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Original Research Article

Proposing a Holistic Definition of the Architecture Design Process

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Abstract

Problem statement: The present paper suggests that despite several decades of design research, most of the models presented for the design process have a partialist approach and have not been able to provide a holistic definition of it. In addition to reducing the overall process, this situation has hindered its comprehensive understanding.

Research objective: This study seeks to provide a comprehensive description of the design process based on a systemic approach (as one of the holistic approaches).

Research method: For this objective, both theoretical and experimental methods have been used to examine the systemic features of the process. The interaction of the process with the environment, identification of its components, and the ability to be controlled through feedbacks have been achieved theoretically and with the help of logical reasoning and inference from the opinions of experts. In the experimental section, to study the relationships (component/ total), totality, and structure, it has been referred to the design process of industrial subjects (in a power plant). In this section, the techniques of "open structured interview", "preparation of design protocols," and "documentation of design products" have been used to collect primary data, and quantitative/ qualitative content analysis has been used to evaluate the data. The research participants include ten experts in the design of power plant complexes.

Conclusion: The results confirm that the design process, as an open system, has a flexible structure and is controlled by feedbacks. Their action, knowledge, manner, agent, and tool, together with their sub-components, are in the form of components and interact with the whole process.

Keywords: *Architecture Design Process, Industrial subjects, Systemic Approach, Open System.*

Introduction and problem statement

The design research is a movement that, according to many experts, dates back to the 1960s. This title refers to excavations aimed at creating knowledge of artifacts (Abel, 2013, 11). One of the topics of design research is understanding the design process. Among the various goals presented for this topic is the reduction of risk-taking in large projects. Despite the multiplicity of research on the design process, this aspect of the design needs to be explored for many

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reasons. First and foremost, the plurality of descriptions of the process. Regardless of their differences, each has its weaknesses and strengths (Ng, 2011). The second reason is to determine the relationship between the process and the design subject. The idea that the design process is not affected by the subject is accepted by some experts as default, in the early steps of the design research movement. That is, the different subjects such as the refinery, the power plant, the church, have a typical process (Gregory, 1966, 3). In contrast, some researchers of design believe that the process is affected by the subject. Despite the severe contradiction in the views of these two groups, none of them provided rational justification. Therefore, analyzing what the design process is can help to understand this issue. However, the most important reason is the partialist nature of the presented patterns for design process, which prevents a comprehensive understanding of this aspect of design. For example, in the three-part model of Lawson (2008, 57), which claims that the design process consists of three activities: analysis, synthesis, and evaluation, there is no indication of the designer's role, tools, stages, and methods. These patterns reduce the design process to a set of activities. Therefore, this research seeks to provide a holistic definition of the design process.

Research question and hypothesis

What pattern of the architecture design process can we present that indicates its totality? What is the relationship between the design process and the subject (for example, industrial power plant issues)?

The research hypothesis is that the whole design process can be defined as an open system. In this system, there is a significant relationship between the overall design process and the subject matter (for example, industrial power plant issues).

Research background

Various studies have studied the design process and provided several models for it. Alexander's pattern (Alexander, 1964, 94), Pena-Parshall's pattern (Pena & Parshall, 1969, 18-22), March's pattern (March, 1984, 266-269), and Darke's pattern (Darke, 1984, 179-181) are an example of these patterns that are categorized into different classes. Dubberly (2004) categorized these patterns into academic, consultant, and cyclic models. Cross (2000, 30-34) also introduced design processes in the form of two descriptive and prescriptive models. Historically, these models have been explained in three forms: intuitive, rational, and controversial (Lang, 2002, 42-51). Careful consideration of these backgrounds confirms that the historical orientation of the patterns is in the direction of describing the design, not prescribing it. Therefore, the present study seeks to provide a descriptive model of the design process. The backgrounds show that although in the rational form, the design research has sought to explain a systematic pattern of design, many aspects of the system have been neglected in these patterns, and the patterns have become partial. All things considered, the presentation of a model of the architecture design process based on a systemic approach is both in line with previous research and has its innovation.

Theoretical framework

A systemic approach is a holistic approach and believes that by reducing phenomena to components, part of their totality is impaired (Farshad, 1983, 36). In this view, the behavior of an independent component differs from the behavior of the same component in interaction with other components. Therefore, understanding the totality of each phenomenon depends on identifying the interactions between the components (Mele, Pels & Polese, 2010, 127). In the (general) systems theory, different phenomena can be thought of as a system, and a common template can be drawn for them. The system in English dictionaries has components, relationships, structure, totality, purpose, and generalization. Bertalanffy (1987, 76-76) emphasizes the constitutive features of the two components in defining the system. The point that emerges from Bertalanffy's definition is the influence of the whole on the part. In Ackoff's definition, each component affects not only the behavior of other components but also the overall performance (Laszlo & Krippner, 1998, 55). Therefore, it should be said that the two-way relationship of the component/ whole is another feature of each system. Open systems are one of the types of systems. These systems interact with the surrounding environment through inputs and outputs (Fig. 1). Control capability is another feature of these systems that results from comparing outputs with system goals (Friedman & Neuman Allen, 2011, 5). From the above, a systemic approach may allow for a holistic definition of various phenomena including the design process. A definition that does not rely solely on the characteristics of the components. It also values the interactions between the components. Moreover, to define the design process as an open system, it must first be determined that the design process is a system. That means that the process has a set of components, coordinated relationships (between components, as well as between a component and total), totality, and structure. In the next step, the design process should be among the open systems. That is, it interacts with the environment (through inputs and outputs of design) and controls (by comparing design goals with feedback). Thus, according to systems theory, to provide a holistic definition of the design process, it must be determined that design creates a real relationship between input and output. That is, there is an interaction between design and the environment. It is also essential to know what components the design has. Moreover, it should be noted that there is a significant relationship between these components and the overall design. It should also be taken into consideration that the design process can be controlled by comparing the output with the goals.

Research methods

Researchers use various theoretical and experimental methods to understand the design process. They believe that the simultaneous use of both areas can increase the richness of the results. Therefore, the present study uses both domains to examine the systemic features of the process. The interaction of the design process with the environment, the identification of its components, and the ability to be controlled are achieved theoretically using logical arguments and inference from the opinions of experts. In the experimental section, to study the relationships (component/ total), totality, and structure, it is referred to the design process of industrial complexes. The reason for choosing these subjects is their importance in the history of design research (Gregory, 1966, 5) and the country's industry. A combined-cycle thermal power plant is one of the industrial complexes that is a collection of components, equipment, buildings, areas, etc. it is one of the important source of electricity generation in the country. In the design process of these power plants, architecture plans are produced only for the buildings and their areas. Also, their buildings are divided into two categories: industrial (such as control building) and non-industrial (such as an administrative building); thus, design subjects in a combined-cycle thermal power plant include industrial buildings, non-industrial buildings, and industrial areas. In other words, in the design process of this power plant, there are two industrial subjects and one non-industrial subject. In the experimental section, the required data is in line with the designer, process, and product of the design (Broadbent, 1973, 1). For data on the designer, open structured interviews were conducted with five architects with more than ten years of experience in power consulting firms. They were asked to talk about the components of the design process, including activities, stages, knowledge, the designers, and their personality, techniques, methods, and tools for designing power plant complexes. For objective observation of the designers' activities (i.e.

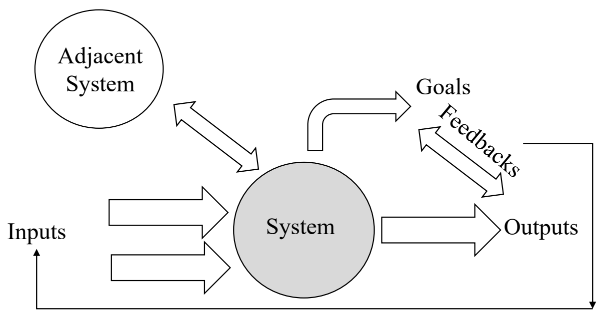


Fig. 1. Conceptual model of open systems. Source: Friedman & Neuman Allen, 2011, 5.

for data on the design process), three 30-minute design tests were performed on three subjects (a switchyard control building, an administrative building, and a fuel area) based on actual documentation of a power plant project. The participants in this section consisted of five architects who had completed their doctoral dissertations on the power plant complexes. The conversations of these people during the design were recorded and documented with the technique of "think-aloud". They were asked to design these subjects within 30 minutes based on the program provided to them, and at the same time, explain their thoughts aloud. The produced documents of these tests were also collected as design products (i.e. for data on the design products). It should be noted that after the design tests, these participants also joined in open structured interviews to match their thought process with the design protocols. Since the initial data were prepared in the form of text, quantitative/ qualitative content analysis was used to analyze them. The numerical quantity of the questions, and time allocated to them, were first determined for each participant while analyzing the content of design protocols. Then, other sections, especially open interviews, were tried to be analyzed qualitatively and in line with the components of the process.

Results

• Design as an interface of input and output

In the field of design research, several definitions have been proposed for design. One of their characteristics is the constructive aspect of design, which believes that design seeks to provide the desired human conditions. This aspect is expressed by words such as realization, creation, transformation, change etc. In fact, the design is the turning of an unfavorable situation into a preferred one (Gero, 2006, 27). From the comparison of the above definition with the definition of the process based on the change from input to output (ISO 9000, 2008, 3), it is clear that design is inherently a process work; because the unfavorable situation is the input of this process, the preferred situation is the output and the design is their interface (Fig. 2).

• Components

Reflecting on the phrase "turning an unfavorable situation into a preferred one" shows that this is an act requiring actions that researchers in explaining it, have resorted to the two concepts of activity and stage. Blessing proposed a two-dimensional structure for design projects. The vertical dimension reflects the stages of project formation, which range from feasibility studies to preliminary design, detailed design, and planning for production/ distribution/ dismantling. The horizontal dimension also characterizes the problem-solving process that occurs at each of the vertical stages. Defining problems, shaping solutions, simulating or predicting performance, evaluating, and selecting the best system are examples of these activities (Wynn & Clarkson, 2005, 36; Roozenburg & Cross, 1991, 216). In addition to these patterns, some researchers pointed to only one of the two concepts of activity and stage in explaining design actions. As an example, Lawson used analysis, synthesis, and evaluation to explain the design process; However, Archer spoke of analytical, creative, and executive stages (Cross, 2000, 35). A design activity is a change that a designer makes in design situations (Reymen, Hammer, Croes & Van Aken, 2006, 153), while each stage confirms the significant changes that occur at different phases of the design, and the plan requires them to go through to reach maturity. The fractal nature of the process allows each segment to be divided into smaller sections or smaller sections to be grouped under larger sections (Dubberly, 2004, 13). Nevertheless, because design activities depend on the hemispheres of the brain, design activities can be organized into two categories: critical and creative. The stages also depend on the design life cycle. Therefore, design actions, as one of the components of the process, define all creative and critical activities that are carried

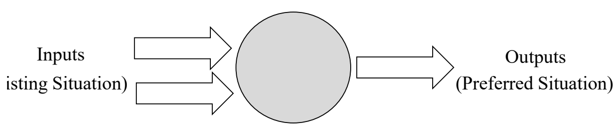


Fig. 2. Design as an interface. Source: author.

out in all stages of design and set the ground for change from input to output.
It can be rationally stated that any change in the unfavorable situation does not end in the preferred situation. That requires design methods of knowing (Cross, 2001, 49-55) that fall under the design knowledge. Lawson points to the dual forms of experiential and theoretical knowledge and argues that these methods of knowing rely on both episodic and semantic memory (Lawson, 2004, 96-105). In the field of cognitive psychology, there is a threefold category of memory and the corresponding knowledge: procedural, semantic, and episodic (Tulving, 1985). Procedural memory deals with the maintenance of the relationships learned between stimuli and responses and cause humans to respond adaptively to the environment. Semantic memory also refers to the ability to create mental patterns from the world around us. Episodic memory also pertains to the ability to capture and maintain experienced events and allows them to be retrieved. These triple memories correspond to the procedural, semantic, and episodic knowledge. The emergence of design as a skill in Lawson's thoughts (2008, 12) shows that procedural knowledge and its corresponding memory are also used in the design process. With this in mind, the design process requires all three of the above knowledge.
In the field of design research, various methods have been mentioned for design, and it is believed that design requires a method. For example, Jones (2011) has mentioned various methods for design. Reflecting on these methods confirms that many of them act only as a technique and have several differences with the method. For example, interviewing users or preparing a questionnaire is just a technique for obtaining information in various design areas. Rezaei (2014) has also introduced popular design methods in a relatively comprehensive study. Careful consideration of these methods shows that some methods, such as program-center and rational methods, are intellectual-logical by nature while some other methods, such as metaphorical and deductive, will be mostly sensory-intuitive by nature. Depending on their nature, these methods fall into the intellectual-logical and sensory-intuitive spectrums. The above confirms that architects use different methods and techniques in the design process which fall in the manner component of the design process.
"Turning an unfavorable situation into a preferred on" as a single act not only requires action, knowledge, and manner, but it also needs an agent to perform the required activities and bring knowledge into the process. Lawson believes that design knowledge is produced in different places and enters the process through exchange between designers, customers, and users (Lawson, 2004, 21-30). Therefore, the agent component in the design process refers to the people through whom design knowledge enters the process. In addition to the person, their personality also affects the process. As an example, divergent thinkers are more efficient at producing options, and convergent thinkers are more efficient at selecting options (Broadbent, 2009, 156). Thus, the personality of individuals is another sub-component of the design process.
Design requires tools. In other words, performing any design activity requires a tool in addition to the agent. Design tools are a set of equipment and media used in the design. Hand tools (both pencil and paper) and computer software (such as CAD, Sketch-Up) are both directly involved in the design process, and indirectly, by producing secondary tools that are drawings, they affect the design. Architecture drawing is divided into five categories: references, diagrams, design, presentation, and imagination (Kheyrollahi, 2013, 73). Architecture drawings can be produced by hand or in a computer environment. Real-world models are other tools that are used in various forms of the sketch, diagram, concept, and final, in the process of completing the design (Mills, 2011, 1-2). Speech is another sub-component of the tools used in this process, and through it, designers create a bunch of complex ideas in the listener's mind (Lawson, 2004, 103-114). Thus, the component of the tool in the design process includes drawing tools, drawings, real-world models, and speech. The above confirms that the design process has multiple components, including the action,

knowledge, manner, agent, and tool. Each of these components has sub-components that participate in the process (Fig. 3).

• **Relationships (between components, between component and total), totality and structure**

To examine the impact of the whole process on its components, structure, and the relationship between components, we must refer to the findings of the experimental part of the research. In the three design tests, observations show that the participants asked questions while reviewing the program to obtain the required information. Findings show that the number of questions and their time in the first and third tests are much higher than the second test (Fig. 4). Examining the questions shows that this difference is not due to general issues such as building orientation, climate, and so on. Instead, it is associated with non-architecture specialized topics such as equipment, functional relationships, and standards, which have caused more questions. These questions, raised at the beginning of the design process, increase the volume of design data collection activity in the first and third tests. The participants' comments in the interviews also confirm that the beginning of the architecture design process in the industrial buildings and areas of the power plant depends on obtaining information from non-architecture disciplines. Architecture, in its early stages, requires the collection and internalization of the desired information. Participants' statements show that the process-based or function-based characteristics of industrial buildings and areas of the power plant increase the similarities between the two power plant complexes. Therefore, the designer's task in these industrial projects is to adapt the previous projects to the new sites. That is why review and modification activities are becoming more widespread in the design of these projects. Since these activities have an analytical nature, the volume of analytical activities increases in the design stages of industrial buildings and areas of conventional power plants. Also, the participants considered the existence of planning, design, construction, and commissioning stages for all industrial and non-industrial parts of the power plant. However, they also made some distinctions. As an example, in the commissioning process of industrial buildings, it is necessary to propose and perform the required tests. These findings show the impact of the design process on the designer's actions including activities and stages. Careful consideration of the design protocols shows that they followed specific design standards in the first and third tests, especially in terms of cable gallery height, space cooling, space specifications, and equipment. But in the administrative building test, this need was not felt. The statements of the participants in the open interviews also confirm that the standards of Iran's electricity industry, oil and gas standards, fire standards, API, ASME, NFPA, and ASTM, are the most critical resources that are needed in designing the industrial subjects of the power plant. The content comparison of the participants' questions also confirms this statement because their questions in the first test are more in line with the standards of the electricity industry, and in the third test, they tend to be in line with oil standards. Moreover, by categorizing the questions of the participants, it can be found that their primary needs are information about spatial relations, functional and process relations, equipment, safety considerations, installation and execution, maintenance, operation considerations, etc., which is closely related to the subject of the first and third tests. Therefore, it can be said that the overall design process has a significant effect on the content of the propositional or semantic knowledge. Open interviews with participants also show that they have specific methods and criteria for distinguishing the design process of experienced personnel from

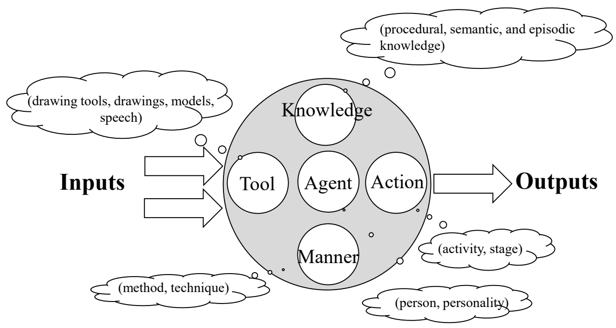
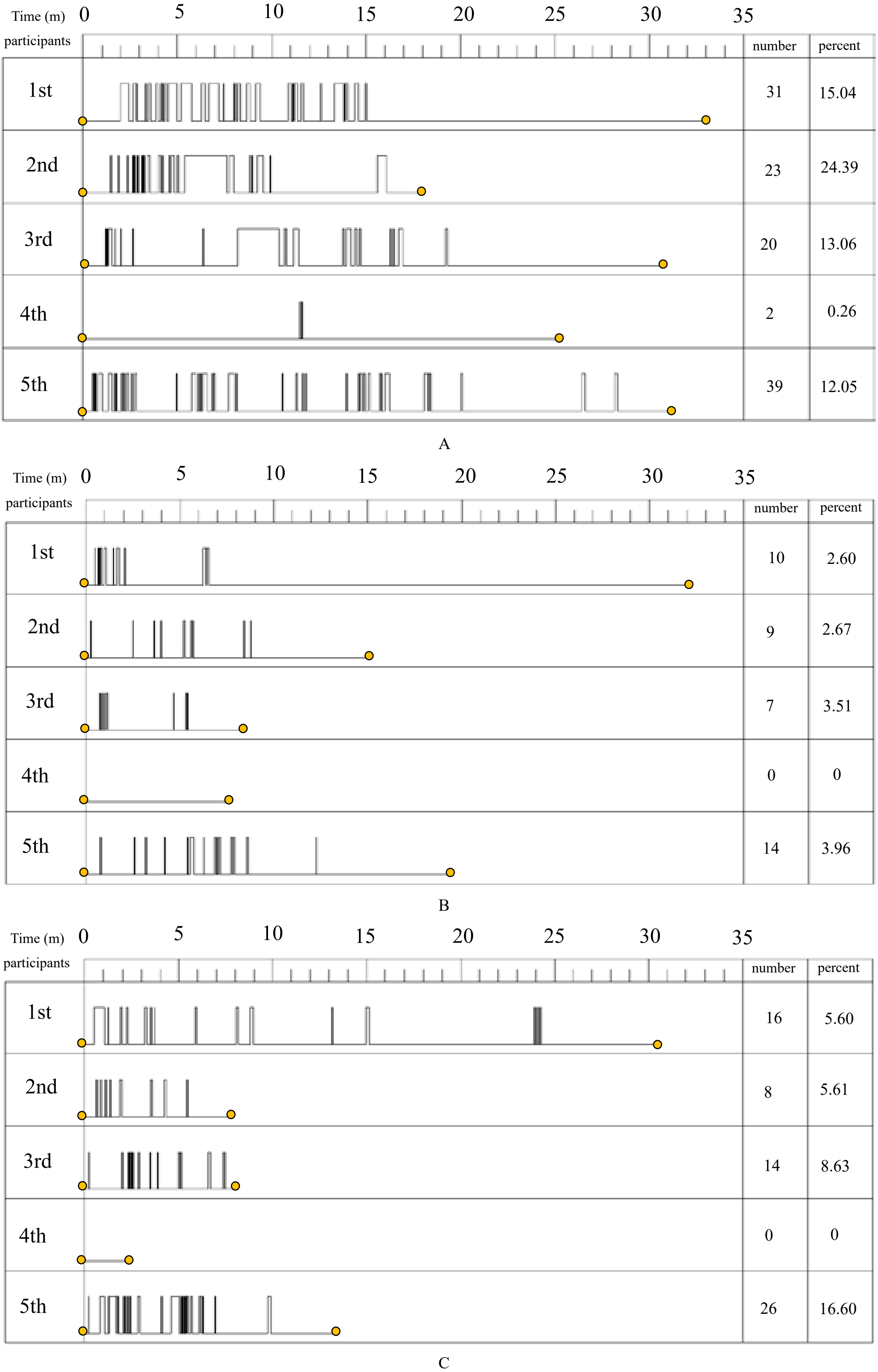


Fig. 3. Components and sub-components of the architecture design process. Source: author.

Fig. 4. The quantity and time of questions, asked by the participants in the first, second and third tests. Source: author.
A) First test B) Second test C) Third test.



beginners. Reflecting on the type of questions, reviewing the priorities and delays of activities, and considering the accuracy of the output of each section are the most critical ways in which participants become aware of the designer's expertise. By re-examining the participants' questions, it can be seen that they have tried to engage in non-architecture specialties in the first and third tests. On the other hand, during most of the test times, they tried to acquire the required technical knowledge before drawing any section. In other words, they consciously tried to follow the design process under non-architecture disciplines. Instead, in the second test, all participants moved in a self-centered way, regardless of the non-architecture disciplines. They also tried to expose their drawings to other disciplines in design. Therefore, it should be said that the overall design process has influenced the knowledge of the designer's procedure (i.e. on procedural knowledge). At the end of the tests, the participants were asked to identify the precedents they had used during the design. The comments show that the precedents of their minds in the first and third tests were the control room of nuclear and hydroelectric power plants, white cylinder fuel tankers, dock, etc., which are industrial, and they are relative to the overall design. The precedents of the participants in the second exam (urban office buildings, the study hall of the library of the Faculty of Architecture, etc.), are non-industrial precedents and are related to the overall design. Therefore, the whole of the design process has influenced the episodic knowledge of design as well as semantic and procedural knowledge.

Careful consideration of the design of the participants indicates that they had a functional approach in all three tests. Functional classification of spaces, preparation of functional diagrams, determination of similar spaces, drawing a component of the main space, and adding step by step other spaces are the essential techniques that architects have done in triple tests, which is a reason to use a functional approach. Participants also claimed in open interviews that they had a functional approach. They also stated that the process-based characteristics of industrial subjects were more closely related to rational-logical methods. On the contrary, they claimed that in the non-industrial subjects of the power plant, sensory-intuitive methods are increasing. These statements are consistent with the design method in the first and third tests. Nevertheless, the point to consider is the differences in the design of the participants in the administrative test. Careful consideration of the design protocols suggests that the architects were somewhat freer in the administrative test. For example, the fourth architect believed that administrative buildings (unlike industrial buildings) needed artistic creativity, consequently, these activities had to be applied in the design process. Therefore, it can be said that the whole design process also affects the design manner (both techniques and methods).

Reflecting on the quantity and content of the participants' questions shows that the designers in the first test need electrical and instrumentation engineers; But in the third test, this need tends to be mechanical. Participants in open interviews also stressed that the second test did not require non-architecture expertise. The comments show that the architects are subject to the specialized opinions of electrical engineers, mechanics, civil engineers, etc. in the process of the architecture design of the industrial subjects of the power plant. The order and importance of each of these individuals depend on the subject and the totality of the process. Nevertheless, in functional topics, the priority of attending in the process is with the individuals mentioned. Accordingly, the totality of the design affects the people needed in the design. On the other hand, according to the comments of participants, analytical and multidisciplinary spirit, management (in two forms of coordination and coherence), interactive spirit, high comprehension power, gaining knowledge, intelligent creativity, intelligent and logical creativity, and the willingness to work on specific or executive projects are the personality traits of industrial designers. Participants believed that by moving toward non-industrial power plant subjects, creative personalities would replace logical ones. So, the whole process also affects the personality sub-component needed in the design.

The findings show that in the triple tests, none of the participants showed a tendency to use a computer (in fact, they used hand tools). Lack of test time was cited as one of the reasons for this. However, the comments support a more persuasive argument that the participants found the hand tools to be more efficient in the early stages of the process due to speed or freedom of action. Despite this, the participants believed that computers could be used more in the design process of industrial power plants. To find out why, based on participants, the opportunity to use computer tools increases, we should refer to increasing the volume of repetitive and corrective works, the stability of the design of some industrial buildings, the restriction of architecture design to non-architecture areas, the non-involvement of architects in the overall layout of the power plant, and the necessary precision in the design. They also believed that hand tools in power plant projects were mainly used in non-industrial subjects, especially in a limited way in the early stages of design. The findings also reveal that in the triple tests, none of the participants were willing to use the model. In open interviews, only one of them stated that he wanted to use the model in the second test, but time has stopped it. Participants' speeches confirmed that the final models are the most widely used models applied in the design of industrial subjects. The stability of some power plant buildings, the process-based characteristics of designing the power plant industrial buildings, the presence of industrial equipment, and machinery in these buildings, which reduces the flexibility of the project, were the reasons for reducing the use of sketch and concept models. They also believed that these models could be used to design non-industrial power plant matters.

Examination of the participants' drawings in the triple tests also proved that none of them were inclined towards imaginary drawings. Open interviews also explicate that such a document is not useful in industrial power plant subjects. However, they did not rule out such a possibility for non-industrial buildings. Participants believed that diagrams of both process and architecture were one of the most widely used documents in power plant projects. However, it was noted that process diagrams are not used directly in the architecture design process. The comments show that architecture diagrams are used in both industrial and non-industrial subjects; the difference is that in designing industrial subjects, diagrams are influenced by the process and movement of materials, but in non-industrial buildings, diagrams are based on the movement of personnel. The participants' drawings in the triple tests also indicate that the diagrams were used in all three tests. The use of numbers is an interesting point to note in these diagrams. According to the participants, the final maps, are the most crucial drawings in the industrial subjects of the power plant. Examining design protocols in the first and third tests, as well as evaluating open interviews, reveals a wide range of specialized terms and expressions that designers utilize to transfer concepts. These words can be categorized in different ranges such as standards, spaces, buildings, grounds, principles, and equipment. Fuel Forwarding, Water Treatment, Firewall… and Boiler is example of these words. These terms were rarely used in second test protocols and open interviews on non-industrial subjects. Hence, we can say that the whole design process also affects the design tool component and its sub-components.

Analysis of design interviews and protocols in the first and third industrial subjects confirms the existence of coherent relationships between the components of the design process. The tendency of activities towards the critical spectrum (consisting analysis) in the active component, at the same time, with the need for analytical characters in the agent component, along with the need to use rational-logical methods (Such as functional), is part of the cornerstone of these relationships. Another example of these connections is strengthening the need for non-architecture engineers and reducing architects' self-centeredness in the agent component, accompanying strengthening the position of industrial standards and the importance of process requirements in the knowledge component, along with strengthening the role of process diagrams in the tool component. Based on the findings, it can be seen that the relationships between the components are in compliance with the totality of the design process and change with it. For example, in the process of designing non-industrial power plant subjects (such as administrative buildings), while increasing the architect's self-centeredness in the agent component, the use of standards in the knowledge component decreases and the ability to use imaginary drawings, sketches, and sketch/ conceptual models are added in the tool component. Not only is there a coherent connection between the components but also a coherent connection between the component and the totality in the process of designing the mentioned subjects. Based on the findings, a flexible structure for the design process can be envisioned. A structure in which each component exhibits its characteristics depending on the subject and the whole process. With the help of this flexible structure, these components change the coordinates to include the content needed in the template. These interactions indicate that the totality of the design process cannot be reduced to components.

- **Ability to control through feedbacks**

Design is a reformable or amendable process. The constant changes that designers make in their sketches, confirm their efforts to improve the previous work. Akin (1979) believes that a continuous definition of goals is another feature of the act of design. In other words, designers not only constantly modify their design, but also change the design goals alternately. On the other hand, the design is a reflecting process. That is, the designer reflects on the context of the sketch and compares what exists and what can exist. The reflection is repeated alternately because the process of reformation is repeated for the stated plan and the purposes. It is during these repetitions and through comparisons that the designer can control the process.

Discussion

Based on the findings, it can be said that the design process seeks to turn adverse situations into preferred ones. The degree to which the preferred position is approached is determined by comparing the project outputs with the goals. For this purpose, the design process requires a set of components including action, knowledge, manner, agent, and tool. Each of these components comprises sub-components that also play a role in the process. In the action component, the process requires passing mental/ objective stages. In the same component, the designer is forced to perform creative or critical activities. It is not possible to achieve a preferred situation without knowledge. Semantic, episodic, and procedural knowledge are the three categories of knowledge that are used in this process. Besides, the design process requires the adoption of appropriate manner, by dual sub-components of method and technique. Design agent, which is considered the common point of other components, is to carry out the activities, lead the plan in different stages, enter the variety of knowledge, and adopt the appropriate design manner. Different people and personalities, as the two main sub-components, are present in the functional component of the process and help to reduce the gap between the design and the preferred situation. Nevertheless, the design agent also needs the right tools. Manual and computer drawing tools, modeling devices, drawings, models, and transmitted conversations throughout the process have a significant impact on the design. With these interpretations, activity, stage, semantic knowledge, episodic knowledge, procedural knowledge, method, technique, person, personality, drawing tools, drawing, model, and speech are the sub-components of the design process that are consistent with the whole process and its flexible structure.

Conclusions

Findings show that the whole process of architecture design in industrial power plant subjects has a systemic nature (Fig. 5). Because

- This process has a set of primary components (such as action, knowledge, manner, agent, and tool), and each of them has its sub-components (activity and stage in the component of action; semantic knowledge, episodic knowledge, and procedural knowledge in the component of knowledge; Method and technique in the manner component; Person and personality in the agent component; Also, drawing tools, drawing, model and speech in the tool component);
- There is a coherent relationship between these major and minor components. For example, activities can move towards a critical spectrum (including analysis) in the component of action, at the same time as the need for analytical characters in the agent component, along with the need to use rational-logical methods (such as functionalism) in the component of the manner;

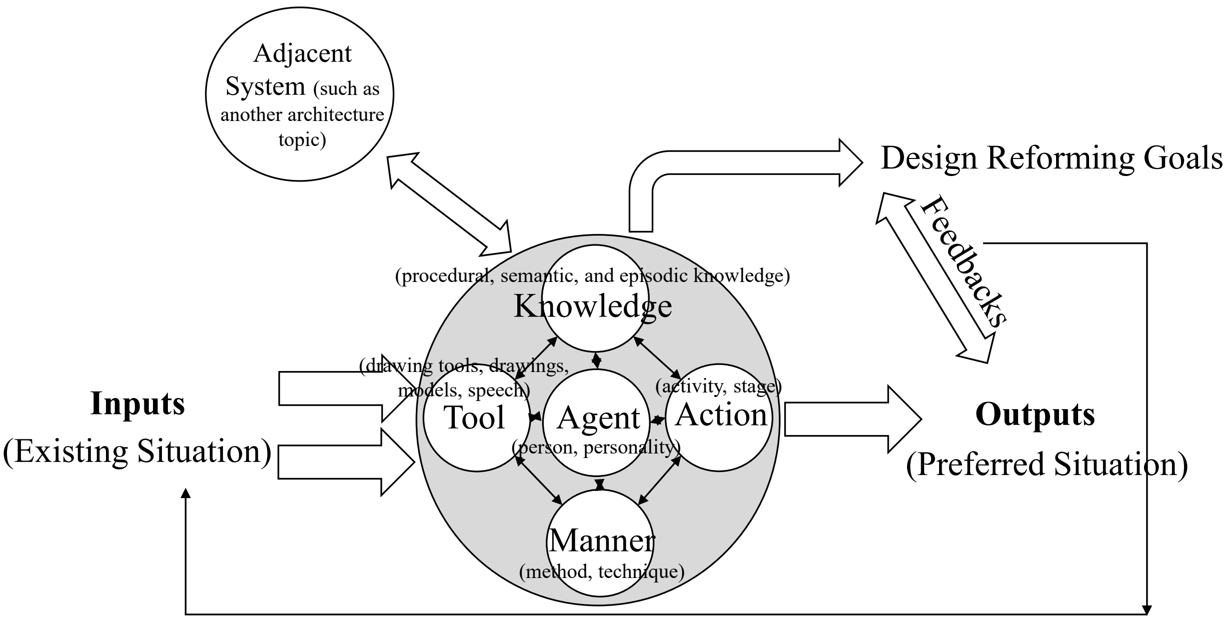


Fig. 5. A holistic model of architecture design process. Source: author.

- There is a two-way connection between the component and the whole process; as they are influenced by each other. The industrial subject affects the major and minor components of the process, and the number of them involved in the process. For example, the industrial subject has caused the design agent to be affected by the fields of mechanic engineering, electrical and instrumentation engineering;
- Based on the findings, it can be stated that the whole design process is more than a component and cannot be decreased to components;
- The totality has a flexible structure in which each component adapts to the necessities of the whole process, and enters into it based on the requirements of the process.

In other words, the characteristics of the components in the process of designing industrial subjects are different from non-industrial ones, and this is due to the influence of the whole process on the components. On the other hand, the research results prove that the design process acts as an open system; that is, it interacts with the external environment through inputs and outputs. Furthermore, the design process can be controlled by comparing the outputs of each design moment with its changeable goals. In this process, the designer helps to bring the real path closer to the ideal design path by defining the goals continuously, constantly adjusting the outputs, continually reflecting and comparing them.

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