceptance model. This provides important implications for this study, which has designed a convergence analysis model of three theories. The convergence and integrated use of various theories is expected to contribute to the deepening of research topics in social science, and expansion of the discourse

Given this awareness and objective, this study proposes operational definitions of the three factors — attitude toward behavior, subjective norm, and perceived behavioral control — suggested from the TPB. In accordance with our study topic, they are defined as "attitude toward the adoption of new technology", "subjective norm toward adoption", and "perceived behavioral control toward adoption", respectively. These are then integrated into a high-level concept called "adoption motives." Then, this study identifies the effect of adoption motives on adoption and recommendation intentions. Specifically, 'adoption motive' is defined as the "action motive" induced by planned behavioral tendencies — particularly the motives for accepting next-generation electronic authentication services. Next, among the sub-factors, "attitude toward adoption" is operationally defined as "the attitude to positively judge and prepare for accepting next-generation electronic authentication services"; the "subjective norm" is defined as the "degree of reference used as one's own criteria of judgment while respecting the social awareness, evaluations, and recommendations of surrounding people toward the adoption of next-generation electronic authentication services"; and "perceived behavior control" is defined as "the degree of control and regulation to actively perceive and implement all judgments, decisions, and executions related to the acceptance of next-generation electronic authentication services". Based on this expanded understanding and design, this study investigates the next-generation variables, such as perceived benefit and perceived sacrifice (variables of the VAM), perceived threat (variable of the PMT), and adoption motive (variable of the TPB). Their effects on adoption and recommendation intentions for electronic authentication services are verified through the quantitative method of survey and statistical analysis.
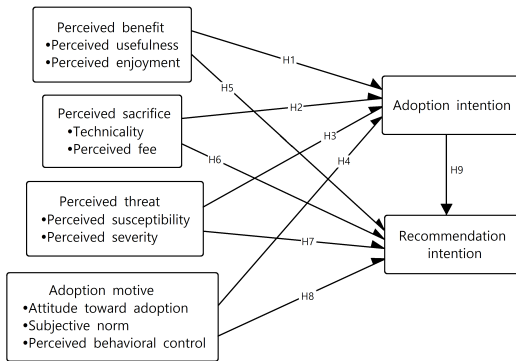
FIGURE 1. Research model.

III. RESEARCH METHOD

A. STUDY MODEL DESIGN

This study comprehensively considers the relationship between each variable and the sub-factors that are extracted and constructed through the literature review of the three theories. Based on this, the following research model is designed as shown in Fig. 1.

B. RESEARCH HYPOTHESIS SETTING

Based on the research model and literature review, this study establishes 9 research hypotheses, and detailed sub-hypotheses for each hypothesis by its research necessity. First, we refer to the studies [24], [31], [37], that have demonstrated that perceived benefit, a variable extracted from the VAM, has a positive effect on the adoption intention of users or consumers. Thus, we define Hypothesis 1 and the detailed sub-hypotheses as follows:

Hypothesis 1: The perceived benefits of next-generation electronic authentication services will have a significant impact on adoption intention.

Hypothesis 1-1: The perceived usefulness of the perceived benefits will have a significant positive (+) effect on adoption intention.

Hypothesis 1-2: The perceived enjoyment of the perceived benefits will have a significantly positive (+) effect on adoption intention.

Next, referring to the empirical studies [29], [37], [54], demonstrating the fact that perceived sacrifice, a variable proposed from the value-based acceptance model, has a negative effect on acceptance intention, we define Hypothesis 2 and the detailed sub-hypotheses as follows:

Hypothesis 2: The sacrifices of next-generation electronic authentication services will have a significant impact on adoption intention.

Hypothesis 2-1: The technicalities of the perceived sacrifices will have a significant negative (−) effect on adoption intention.

Hypothesis 2-2: The perceived fee of the perceived sacrifices will have a significant negative (−) effect on adoption intention.

Then, we refer to the studies [42], [43], [45], that demonstrated the effect of perceived threat, a variable

extracted from the PMT, on protection behaviors in various domains and the intention to accept technology, tools, and equipment for protection, response, and prevention. Thus, we define Hypothesis 3 and the detailed sub-hypotheses as follows:

Hypothesis 3: The perceived threat of next-generation electronic authentication services will have a significant effect on adoption intention.

Hypothesis 3-1: The perceived susceptibility of the perceived threat will have a significant positive (+) effect on adoption intention.

Hypothesis 3-2: The perceived severity of the perceived threat will have a significant positive (+) effect on adoption intention.

We also refer to the studies [49], [51], [52], [53], that have demonstrated the effect of behavior motive (operationally defined as adoption motive in this study), a variable conceptualized from the TPB, on adoption intention. Thus, we define Hypothesis 4 and the detailed sub-hypotheses as follows:

Hypothesis 4: The adoption motive for next-generation electronic authentication services will have a significant effect on adoption intention.

Hypothesis 4-1: Attitudes toward adoption will have a significant positive (+) effect on adoption intention.

Hypothesis 4-2: The subjective norm of the adoption motive will have a significant positive (+) effect on adoption intention.

Hypothesis 4-3: The perceived behavioral control of the adoption motive will have a significantly positive (+) effect on adoption intention.

There are relatively few studies that have directly analyzed the effects of perceived benefits, perceived sacrifices, perceived threats, and adoption motives on recommendation intentions, which is the second dependent variable in this study. Thus, the studies that have dealt with similar variables to recommendation intentions are indirectly referenced in Hypotheses 5 to 9. Then, we indirectly refer to the research [38], which demonstrates the effect of the perceived benefits of convenience store lunch boxes on recommendation intentions, and Song's study [55], which reports the effects of restaurant consumers' perceived benefits on online word-of-mouth intentions. We define Hypothesis 5 and the detailed sub-hypotheses as follows:

Hypothesis 5: The perceived benefits of next-generation electronic authentication services will have a significant effect on recommendation intention.

Hypothesis 5-1: The perceived usefulness of the perceived benefits will have a significant positive (+) effect on recommendation intention.

Hypothesis 5-2: The perceived enjoyment of the perceived benefits will have a significant positive (+) effect on recommendation intention.

We indirectly refer to the study [56], which has demonstrated that the perceived sacrifice of a convention event has a negative effect on the recommendation intention for

the event. Thus, we define Hypothesis 6 and the detailed sub-hypotheses as follows:

Hypothesis 6: The perceived sacrifices of next-generation electronic authentication services will have a significant effect on recommendation intention.

Hypothesis 6-1: The technicality of the perceived sacrifices will have a significant negative impact on recommendation intention.

Hypothesis 6-2: The perceived fee of the perceived sacrifices will have a significant negative ($-$) effect on recommendation intention.

We define Hypothesis 7 and the detailed sub-hypotheses by indirectly referring to the study of Choi [57], who has reported the effects of perceived threats to the world heritage environment on reducing the intention to recommend tourist destinations.

Hypothesis 7: The perceived threats of next-generation electronic authentication services will have a significant impact effect on recommendation intention.

Hypothesis 7-1: The perceived susceptibility of the perceived threats will have a significant positive ($+$) effect on recommendation intention.

Hypothesis 7-2: The perceived severity of the perceived threats will have a significant positive ($+$) effect on the recommendation intention.

Next, we indirectly refer to the study [47], which has reported the effects of various behavioral motives (attitude, subjective norm, perceived behavioral control), raised from the TPB, on the intention to continue using sports wearable devices. Thus, we define Hypothesis 8 and the detailed sub-hypotheses as follows:

Hypothesis 8: The adoption motive for next-generation electronic authentication services will have a significant impact on the recommendation intention.

Hypothesis 8-1: Attitudes toward the adoption motive will have a significant positive ($+$) effect on the recommendation intention.

Hypothesis 8-2: The subjective norm of the adoption motive will have a significant positive ($+$) effect on the recommendation intention.

Hypothesis 8-3: The perceived behavioral control of the adoption motive will have a significant positive ($+$) effect on the recommendation intention.

Finally, we refer to the studies [58], [59], that have demonstrated that adoption intentions or attitudes toward various new technologies and innovative services affect the recommendation intentions related to them. Thus we define Hypothesis 9 as follows:

Hypothesis 9: The adoption intention for next-generation electronic authentication services will have a significant effect on the recommendation intention.

C. MEASURING TOOLS

This study has conducted an empirical survey targeting the actual users of the next-generation electronic authentication service. For rational and scientific empirical investigation,

this study has created effective measurement tools by summarizing the literature reviews. The measurement tools of this study consist of seven areas as follows: 1) Perceived usefulness of the perceived benefits from the next-generation electronic authentication service, 2) Perceived enjoyment of the perceived benefit, 3) Technicality of the perceived sacrifice, 4) Perceived fee of the perceived sacrifice, 5) Adoption intention, 6) Recommendation intention, and 7) Demographic characteristics of the survey respondents. The areas 1) to 6) are measured using a five-point Likert scale.

D. DATA COLLECTION AND ANALYSIS METHODS

This study aims to identify and empirically prove the variables that affect the adoption and recommendation intentions of next-generation electronic authentication services by individual users, based on an in-depth and complex analysis model that converges three theories — VAM, PMT, and TPB. To achieve this research goal, theoretical (literature) reviews and empirical investigations are conducted in parallel. The empirical survey of this study was conducted through online for 25 days from February 25 to March 21, 2022, targeting the customers using electronic authentication services (including both biometric-based FIDO and blockchain-based DID) of K, S, H, and W commercial banks — leading domestic financial institutions. Considering the representativeness of the sample, subjects were extracted from actual electronic authentication users during the period, and a survey was conducted with four different commercial bank users in consideration of the homogeneity and heterogeneity of the sample. The online survey was conducted to minimize the impact of COVID-19.

The subjects were selected and recruited while considering an equal distribution based on age, sex, occupation, and educational background. The questionnaire composition is shown in the Table 1. During the online survey period, a total of 500 questionnaires were distributed and 467 respondents (response rate of 93.4%), excluding lost responses or non-respondents, were obtained. Following this, 435 respondents (excluding 32 respondents) were finally confirmed as the target group for analysis (final adoption rate 87.0%). The final adopted data were checked and analyzed using the SPSS Statistics 21.0 program, and the hypothesis verified. The data analysis method used in this study is as follows.

First, a frequency analysis was performed on the demographic characteristics (sex, age, final education, occupation, and monthly income) of the survey respondents. Second, an exploratory factor analysis (validity analysis) was performed to verify the validity of the constructs between the independent and dependent variables, and sub-factors of this study. Third, a reliability analysis was performed to examine the internal consistency of the sub-factors constituting the independent and dependent variables. Fourth, a regression analysis was performed to demonstrate the mutual influence relationship between the study's four independent variables and two dependent variables and to verify the research hypotheses 1 to 9.

TABLE 1. Questionnaire composition.

[Factor] and measurement questions	Source
[Perceived usefulness of perceived benefit] I believe that using the new electronic authentication service will be helpful in my daily life and work. I believe that the new electronic authentication service will further enhance the standard of my daily life and work. I believe that by using the new electronic authentication service, my daily life and work can be performed more usefully and easily. I think it will be useful and efficient overall to use a new electronic authentication service. **[Perceived enjoyment of perceived benefit]** I think it will be fun to use the new electronic authentication service. I think using the new electronic authentication service will bring me a lot of joy. I think using the new electronic authentication service will be enjoyable and satisfying. I think using the new electronic authentication service will not be boring.	[24], [31], [37]
[Technicality of perceived sacrifice] I think using the new electronic authentication service will be difficult in general. I think it would be difficult to learn how to use the new electronic authentication service. I think a lot of effort is needed to make good use of the new electronic authentication service. I think it will be difficult to skillfully use the new electronic authentication service. **[Perceived fee of perceived sacrifice]** I think the privacy security system of the current electronic authentication service is not secure. I believe that my personal information may be leaked in the process of using the current electronic authentication service. I believe that current electronic authentication services and related systems are not safe from attacks such as spam and hacking.	[29], [54], [56]
[Perceived susceptibility of perceived threat] I believe that there is a risk that someone may collect my financial-related information without my consent. Due to the vulnerability of the financial system, I believe that there is a risk of financial-related information being leaked. I think the security of the current electronic authentication service is weak. **[Perceived severity of perceived threat]** If finance-related information is leaked, it will cause great damage to personal life(study, work, etc.). If personal information related to finance is leaked, it will paralyze social and public functions. If personal information is leaked, it will also cause chaos in international networks.	[24], [31], [34]
[Adoption motive of attitude toward] I think it is desirable to adopt the new electronic authentication services. I think the act of adopting the new electronic authentication services is positive. Actions that adopt the new electronic authentication services will be beneficial. **[Subjective norm of attitude toward]** My dear people will want me to adopt the new electronic authentication services. My dear people will say that I like to adopt the new electronic authentication services. My dear people will recommend that I adopt the new electronic authentication services. **[Perceived behavioral control of attitude toward]** I can decide whether to accept the new electronic authentication service of my own will. If I want to, adopting the new electronic authentication services is easy. It is entirely up to me whether or not I accept the new electronic authentication service.	[49], [50], [52]
[Adoption intention] I intend to adopt the new electronic authentication services in the near future. I intend to actively adopt the new electronic authentication services. I intend to adopt the new electronic authentication service to achieve a higher level of satisfaction in my life. I intend to adopt the new electronic authentication service for a higher value in my life.	[28], [34], [37]
[Recommendation intention] I would recommend the new electronic authentication service to people around me. I will positively convey the many benefits of the new electronic authentication service to people around me. I will promote many pieces of information about the new electronic authentication service online and offline.	[58], [59]

IV. EMPIRICAL ANALYSIS

A. ANALYSIS OF DEMOGRAPHIC CHARACTERISTICS OF SURVEY RESPONDENTS

Table 2 presents the frequency analysis results for the demographic characteristics (sex, age, educational background, occupation, and income) of the survey respondents.

B. VERIFICATION OF VALIDITY, RELIABILITY, AND CORRELATION OF MEASUREMENT TOOLS

1) VALIDATION

In this study, a principal components analysis was used as a factor extraction method to verify the validity of the construct between the independent and dependent variables and each sub-factor; the Varimax method was adopted for factor rotation. Based on this, only factors with an eigenvalue of 1.0 or higher, and a factor loading of 0.4 or higher, were identified and adopted as significant factors [60]. The results of the validity analysis are summarized in Tables 3 to 8.

According to Table 3, the eigenvalues of the two sub-factors constituting ''perceived benefit'', the first independent variable of this study, were 3.243 and 3.153, respectively; while the factor loadings ranged from 0.844 to 0.933, both of which satisfied the criteria of an eigenvalue above 1.0 and factor loading above 0.4. Additionally, the

TABLE 2. Demographic characteristics of respondents.

Factor	Sub-groups	N	(%)
Sex	Man	236	54.3
	Woman	199	45.7
Age	20's	141	32.4
	30's	155	35.6
	40's	71	16.3
	50's	42	9.7
	60's	26	6.0
Educational background	High school graduation	60	13.8
	Graduate from college	95	21.8
	4-year college graduation	215	49.4
	Postgraduate or above	46	10.6
	Etc.	19	4.4
Month average income	1.01 to 2 million won	33	7.6
	2.01 to 3 million won	120	27.6
	3.01 to 4 million won	118	27.1
	More than 4.01 million won	106	24.4
Job	Self-employment	44	10.1
	Office/Technical job	160	36.8
	Sales/Service job	21	4.8
	Management/Control job	23	5.3
	Freelancer/Professional job	21	4.8
	Undergraduate and graduate students	67	15.4
	Housewife	58	13.3
	Public official	21	4.8
	Inoccupation	7	1.6
	Etc.	13	3.0

TABLE 3. Validity analysis of perceived benefit.

Sub-factors	Measurement questions	Factor loading	Eigen-value	Variance (%)
Perceived usefulness	Usefulness 1	0.912		
	Usefulness 2	0.894	3.243	40.533
	Usefulness 3	0.880		
	Usefulness 4	0.849		
Perceived enjoyment	Enjoyment 1	0.914		
	Enjoyment 2	0.844	3.153	39.408
	Enjoyment 3	0.893		
	Enjoyment 4	0.933		
				79.941

TABLE 4. Validity analysis of perceived sacrifice.

Sub-factors	Measurement questions	Factor loading	Eigen-value	Variance (%)
Technicality	Technicality 1	0.875		
	Technicality 2	0.914	3.470	49.574
	Technicality 3	0.902		
	Technicality 4	0.926		
Perceived fee	Perceived fee 1	0.845		
	Perceived fee 2	0.865	2.514	35.912
	Perceived fee 3	0.874		
				85.486

TABLE 5. Validity analysis of perceived threat.

Sub-factors	Measurement questions	Factor loading	Eigen-value	Variance (%)
Perceived susceptibility	Susceptibility 1	0.806		
	Susceptibility 2	0.898	2.272	37.862
	Susceptibility 3	0.900		
Perceived severity	Severity 1	0.887		
	Severity 2	0.864	2.266	37.768
	Severity 3	0.855		
				75.630

TABLE 6. Validity analysis of adoption motive.

Sub-factors	Measurement questions	Factor loading	Eigen-value	Variance (%)
Attitude toward adoption	Attitude 1	0.900		
	Attitude 2	0.902	2.539	28.210
	Attitude 3	0.872		
Subjective norm	Subjective norm 1	0.846		
	Subjective norm 2	0.891	2.532	28.137
	Subjective norm 3	0.861		
Perceived behavioral control	Control 1	0.895		
	Control 2	0.888	2.463	27.367
	Control 3	0.902		
				83.714

TABLE 7. Validity analysis of adoption intention.

Measurement questions	Factor loading	Eigen-value	Variance (%)
Adoption intention 1	0.820		
Adoption intention 2	0.766	2.453	61.334
Adoption intention 3	0.812		
Adoption intention 4	0.731		

total explanatory power by the variance of "perceived benefits" is cumulatively 79.941%. In general, the validity and appropriateness of sub-factors in social science fields are judged based on the cumulative variance criterion of 60% and above [61], [62]. Accordingly, the sub-factor composition of "perceived benefits" in this study was found to be valid.

According to Table 4, the eigenvalues of the two sub-factors of "perceived sacrifice", the second independent variable of this study, were 3.470 and 2.514, respectively, while the factor loading values ranged from 0.845 to 0.926 and the total explanatory power by variance was 85.486%. Thus, the sub-factor composition of "perceived sacrifice" was found to be valid.

According to Table 5, the eigenvalues of the two sub-factors of "perceived threat", the third independent variable of this study, were 2.272 and 2.266, respectively, while the factor loading ranged from 0.806 to 0.900 and the total explanatory power by variance was 75.631%. This indicates that the composition of the sub-factors of the variable "perceived threat" was found to be valid.

According to Table 6, the eigenvalues of the three sub-factors of "adoption motive", the fourth independent variable of this study, were 2.539, 2.532, and 2.463, respectively, while the factor loading values ranged from 0.846 to 0.902 and the total explanatory power by variance was 83.714%. Thus, the composition of the sub-factors of "adoption motive" were all found to be valid.

According to Table 7, the eigenvalue of the detailed measurement items constituting "adoption intention", the first dependent variable of this study, was 2.453, the factor

TABLE 8. Validity analysis of recommendation intention.

Measurement questions	Factor loading	Eigen-value	Variance (%)
Recommendation intention 1	0.643		
Recommendation intention 2	0.814	1.849	61.625
Recommendation intention 3	0.879		

TABLE 9. Reliability verification results of variables.

Variable	Sub-variable	N	Cronbach's α
Perceived benefit	Perceived usefulness	4	0.909
	Perceived enjoyment	4	0.919
Perceived sacrifice	Technicality	4	0.958
	Perceived fee	3	0.880
Perceived threat	Perceived susceptibility	3	0.836
	Perceived severity	3	0.835
Adoption motive	Attitude toward adoption	3	0.901
	Subjective norm	3	0.898
	Perceived behavioral control	3	0.902
Adoption intention		4	0.788
Recommendation intention		3	0.675

loading values varied from 0.731 to 0.820, and the total explanatory power by variance was 61.334%. Thus, this indicates that the composition of the measurement items of "adoption intention" was found to be valid.

According to Table 8, the eigenvalue of the detailed measurement items constituting "recommendation intention", the second dependent variable of this study, was 1.849, the factor loading ranged from 0.643 to 0.879, and the total explanatory power by variance was 61.625%. This indicates that the composition of the measurement items of "recommendation intention" was found to be valid.

2) RELIABILITY VERIFICATION
Reliability implies that the measurement result contains little error and is hence, reliable. Reliability evaluation methods include parallel verification, internal agreement, and Cronbach's α [63]. This study uses Cronbach's α. In the social sciences, Cronbach's α is considered reliable if it is greater than 0.6 [64]. As a result of the analysis, Cronbach's α of all the variables was calculated to be 0.6 or higher as shown in Table 9, thus, proving their reliability.

3) CORRELATION ANALYSIS
Next, for the correlation analysis between the variables and sub-factors of this study, the Pearson correlation coefficient is calculated. Table 10 presents the results of the correlation analysis. As a result of this analysis, among the 55 pairs of correlations, 16 pairs of correlations were distributed between ±0.4 and ±0.8, 23 pairs of correlations were distributed between ±0.2 and ±0.4, and 16 pairs of correlations were under ±0.2, which verifies that a relatively good correlation is exhibited. As a result, the validity of the variable-factor correlation in this study is obtained, and it is confirmed that the research hypothesis and model were correctly designed.

C. HYPOTHESIS TEST RESULTS AND INTERPRETATION
The following verification results of hypotheses 1 to 9 demonstrate and analyze the variables affecting the adoption and recommendation intentions of users for next-generation electronic authentication services.

1) TEST AND INTERPRETATION OF HYPOTHESIS 1
Table 11 shows the results of the multiple regression analysis of hypothesis 1 to verify the relationship between the perceived benefits and adoption intention. According to this, the adjusted R-squared value is 0.357; the F statistic value is 121.282; the significance of F is 0.000; and the Durbin-Watson value is 1.751. These values demonstrate the validity of the regression model. As the adjusted R-squared value is 0.357, the perceived benefit has an explanatory power of 35.7% for the dependent variable, adoption intention. If the Durbin-Watson value is close to 2, the regression equation is interpreted to be valid.

The β value of perceived usefulness is 0.522, and that of the perceived enjoyment is 0.217, both of which suggest a significant positive (+) effect on acceptance intention. However, it was verified that the influence of perceived usefulness is larger.

In the multiple regression analysis, wherein the independent variables with multiple sub-factors are input, the problem of multicollinearity needs to be addressed. Multicollinearity refers to a situation in which a strong correlation exists between the multiple independent variables [65]. Since the presence of multicollinearity can distort the results of the regression analysis, it is necessary to solve this problem to secure the validity of the multiple regression analysis. Multicollinearity is identified through the value of the variance inflation factor (VIF); if it is less than 10.0, it is judged that there is no multicollinearity [66]. The VIF value of this regression equation is 1.0320, which resolves any questions regarding multicollinearity.

The results of the multiple regression analysis between the perceived benefits and adoption intention show that the perceived usefulness and perceived enjoyment, which are the two sub-factors of perceived benefit, have a significant effect on the adoption intention. The β value of perceived usefulness is 0.522, while that of perceived enjoyment is 0.217; both have a significant positive (+) effect on acceptance intention, but the influence of perceived usefulness is larger. Therefore, hypothesis 1 and the detailed sub-hypotheses 1-1 and 1-2 are accepted.

2) TESTING AND INTERPRETATION OF HYPOTHESIS 2
Table 12 presents the results of the multiple regression analysis of hypothesis 2 to verify the relationship between the perceived sacrifices and adoption intention. The corrected R-squared value is 11.1%; the F value is 28.057; the significance is 0.000; and the Durbin-Watson value is 2.093. These values prove the validity of the regression equation and solve the multicollinearity problem. The results of the analysis

TABLE 10. Correlation analysis results between variables and sub-variables.

Sub-factor	1	2	3	4	5	6	7	8	9	10	11
1. Perceived usefulness	1										
2. Perceived enjoyment	0.177**	1									
3. Technicality	0.009	-0.271**	1								
4. Perceived fee	-0.095*	-0.255**	0.545**	1							
5. Perceived susceptibility	0.198**	0.092	-0.155**	-0.174**	1						
6. Perceived severity	0.388**	0.143**	-0.026	-0.145**	0.024	1					
7. Attitude toward adoption	0.453**	0.316**	-0.320**	-0.266**	0.247**	0.305**	1				
8. Subjective norm	0.322**	0.248**	-0.462**	-0.322**	0.199**	0.267**	0.438**	1			
9. Perceived behavioral	0.327**	0.274**	-0.278**	-0.161**	0.110*	0.350**	0.179**	0.412**	1		
10. Adoption intention	0.560**	0.309**	-0.288**	-0.307**	0.385**	0.499**	0.579**	0.585**	0.529**	1	
11. Recommendation intention	0.580**	0.357**	-0.180**	-0.239**	0.274**	0.488**	0.533**	0.540**	0.542**	0.736**	1

$*p<0.05, **p<0.01$

TABLE 11. Multiple regression analysis results between perceived benefit and adoption intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	2.432	0.135		18.076	0.000
Usefulness	0.326	0.024	0.522	13.343	0.000**
Enjoyment	0.176	0.032	0.217	5.539	0.000**

$Adj.R^2$=0.357, F=121.282, df1=2, p=0.000
Tolerance=0.969, VIF=1.032, Durbin-Watson=1.751

Dependent Variable : Adoption intention. $* p < 0.05 ** p < 0.01$

TABLE 13. Multiple regression analysis results between perceived threat and adoption intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	1.916	0.143		13.374	0.000
Susceptibility	0.273	0.028	0.373	9.914	0.000**
Severity	0.317	0.024	0.490	13.006	0.000**

$Adj.R^2$=0.385, df1=2, F=136.845, p=0.000
Tolerance=0.999, VIF=1.001, Durbin-Watson=2.065

Dependent Variable : Adoption intention. $* p < 0.05 ** p < 0.01$

TABLE 12. Multiple regression analysis results between perceived sacrifice and adoption intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	5.416	0.162		33.388	0.000
Technicality	-0.100	0.031	-0.172	-3.179	0.002**
Perceived fee	-0.167	0.042	-0.214	-3.956	0.000**

$Adj.R^2$=0.111, df1=2, F=28.057, p=0.000
Tolerance=0.703, VIF=1.422, Durbin-Watson=2.093

Dependent Variable : Adoption intention. $* p < 0.05 ** p < 0.01$

between the perceived sacrifice and adoption intention verify that the sub-factors of perceived sacrifice have a significant negative (−) effect on the adoption intention, in the order of the perceived fee (β =−0.214) followed by the technicality (β =−0.172). Therefore, hypothesis 2 and the detailed sub-hypotheses 2-1 and 2-2 are adopted.

3) TESTING AND INTERPRETATION OF HYPOTHESIS 3
Table 13 shows the results of the multiple regression analysis of hypothesis 3 to verify the relationship between

the perceived threats and adoption intention. The corrected R-squared value is 38.5%; the F value is 136.845; the significance is 0.000; and the Durbin-Watson value is 2.065; These values establish the validity of the regression equation and solve the multicollinearity problem. The results of the analysis between the perceived threat and adoption intention show that the sub-factors of the perceived threat have a significant positive (+) effect on the adoption intention, in the order of the perceived severity ($\beta = 0.490$) followed by the perceived susceptibility ($\beta = 0.373$). Therefore, hypothesis 3 and the detailed sub-hypotheses 3-1 and 3-2 are adopted.

4) TEST AND INTERPRETATION OF HYPOTHESIS 4
Table 14 shows the results of the multiple regression analysis of hypothesis 4 to test the relationship between the adoption motive and adoption intention. The adjusted R-squared value is 56.9%; the F value is 191.631; the significance is 0.000; and the Durbin-Watson value is 1.834. These values confirm the validity of the regression model. As a result, the sub-factors and adoption motive have a significant positive (+) effect and are in the order of the acceptance attitudes (β =0.400), followed by perceived behavior controls (β =0.348) and

TABLE 14. Multiple regression analysis results between adoption motive and adoption intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	1.478	0.131		11.304	0.000
Attitude	0.276	0.024	0.400	11.413	0.000**
Norm	0.140	0.020	0.266	7.031	0.000**
Control	0.267	0.027	0.348	10.043	0.000**

$Adj.R^2$=0.569, df1=3, F=191.631, p=0.000
Tolerance=0.808, 0.693, 0.830, VIF=1.238, 1.443, 1.205
Durbin-Watson=1.834

Dependent Variable : Adoption intention. * $p < 0.05$ ** $p < 0.01$

TABLE 15. Multiple regression analysis results between perceived benefit and recommendation intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	2.031	0.153		13.270	0.000
Usefulness	0.394	0.028	0.534	14.143	0.000**
Enjoyment	0.251	0.036	0.263	6.961	0.000**

$Adj.R^2$=0.401, df1=2, F=146.305, p=0.000
Tolerance=0.969, VIF=1.032, Durbin-Watson=1.952

Dependent Variable : Recommendation intention. * $p < 0.05$ ** $p < 0.01$

TABLE 16. Multiple regression analysis results between perceived sacrifice and recommendation intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	5.401	0.197		27.415	0.000
Technicality	-0.048	0.038	-0.071	-1.273	0.204
Perceived fee	-0.186	0.051	-0.201	-3.613	0.000**

$Adj.R^2$=0.057, df1=2, F=13.998, p=0.000
Tolerance=0.703, VIF=1.422, Durbin-Watson=2.135

Dependent Variable : Recommendation intention. * $p < 0.05$ ** $p < 0.01$

TABLE 17. Multiple regression analysis results between perceived threat and recommendation intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	1.991	0.180		11.083	0.000
Susceptibility	0.226	0.035	0.262	6.543	0.000**
Severity	0.368	0.031	0.482	12.039	0.000**

$Adj.R^2$=0.304, df1=2, F=95.796, p=0.000
Tolerance=0.999, VIF=1.001, Durbin-Watson=2.029

Dependent Variable : Recommendation intention. * $p < 0.05$ ** $p < 0.01$

subjective norms (β =0.266). Therefore, hypothesis 4 and the detailed sub-hypotheses 4-1, 4-2, and 4-3 are accepted.

5) TEST AND INTERPRETATION OF HYPOTHESIS 5
Table 15 shows the results of the multiple regression analysis of hypothesis 5 to verify the relationship between the perceived benefits and recommendation intention. The adjusted R-squared value is 40.1%; the F value is 146.305; the significance is 0.000; and the Durbin-Watson value is calculated as 1.952. These values prove the validity of the regression model and the results also verify that the sub-factors of the perceived benefits have a significant positive (+) effect on the recommendation intention, in the order of the perceived usefulness (β =0.534), followed by the perceived enjoyment (β =0.263). Therefore, hypothesis 5 and the detailed sub-hypotheses 5-1 and 5-2 are both adopted.

6) TEST AND INTERPRETATION OF HYPOTHESIS 6
Table 16 shows the results of the multiple regression analysis of hypothesis 6 to verify the relationship between the perceived sacrifices and recommendation intention. The adjusted R-squared value is 5.7%; the F value is 13.998; the significance is 0.000; and the Durbin-Watson value is calculated as 2.135. These values establish the validity of the regression model and solve the multicollinearity problem. As a result of the analysis, the perceived cost (β =−0.201) is the only one among the sub-factors of the perceived sacrifice that have a significant negative (−) effect on the recommendation intention. By contrast, the complexity of the description has no effect. Therefore, only 6-2 of the detailed

sub-hypotheses of hypothesis 6 can be adopted, implying that hypothesis 6 is partially accepted.

7) TEST AND INTERPRETATION OF HYPOTHESIS 7
Table 17 shows the results of the multiple regression analysis of hypothesis 7 to verify the relationship between the perceived threat and recommendation intention. The adjusted R-squared value is 30.4%; the F value is 95.796; the significance is 0.000; and the Durbin-Watson value is 2.029. These results prove the validity of the regression model and solve the multicollinearity problem. The sub-factors of the perceived threat have a significant positive (+) effect on the recommendation intention, in the order of the perceived severity (β =0.482), followed by the perceived susceptibility (β =0.262). Therefore, hypothesis 7 and the detailed sub-hypotheses 7-1 and 7-2 are adopted.

8) TEST AND INTERPRETATION OF HYPOTHESIS 8
Table 18 presents the results of the simple regression analysis of hypothesis 8 to verify the relationship between the adoption motive and recommendation intention. The adjusted R-squared value is 52.1%; the F value is 158.336; the significance is 0.000; and the Durbin-Watson value is 2.105. These results prove the validity of the regression model and solve the multicollinearity problem. The sub-factors of the variable adoption motive have a significant positive (+) effect on the recommendation intention, in the order of the perceived behavioral control (β =0.386), followed by adoption attitudes (β =0.368) and the subjective norm (β =0.220). As a result, hypothesis 8 and the detailed sub-hypotheses 8-1, 8-2, and 8-3 are accepted.

TABLE 18. Multiple regression analysis results between adoption motive and recommendation intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	1.146	0.162		7.055	0.000
Attitude	0.299	0.030	0.368	9.953	0.000**
Norm	0.136	0.025	0.220	5.505	0.000**
Control	0.350	0.033	0.386	10.589	0.000**

$Adj.R^2$=0.521, df1=3, F=158.336, p=0.000
Tolerance=0.808, 0.693, 0.830, VIF=1.238, 1.443, 1.205
Durbin-Watson=2.105

Dependent Variable : Recommendation intention. * $p < 0.05$ ** $p < 0.01$

TABLE 19. Simple regression analysis results between adoption intention and recommendation intention.

Independent Variable	Unstd. Coefficient		Std. Coefficients	t	Sig
	B	S.E	Beta		
(Constant)	0.177	0.133		1.334	0.003
Adoption intention	0.786	0.031	0.736	31.764	0.000**

R^2=0.701, df1=1, F=708.951, p=0.000
Tolerance=1.000, VIF=1.000, Durbin-Watson=1.792

Dependent Variable : Recommendation intention. * $p < 0.05$ ** $p < 0.01$

9) TEST AND INTERPRETATION OF HYPOTHESIS 9

Table 19 presents the results of the simple regression analysis of hypothesis 9 to test the relationship between the adoption and recommendation intentions. The R-squared value is 70.1%; the F value is 708.951; the significance is 0.000; and the Durbin-Watson value is 1.792. These results demonstrate the validity of the regression model. As a result of this simple regression analysis between the adoption intention and the recommendation intention for next-generation electronic authentication services, the β value of the acceptance intention is 0.736, which verifies a significant positive effect of the adoption intention on the recommendation intention. Therefore, hypothesis 9 is accepted.

V. RESULTS

The main results of this study are summarized as follows. First, it was found that the perceived benefits of next-generation electronic authentication services have a significant positive (+) effect on the acceptance intention of the users. The two sub-factors of perceived benefit were verified to have a positive effect on the adoption intention, in the order of perceived usefulness (β =0.522) and perceived enjoyment (β =0.217). Thus, it is interpreted that individual users place greater importance on practical usefulness and attributes that are useful for daily life and work, rather than the pleasure of using the next-generation electronic authentication service.

Second, the perceived sacrifices of next-generation electronic authentication services were found to have a significant negative (−) effect on the acceptance intention. The two sub-factors of perceived sacrifice, in the order of perceived

fee (β =−0.214) and technicality (β =−0.172), also have a negative effect on adoption intention. Hence, it can be interpreted that individual users are more concerned about the perceived costs, than the technological complexity with respect to the acceptance of next-generation electronic authentication services. As the installation method of most authentication services is simplified and integrated, the perceived technical difficulties have gradually decreased. This is an important implication for companies and institutions that will lead the domestic next-generation electronic authentication service market in the future.

Third, the perceived threats to the current electronic authentication service were found to have a significant positive (+) effect on the acceptance intentions of the next-generation electronic authentication services. The two sub-factors of perceived threats were verified to have a positive effect on adoption intention, in the order of the perceived severity (β =0.490) and perceived susceptibility (β =0.373). This result reveals that next-generation authentication technologies can provide an alternative solution to the susceptibility and severity that most current users perceive about electronic authentication technologies. The results also imply that related companies and institutions need to secure service reliability and preferences that can facilitate the transition and adoption of new technologies in this process.

Fourth, the adoption motive for next-generation electronic authentication services was found to have a significant positive (+) effect on adoption intention. The three sub-factors of acceptance motivation have a positive effect on adoption intention in the order of attitudes toward adoption (β =0.400), perceived behavioral control (β =0.348), and subjective norms (β =0.266). Thus, it can be inferred that individual users decide to adopt or switch to a new electronic authentication technology based on positive judgments and behavioral controls prepared in advance. Additionally, it can be confirmed that voluntary and internal judgments or controls are relatively more important than external viewpoints or standards, such as advice from other people.

Fifth, the perceived benefits of next-generation electronic authentication services were found to have a significant positive (+) effect on recommendation intentions in the order of their perceived usefulness (β =0.534) and perceived enjoyment (β =0.263). Thus, the acceptance and recommendation intentions are both affected more by the perceived usefulness than the perceived pleasure of usage.

Sixth, the perceived fee (β =−0.201) has a significant negative effect on recommendation intentions, but technicality does not affect the perceived sacrifice involved in using next-generation electronic authentication services. Therefore, while technicality has a smaller effect than the perceived fee on adoption intentions, it has no effect on the recommendation intentions. As a result, the factor that has a significant negative affect on the adoption and recommendation intentions for next-generation electronic authentication service is related to the cost issue. Based on this, it is necessary for companies developing the

next-generation of electronic authentication services to focus on providing the latest services free of charge.

Seventh, the perceived threat to the current electronic authentication technology has a significantly positive (+) effect on the recommendation intentions for the next-generation of electronic authentication services. The sub-factors impact it in the order of the perceived severity ($\beta = 0.482$) followed by the perceived susceptibility ($\beta = 0.262$). Thus, this result is consistent with the analysis results of adoption intentions.

Eighth, the three sub-factors of adoption motives have a positive effect on recommendation intentions in the order of the perceived behavioral control ($\beta = 0.386$), adoption attitudes ($\beta = 0.368$), and subjective norms ($\beta = 0.220$). Thus, unlike adoption intentions, perceived behavioral controls have a greater effect on recommendation intentions. This may be interpreted as the active disposition to take responsibility for and control one's actions playing a more significant role than a simple positive attitude. This is because the intent to recommend to others requires clearer conviction and deeper judgment than the adoption intention. The significance of this study is that it has newly confirmed the validity and value of the TPB by understanding the fact that the planned behavior types or detailed attitudes of users change depending on the given situation or conditions.

Ninth, it was found that the adoption intentions for next-generation electronic authentication services have a significant positive (+) effect on the recommendation intention. Users who have decided to adopt the next-generation of electronic authentication services can move to the more in-depth intent to recommend it to others. Measures to promote their spread should be actively devised by new technology development companies by encouraging user's individual adoption and recommendation intentions. Thus, it is possible to enhance the recommendation intentions of more users, and to realize the dissemination, popularization, and promotion of next-generation electronic authentication service by widely confirming and announcing the positive value, high efficiency, and security stability of next-generation electronic authentication services as much as possible. A lot of attention and effort should be made in various fields, including other related industries, institutions, and academia.

VI. DISCUSSION
A. STUDY IMPLICATIONS
This study has important academic and theoretical implications. First, it has empirically analyzed multiple variables that promote and deepen the adoption and recommendation intentions for next-generation electronic authentication services. This analysis has been done using the convergence of three theories — VAM, PMT, and TPB. The results have shown that the independent variables derived from these theories have a significant effect on both dependent variables (adoption and recommendation intentions), which have an organic relationship with each other. It is difficult to find previous domestic studies that use an extended convergence model across multiple theories to verify the effect these variables have on user intentions to accept and recommend new technology. In this regard, this study proposes a more refined methodology while deepening and expanding the design and scope of studies that have combined or employed specific subject-related theories or models. It is hoped that these academic attempts will be used as useful guidelines for subsequent research.

Second, there are specific practical and strategic implications. The results of this study can be used as effective practical and strategic guidelines for the future-oriented development of next-generation electronic authentication services and the improvement of mid-to-long-term performance. Thus, technological, institutional, and policy based attention, effort, and support should be continued by companies to improve user perceptions of usefulness of next-generation electronic authentication services, and the enjoyment and satisfaction of using it, while minimizing technicalities and cost problems, and making it easier for users to use the new technology without any burden. In addition, it is hoped that policy makers or managers of related institutions will refer to the results of this study as basic data that they can refer to when conducting new projects. It is expected that the results of this study will provide valid theoretical and practical guidelines for disseminating and promoting the next-generation of electronic authentication services through such multi-faceted efforts and searches.

B. RESEARCH LIMITATION AND FUTURE RESEARCH
This study has the following limitations. First, a small-scale sample survey method was adopted. Only those respondents who participated in the survey of this study were analyzed when verifying the variables that affect the adoption and recommendation intentions for next-generation electronic authentication services. In addition, since the dependent and independent variables were not collected separately, it should be cautious when generalizing the results and conclusions of this study. Second, as additional variables that affect the adoption and recommendation intentions for next-generation electronic authentication services, personal literacy including an individual's familiarity, skill, utilization, and IT/mobile system management habits and attitudes, psychological state, and usage behaviors are also expected to have a partial influence. However, this study does not take them into account. Last but not least, this study only used regression analysis for its statistical analysis without exploring dynamic relationship between variables. This is because it is still in the early stages of research. However, it is expected that sophisticated and professional measurement tools that can investigate and verify such delicate and detailed aspects will be developed in the future.

Therefore, it is necessary to 1) conduct a larger-scale sample survey than that used in this study with considering common method bias, 2) identify and explore the relationship among variables to fully analyze the dynamic relationship,

3) develop a research model including control variables to satisfy and increase explainability, and 4) develop specialized and in-depth measurement items that can identify more detailed and multifaceted intentions to adopt and recommend next-generation electronic authentication services in follow-up studies. It is expected that these additions will lead to more meaningful research results and conclusions.

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EUNCHAN KIM received the B.A. degree in economics from the University of Minnesota, Twin Cities, in 2012, and the M.S. degree in management information systems from Seoul National University in 2017. He is currently pursuing the Ph.D. degree with the Department of Intelligence and Information, Seoul National University in parallel with his career as a Senior Researcher with Hanwha Group, Republic of Korea. He is also working as a Visiting Researcher at Seoul National University Hospital and Jeonbuk National University Hospital. His research interests include information systems, artificial intelligence (AI), and applications of AI in academic fields, such as medical science and financial studies.
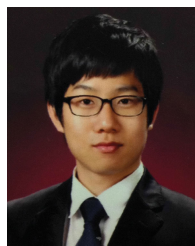
YEUNWOONG KYUNG received the B.S. and Ph.D. degrees from the School of Electrical Engineering, Korea University, Seoul, South Korea, in 2011 and 2016, respectively. He was a Staff Engineer at the Advanced CP Laboratory, Mobile Communications Business, Samsung Electronics, from 2016 to 2020. He was an Assistant Professor with the School of Computer Engineering, Hanshin University, from 2020 to 2022. He is currently an Assistant Professor with the Division of Information and Communication Engineering, Kongju National University, Cheonan, Republic of Korea. His current research interests include 6G networks, mobility management, mobile cloud computing, SDN/NFV, the IoT, and information systems.

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