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Review Article

Technological Innovation Adoption Model for Construction Products

Pelin KARAÇAR[1], Erkan AVLAR[2]

[1]Istanbul Medipol University, Faculty of Fine Arts Design and Architecture

[2]Yıldız Technical University, Faculty of Architecture

Abstract: The construction sector is in need of further self-development due to recent innovations in technology. This is because the environmental problems which have been handled seriously all over the world in recent years, and studies related to the way of creating requirements and measures for healthy construction environments have been emphasized. For adoption of new technological construction products in that sector; a system which will encompass designers, contractors and users is required. For selection and widespread use of new technological products, the decision-making is not only sufficient but also cultural and socio-economic factors and conditions are gaining in importance.

For the implementation and control of the new construction product assigned, a process of testing is required. The process of testing should be structured by allowing the use of new technological products in a system of continuous self-improvement by preventing the usage without change for a substantial amount of time. All of these processes have been examined within the scope of the doctoral thesis in model, which was developed for the adoption of technological innovation. In this study, the aim is to contribute to the creation of an appropriate adoption roadmap for constant self-renewal and self-improvement of construction environments, which are sensitive to the environment.

Keywords: *Technology, innovation, construction sector, adoption of technological innovation, Adoption Model.*

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Corresponding Author: Pelin KARAÇAR , pkaracar@medipol.edu.tr

0 Introduction

Technological innovation in the construction sector is the application of new technologies for an organization, and which significantly improves design and production of construction through the development of construction performance, business performance and a reduction in the cost of production.

Domestic requirements as well as technological developments internationally play an active role in the adoption of technological innovations of the construction products. Therefore, the adoption of technological innovations is determined by many internal and external factors. When deciding upon a variety of factors, the issue should be studied in detail.

A single focus upon approaches based on intuitive, trial-and-error methods used for adoption of new construction products merging with technological innovations reduces the possibility of making an accurate determination of the methods. A lack of these methods during the adoption process leads to the selection of inappropriate products, loss of product, time and labor economically on the applications of the construction sector. In addition, because of these deficiencies, the performance conditions of the construction are affected; accordingly, the service-life of the construction is shortened, interaction with the environment is damaged and as a result, adverse conditions in terms of users arise. For this reason, the adoption of new construction products within the construction sector through systematic decision-making is important in terms of expedient product selection.

This article which is the result of doctoral study prepared at Yıldız Technical University includes a

proposal for the adoption of technological innovation for construction products starting with the literature review related to technology, innovation, adoption of technological innovations and merging with examination and discussion of adoption of technological innovation in general and for the construction sector.

1 Technological Innovation Adoption Model for Construction Products

In the technological innovation adoption model which was developed for construction products, primary factors and steps contributed to the structure of suggestion model through the assessment of general adoption models and adoption models related to construction sector models were reviewed, and the strengths and weaknesses of analyzed models were determined.

There are general model studies for adoption of innovations [1, 2, 3, 4, 5], innovation adoption models as well as model studies for the adoption of innovations in the construction industry [6, 7, 8, 9, 10, 11]. Investigation data obtained from these models and a technological innovation adoption model proposed by Karacar [12] were developed for building products. Especially Roger's model played an important role in the creation of a structural model proposal [1].

Taking the data obtained from these models into account, a model of technological innovation adoption that could be used for adoption of constructional products in the construction sector was developed[12].

1.1 General Structure of Technological Innovation Adoption Model for Construction Products

In this model, four processes are defined as information gathering, persuasion, decision-making and testing (Figure 1). In the process of information gathering, which is the first process of the model and the inputs created by requirements, problems and requirements, innovativeness and new technologies, two outputs arise; one is inadequate information, the other is appropriate and adequate information. The appropriate and adequate information is transferred to the persuasion process as an input in order to continue the process. On the other hand, inadequate information is returned to the information gathering process.

There are two outputs of the process of persuasion; one being dissuasion, the other persuasion. In the case of dissuasion, there should be a return to the information gathering process. The situation of persuasion is transferred to the decision-making process as an input.

Outputs of the decision-making process are acceptance, rejection or a state of indecision. In the case of rejection, it moves to the process of information gathering. In the case of indecision, it is returned to the persuasion process. Acceptance creates the input of the testing process.

The testing process is the last process of the model and it ends with the request to change the technological product to another product. In the case of a request for another product, it gets to the process of a new technological request. In this case, to repeat the processes placed in the adoption model, feedback should be provided for the information gathering process with a request concerning the technological product.

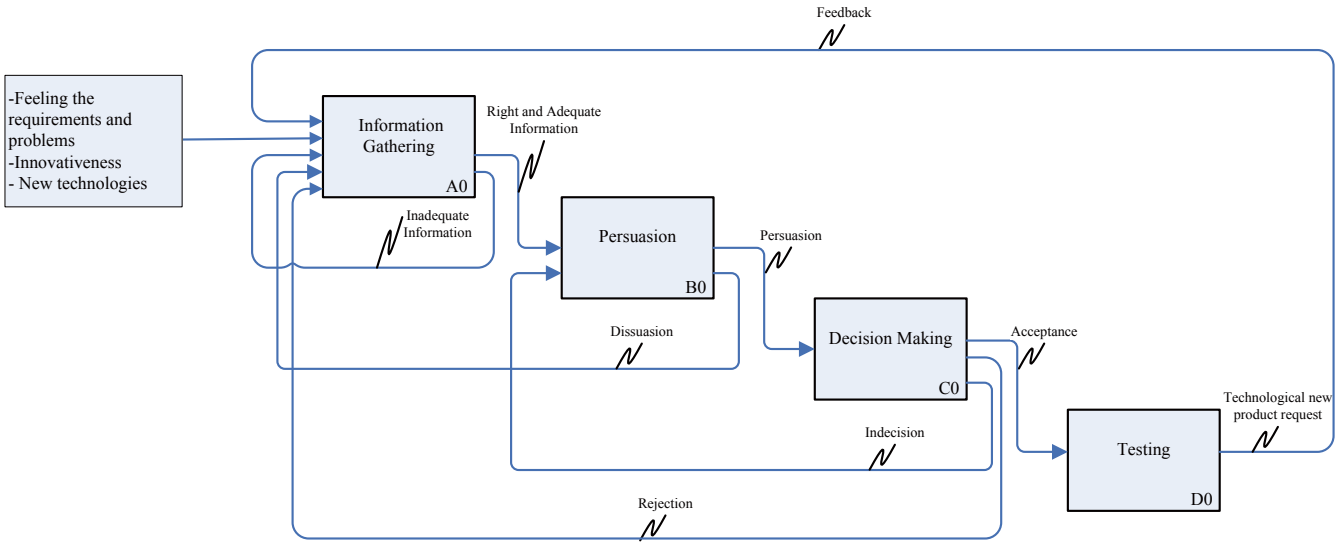

Figure 1 Technological Innovation Adoption Model for Construction Products [12]

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In the proposal model developed by the IDEF0 Integrated Definition for Function Modeling technique, each process is comprised of inputs, checks and limitations, and mechanisms and outcomes (Figure 2). Input is defined as the involvement of the product to be adopted in the process. Checks and limitations provide the process control and limitation [13]. The process directly affects and manages the study. The mechanism operates the process by converting input to output. Output is the result of the process and is transferred to other processes [12].

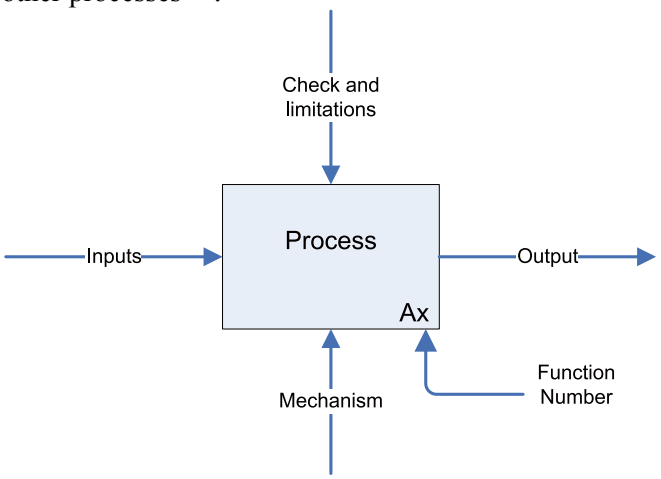

Figure 2 Process modeling with IDEF0 modeling method[13]

1.2 Processes which take place in Technological Innovation Adoption Model for Construction Products

1.2.1 Process of Information Gathering

In recent years information has forged ahead of traditional production factors, and in many sectors it has become the most important production factor. It requires an extensive process comprised of successive steps to manage information which becomes an important production input, not only for economies on the macro level, but also for those on the micro level. Loss of information means loss of competence in achievement of aims [14].

To obtain the accurate information by identifying steps in the information process and evaluating them systematically is the most important stage of the adoption of innovations.

It is difficult to get appropriate and adequate information in the adoption model in the case of deficiencies during the information gathering process. Such information output that is to be obtained during the information gathering process affects the phases of selection and use of the new product (new products).

To reach the information, phases of communication, networking, information reviews and determining the information scale have to be determined (Figure 3). Appropriate and adequate information obtained in the process of information gathering is the input of the process of persuasion. The input of the process of persuasion is the obtaining of appropriate and adequate information during the process of information gathering.

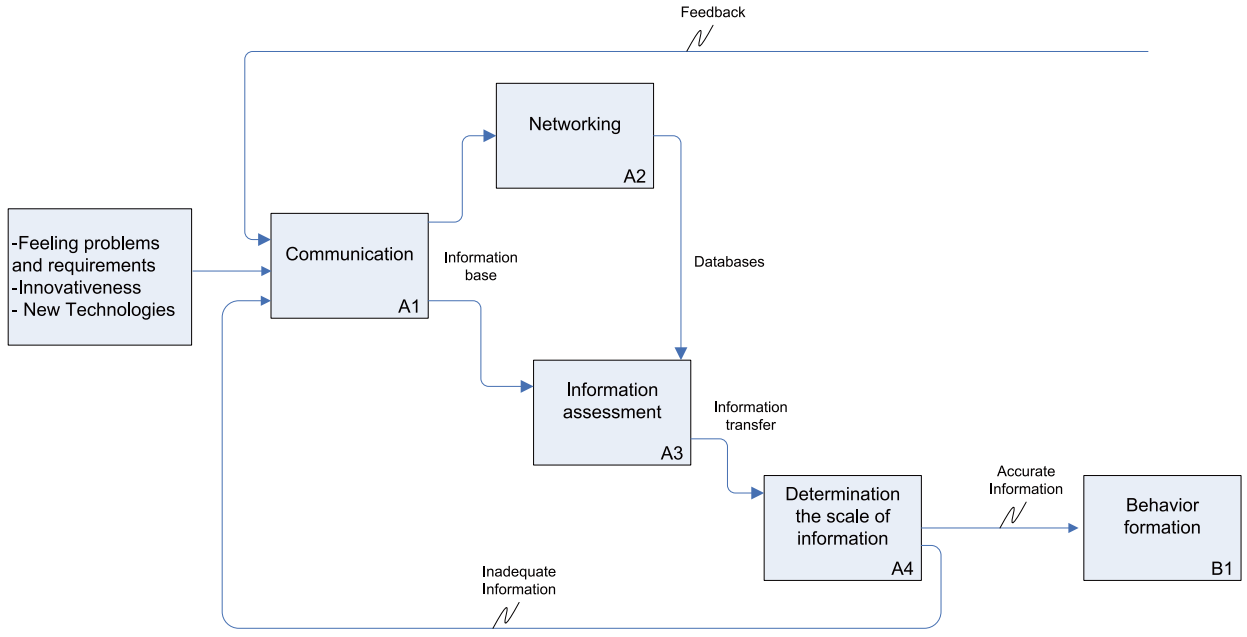

Figure 3 Phases of the information gathering process

1.2.1.1 Communication phase

Communication is a programmed data set and constitutes the raw material of information. The purpose of communication is to change and assess the client's thoughts concerning an issue or impress upon their behavior. Communication is also defined as data which makes a difference [15]. Accordingly, the inputs during the communication process consist of requirements and problems, innovativeness, finding new technologies, socio-economic factors, communication features and personal variables. The checks and limitations are the experts, patents and licenses, contracts and national policies. Mechanisms are sharing the platform, web, messages and media. Outputs obtained during the communication phase are transferred to phases of networking and information assessment (data base).

1.2.1.2 Networking Phase

The subject of One of the last studies performed is the role of networks in determining innovations. Especially, small and medium-sized enterprises use external sources and information networks as an innovation input more frequently than any of the large-scale enterprises [1]. On the other hand, large scale construction companies need more interaction with innovation brokers and enhance their collaborations in order to keep up their competitive advantage between international contractors [16]. In this direction, inputs into the networking phase are communication, experience and expertise, culture, strategy, and the social information network. The checks and limitations are composed of experience and expertise with corporate goals. Mechanism is the raw data of information systems. Databases, which are the output of the networking, create checks and limitations of the information assessment phase as input.

1.2.1.3 Information assessment Phase

The information assessment phase is discussed in any process that is open to change. For this reason, the information assessment phase has an important role in the process of information. Data base from communication reaches the information assessment phase as the input. Other inputs are coincidences and the principles of information. In the information assessment phase, checks and limitations, information sources, selection makers, skills, experts, request and presentation, standards, legislation and data bases are anticipated. Mechanisms are social systems, trial-ability, software and research and collection of information. Information transfer obtained as output provides input to determine the scale of information.

1.2.1.4 Phase of determination of the scale of information

The phase of determination of the scale of information is a phase which regards how much was focused on the information contained in the model structure. Inputs in determining the scale of information are information transfer and sources of expertise. Checks and limitations are the level of information, uncertainty and required learning level and inexperience. Mechanisms are the analysis of information, estimation and filtering. There are two outputs of this phase, namely appropriate and adequate information, and inadequate information. Appropriate and adequate information obtained as output is transferred to the behavior formation phase of the persuasion process and inadequate information output is transferred to the communication phase of the information process.

1.2.2 Process of Persuasion

The process of persuasion is an attitude of (the) individuals in choosing or rejecting the innovation or the innovation decision. Those who want to adopt the technology are very interested in the topic of innovation. These people research the details and effective information regarding innovation. Assessment information is accessed through interpersonal networks [2].

The process of persuasion consists of behavior formation, identification of an opportunity, assessment of a competitive environment, assessment of corporate facilities, gap analysis and SWOT (Strengths, Weaknesses, Opportunities, and Threats) analysis. Appropriate and adequate information obtained from information is transferred to the behavior formation phase as input, which is the first stage of the persuasion process. The output of the behavior formation, that is the innovation attitude, is introduced to the phase of opportunity identification as an input. Creating the agenda, output of the phase of opportunity identification is transferred to assessment of the competitive environment, assessment of corporate facilities and gap analysis phases as an input. Outputs of the phases of assessment of the competitive environment and assessment of corporate facilities are the input of gap analysis.

The output of the gap analysis creates the input of swot analysis. As an output on swot analysis, it is concluded with persuasion or dissuasion. Output of dissuasion is reassessed during the information gathering process. Output of persuasion provides an

input of the choice-evaluation stage in the decision making process (Figure 4).

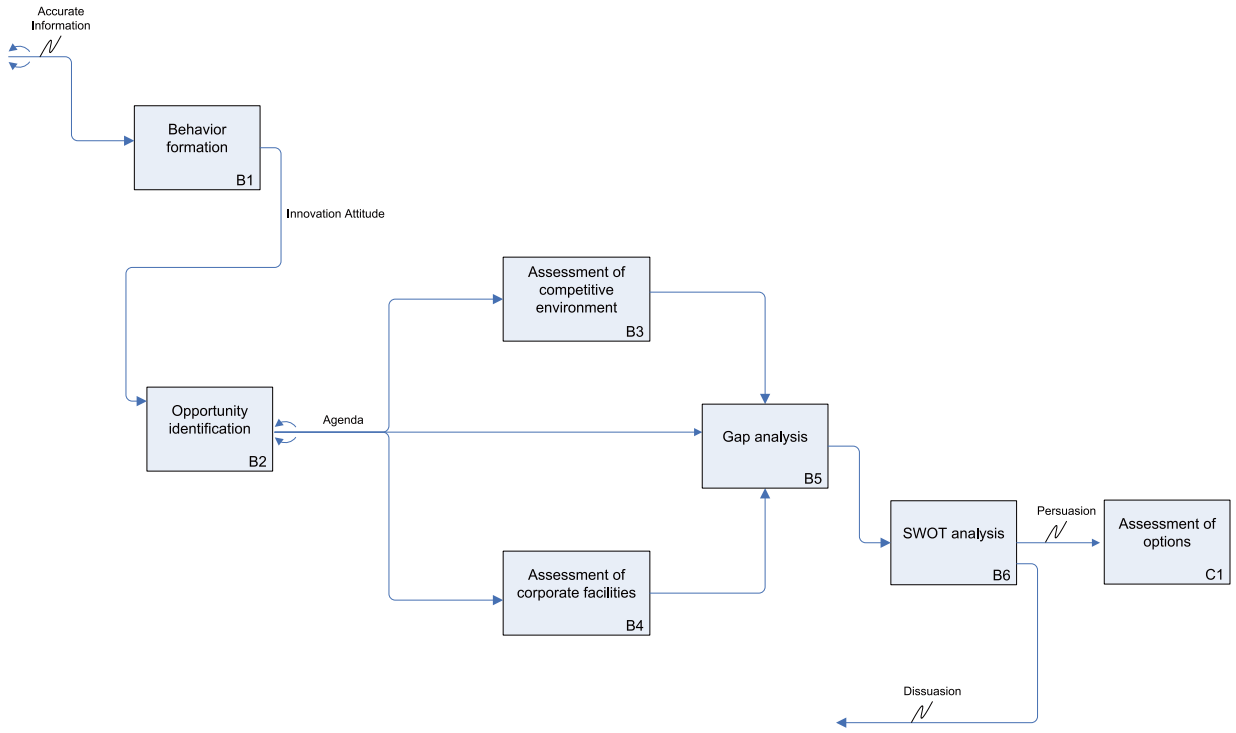

Figure 4 Phases of the process of persuasion

1.2.2.1 Process of behavior formation

In the most general sense, behavior is a concept that occurs in the actions and reactions of all people. One of the most important features of human behavior, the main subject of psychology, is that they are multi-causal and complex. In terms of behavior, it is a fact that each event is a result of a number of existing conditions. Behavior formation is the first stage of the process of persuasion. Inputs of behavior formation consist of appropriate and adequate information and samples from the information gathering process. Checks and limitations are the relative benefits, complexity, conformity, trialability and distinguishing ability. Mechanisms consist of attitudes and behavior within the social sciences concerning encouragement and ideas. The attitude of innovation which is the output of the behavior formation is transferred to the phase of opportunity identification as an input.

1.2.2.2 Opportunity Identification Phase

In the phase of identification of an opportunity, technological predictions should be made and opportunities and risks should be evaluated as a priority in order for the product to be selected. There are two kinds of technological predictions: one is made by research, the other by means of application. Research prediction means heading into the future with today's knowledge. On a prediction based upon application, future community requirements and possible market analysis are assessed. According to researchers, technological predictions based on application are more successful. In the opportunity identification phase, technological prediction techniques are required. In the technological predictions, the aim is to study long-term technological levels and possible effects of a technology [17].

Based on this information, the attitude toward innovation which is the output of the behavior formation phase is transferred to the opportunity identification phase as an input. Other inputs of this phase consist of current developments of process, method and device within the market, and technological information. The checks and limitations include product data management systems and applications. Mechanisms of the phase are opportunity scanning, technology forecasting methods, replacement and maintenance with benefit analysis. As an output, an agenda is formed. This agenda is transferred to assessment of the competitive environment, assessment of corporate opportunities and gap analysis as an input.

1.2.2.3 Assessment competitive environment phase

Competition, which is the basic foundation of the market economy model provides for the distribution

and usage limited resources of the community in the most efficient way and offers goods and services to consumers at the lowest price and highest quality possible on the basis of supply and demand under market conditions [18].

One of the phases in the persuasion process, the agenda, which is the output of the identification of the opportunity phase , enters the assessment competitive environment phase as an input Checks and limitations consist of the request and presentation, production criteria, infrastructure, marketing criteria, financial criteria, and environmental and ecological criteria. As a mechanism, the research and development strategy, the sensing of market opportunities are involved. The output of assessment of the competition environment reaches gap analysis as an input.

1.2.2.4 Assessment of corporate opportunities phas

Nowadays, the use of information tools within institutions is associated with an acceleration of the corporate operations which existed at the first stage. Applications such as the chain of supply has allowed corporate coordination to be expanded in a such way that includes units and business partners, and has provided faster business processes [19]. The agenda, which is the output of identification of opportunity phase, enters the assessment of corporate facilities phase as an input. At this stage, there is no check or limitation. The size of the firm, and its strategy, organizational structure and culture are all involved as a mechanism. The output of the phase of corporate opportunities assessment reaches the gap analysis as an input.

1.2.2.5 Gap analysis phase

Gap analysis is a marketing study aimed at creating opportunities to explore the gaps in the market. These gaps are determined in three areas. A neglected consumer group is a suitable area for making discoveries due to technological advances and lack of current product preferences [17].

Inputs of the gap analysis are markets, changes and new products outside the agenda which is the output of identification of opportunity. When output of the competitive environment assessment phase affects the checks and limitations, the output of corporate opportunities assessment phase becomes effective as a mechanism. Output of gap analysis reaches SWOT analysis as input.

1.2.2.6 SWOT analysis Phase

Techniques for the analysis of corporate structure subjected to a number of criteria are the tools of modern business management used consistently. Thus, it can be readily identified whether or not the current status of the organization is functioning correctly. One of these techniques, SWOT Analysis, is one of the most effective methods of assessment that enables internal and external assessments such as the company's institutional functioning, competitiveness, position of the industry within the market, and the presence of external threats [20].

Output of the gap analysis phase is an input to the SWOT analysis phase. In the SWOT analysis phase, as the check and limitation, the factors preventing the adoption of products and main parties are located. This acts as a mechanism factor that allows the adoption of the product to be activated. There are two outputs of SWOT analysis, namely persuasion and dissuasion. In the case of dissuasion, it should be returned to the process of information gathering. Output of persuasion is the input of evaluating choices phase in the decision making process.

1.2.3 Decision Making Process

The decision reflects the results concerning the future in the context of a previous behavior. Therefore, decision making is treated as a process of making a rational and conscious selection which consists of various stages [21]. The decision-making process consists of evaluating choices, design, obligations and stages in the selection process. In the decision-making process, the output of the process of persuasion is transferred to the phase of evaluating choices as an input. The output of evaluating choices phase, option of the new technological product constitutes an input into the design phase. The prototype, which is one output of two of the design phases, is transferred to the selection phase as an input and design outputs become checks and limitations of the selection phase.

Outputs of the obligation phase are transferred to the design and selection phases as checks and limitations. The selection phase, which is the last phase of the decision process, creates three outputs; namely, acceptance, rejection or indecision. In the case of rejection, it is then sent to the information gathering process for a request for new technological products. In the case of indecision, it is returned to the persuasion process. Acceptance creates the input of the resource allocation phase which is the first phase of the construction process (Figure 5).

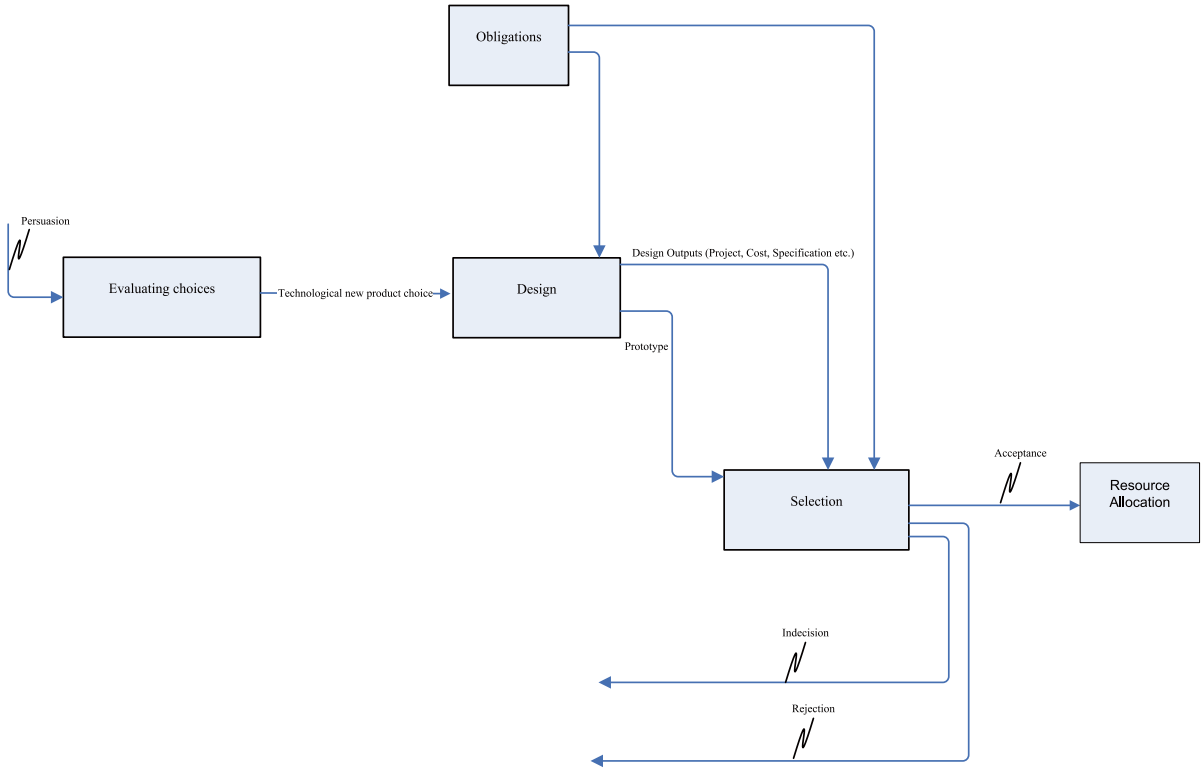

Figure 5 Phases of the decision-making process

1.2.3.1 Phase of evaluating choices

The decision-making process is actually a process of assessment and selection. The selection is made between the options of action. Determining the best option requires the evaluating choices. Evaluation is performed by measuring the efficiency of each option in achieving the objectives [22].

Inputs of evaluating choices are the output of the process of persuasion and types of information. As the check and limitation, they comprises competition, project criteria, company criteria, lack of product range, physical characteristics, comprehension, memory, attention range, communication problems, legislation, performance, quality, labor, cost, the environmental context and modification of the specification with the risk and uncertainty. As a mechanism, it comprises a technological context, CRM (customer relationship management), organizational context, technological capability, control mechanisms, perceived characteristics of innovation, information exchange, innovation stability and leadership, automation systems, supply chain management, process management, effective change management and a technology acceptance model (TAM). As output, the new technological product option is transferred to the design process as input.

1.2.3.2 Design phase

When the whole design process is analyzed, it is seen that the design phase of architectural structural elements, which is defined by the technology used in its construction, is one of the phases in which the structural quality of the construction is discussed in detail, and a solution is found by an evaluation.

Inputs of the design phase are experience and expertise, product range, previous applications, goals and values of design, knowledge, creativity and communication, apart from the technological product which option comes from the assessment of options phase. Checks and limitations of this process can be listed as time, performance and quality, environmental factors, physical characteristics, applicability, complexity, and the disagreements which occur with the output of the obligations phase. In this phase, the mechanisms are determined as perception, competition, systems for procurement, consulting, innovativeness, technological factors, confidence, proportion, aesthetics and creativity. There are two outputs of this process. First, the design output (project, cost, specification) is transferred to the selection process as control and limitation. The prototype, the second output, is transferred to the selection process as input.

1.2.3.3 Obligations phase

Obligations include all necessary rules to be followed and established by the institutions concerning construction and the construction production system. Related obligations must be taken into account in determining the criteria to evaluate options [23].

As input, private documents, guidelines, laws, specifications, regulations, standards and regulations enter the phase of determining obligations. Checks and limitations of this process consist of national conditions and the mechanism consists of the bureaucracy. Obligations as output are transferred to both the design and selection phases as checks and limitations.

1.2.3.4 Selection phase

Decisions regarding product selection are apparent at the stage of construction. When making a decision, it is required to choose the technological product in accordance with the current domestic conditions. Making the right decision depends on the designer, who is in the position of decision-making to take the responsibility and fulfill his/her duties during product selection, and the relevant bodies to check the results, and the users to examine the decisions.

Inputs into the selection phase are technical characteristics of innovation, types of innovation, requirements based on perception, customer requirements, physical characteristics, industrial characteristics, experience and expertise, business strategy, cost and performance data, and previous experience which disregards the prototype that comes from the design phase.

The output of the design phase (project, cost, specification), enters into the selection phase as checks and limitations. In addition, other checks and limitations consist of technological conditions and the environment, availability, applicability, domestic conditions, the complexity, responsibility, time, cost, performance and quality, complex product systems and environmental factors, organizational factors, bias, compliance with existing procedures, and receiving tender and innovativeness requirements.

The mechanisms of the process comprise services, advertising, competition, market function, parameters of the decision-making process, organizational culture, health and protection, aesthetics, confidence, creativity, availability, change and maintenance, efficiency, selection methods and techniques, and the monitoring of the technology.

Outputs of the selection phase, which is last stage of the decision-making process, are acceptance, rejection or state of indecision of application of the technological product. In the case of rejection, it is returned to the process of information gathering for new technology. In the case of indecision it is returned to the persuasion phase. Acceptance creates the input for the resource allocation phase which is the first phase of the application process.

1.2.4 Testing Process

The fourth process of the proposed model of adoption of the technological innovation concerning the construction product is the testing process. Testing is an attempt to measure, and check.

The testing process comprises the phases of resource allocation, preparation, construction and confirmation. In the decision making process, acceptance of the new technological product which is the output of the selection phase, enters the resource allocation phase of the testing process as an input. The output of the resource allocation creates the input of the preparation phase.

The output of the preparation phase is transferred to the construction phase as an input. Outputs of the construction phase, current usage and types of information create the input for the confirmation phase. Outputs of the confirmation phase are the widespread use of new technological products and changing the accepted technological product to another product. When a required product change is considered, it is returned to the process of technological product request. A technological product Request provides feedback to the process of information gathering as an input and processes in the adoption model are repeated .

1.2.4.1 Resource allocation phase

Timing and allocation of available resources are required for the completion of a construction project. Labor, equipment and materials are the important project sources to be carefully managed. Some disruptions may occur because of seasonal deficiencies, labor disputes, equipment defects, competition demands, delayed deliveries and other related uncertainties. The main purpose of resource planning and resource allocation is to provide and support the procurement and implementation phases within the targeted time and budget [24].

Resource allocation research is usually focused on a single type of resource: money, manpower, equipment, managerial effort and so on. In innovation application, the stability of making resource allocation is of importance for the application to be successful [25].

Inputs of resource allocation are finance and communication. Apart from this, the decision-making situation comes from the selection phase during the decision-making process. Checks and limitations consist of technology, environment, cost, quality and performance. As a mechanism, expert resources are engaged. Output of the resource allocation phase is the input to the preparation phase(Figure 6).

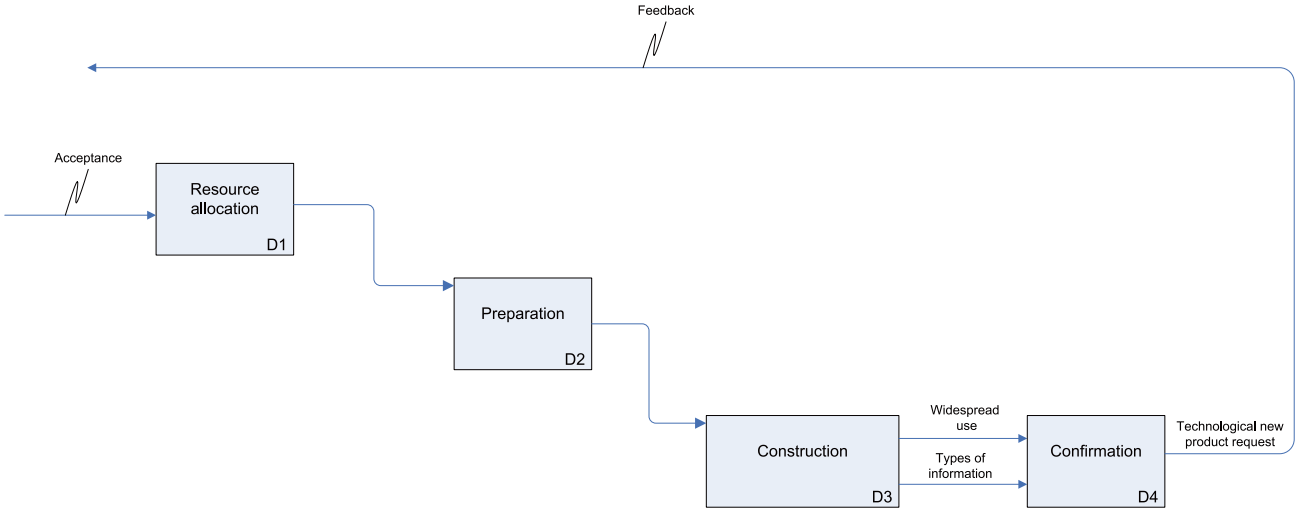

Figure 6 Phases of the testing process

1.2.4.2 Preparation phase

In this phase, the contractor employs sub-contractors for construction work. He/She benefits from the expert knowledge of sub-contractors [26]. During this phase, the project proposal is the result. The preferred option is adopted and the design is detailed within the scope of variables such as the determined cost, time and quality, and resource allocation is made.

In the preparation phase, inputs consist of resource allocation, labor, machinery, equipment, technical assistance, communications, and financing. Checks and limitations are time, quality, cost, technology, environmental issues, legislation and design decisions. The mechanism consists of scalability and expert sources. The output of the preparation phase creates the input for construction.

1.2.4.3 Construction phase

In construction, the most important task is to prepare those who are responsible for implementation. To do this, to provide good notice. And to concentrate on the scope are needed. Otherwise it means inertia and passive resistance, and it has the characteristic of being forced [27].

Inputs into the construction process are the outputs of the preparation phase: information, technical assistance, manpower, machinery and equipment, and financing. The checks and limitations consist of the performance, quality, cost, time, market and technical uncertainties and risks, environmental problems, speed of construction processes, regulations, specifications and design decisions. As a mechanism, incentives, experts, technology, experience and the project production management occur. The outputs, namely current usage and types of information reach the confirmation phase as inputs.

1.2.4.4 Confirmation phase

In this phase, adopters are needed for the support for the innovation decision. If negative situations related to innovation occur, the innovation decision may be abandoned.

Current usage and information types enter the confirmation phase from the construction phase as inputs. Checks and limitations consist of warranty terms, environmental and scheduling conditions. Mechanism is the usage assessment and innovation attitude of the adopters. A product change request is created as the output. In the case of losing the importance of a new technological product in time, and developing another product instead, the output of the confirmation phase creates input to the phase of a new technology request and a feedback is provided for another technological construction product to the information phase in the model.

1.3 Steps of Technological Innovation Adoption Model for Construction Products

In the application of the model to various construction products, guidelines are needed for both preventing incomplete and inaccurate application, and sequential and orderly implementation of the relationship between processes and stages of the model. These steps are accomplished with the expansion of the processes developed in the model as directory. In that directory, four processes of the model are identified as main steps. Sub-steps are explained by the phases placed in the processes.

The main steps of the model of proposal adoption are composed of information gathering, persuasion, decision-making and the testing processes. Expansion of these phases are processes according to these main steps, and are placed in the sub-steps, and organized by the steps of input, mechanisms, checks and limitations, and output. Required descriptions of step expansion are provided according to the sampled product and the product is evaluated in accordance with the result obtained here (Table 1.).

Table 1. General expansions of steps of the model [12]

Process name	**Phase name**	
Step type	Step expansion	Description
Input	...	…
Mechanism	…	…
Control and Restriction	…	…
Output	…	…

2 Conclusion

The survey concerning the adoption of technological innovations in the construction sector shows that low levels of technological adoption due to low level usage of new products, slow adoption of technology and project-oriented sector, and slow change or the remaining unchanged laws and regulations of innovation works of the construction sector, prevent the construction sector from discovering new technologies and the adoption of these innovations by the firms.

However, it is known that in the constantly changing conditions of the construction sector, the fourth dimension of performance in addition to cost, quality and time, which are the traditional dimensions of the construction industry, will be formed by technological innovations; and these will gain importance in reducing costs and accelerating the processes of construction as well as improving quality. In the construction sector, developing new technology and effective usage will provide competitive benefits.

Decisions taken and recent advances in the construction sector seriously affect other sectors and accordingly the entire domestic economy. In recent years, it has fallen into a very complex structure in parallel with development and production as a result of technological changes which have emerged in the construction sector and simultaneously quick development of the sector by obtaining a usage area of many imported products along with domestic products .Due to lack of sufficient information on a product or limited time allowed to persons, who evaluate and select a product, leads to inappropriate usage of the construction product. In this context, it is believed that there is a need for a model, including systematic processes, for the adoption of technological innovations and a spread of technological innovations in products for the construction sector. In this study, a model was developed for the adoption of technological innovations for construction products.

With regard to the selection of construction products, application of the technological innovation adoption model developed in this study will be helpful for the following reasons:

- It leads to an increase in the quality and performance of the construction,
- It results in a reduction in the loss of product, time and labor in terms of cost,
- It provides a significant contribution to the designer, contractor and user (who are in charge of decision-making concerning selection of technological innovations in construction products) in terms of time, cost, and quality, as well as a competitive advantage,
- It supports the designer, practitioner and user in making their decisions systematically on the construction products,
- It provides the opportunity to choose in the right products of technological construction in the construction sector, which is growing, changing and improving all over the world and in this context, enables widespread usage,
- It facilitates the appropriate usage of energy in production, application and usage,
- It contributes towards the formation of environmentally sustainable construction technology and protection of human health and the natural environment,
- It provides an advantage in satisfying the customer requirements,
- It is helpful in accelerating the production process of construction products,

·It is helpful in enhancing the prestige, reliability and profitability of the construction sector in the market.

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