

# Exploring the Theory of Structural Architecture Using Grounded Theory\*

Maryam Ghorbanzadeh<sup>a</sup>- Mahmood Golabchi<sup>b\*\*</sup>

<sup>a</sup> Ph.D. Candidate of Architectural Technology, Faculty of Fine Arts, University of Tehran, Tehran, Iran.

<sup>b</sup> Professor of Architectural Technology, Faculty of Fine Arts, University of Tehran, Tehran, Iran (Corresponding Author).

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## ABSTRACT

A key question is raised in the case of integrating and matching structure and architecture when creating structural architecture: is it possible to identify factors affecting this architecture and the status of these factors? For this purpose, this study explores the "theory of structural architecture" using grounded theory to reveal the causal, intervening, and context conditions, as well as the strategy and consequence of structural architecture. The results of this study show that the underlying approach for the design of structural architecture is to obtain causal conditions with some attributes, such as scientism and critical wisdom. Moreover, intervening conditions in this architecture includes tectonic background including executive power, economic issues, land and adjacencies, building use, ecology and vernacular identity and climate, culture, and coordination with time and building scale that have intervening effect on the context conditions or tectonic features within three functional, Formal, and semantic or meaning fields. These attributes include 18 features: smartness, safety, flexibility and resilience, strength and balance, optimality, paying attention to details, the definition of space, inspired by nature, paying attention to post-operational requirements, unity, combined with context, force cutting and optimal form, geometry, scale-based proportions, conveying a message, beauty, consistency, and stability. The structural architecture strategy derived from this study is divided into two parts of survey and action. In tectonic surveys and categories of analysis and decision, the designer must pay attention to vernacular architecture and ecology architecture, while it is essential in tectonic or tectonic action to use constructive pedagogy in structural architecture instruction based on various components, including exploratory model, critical and creative thinking. The consequence of structural architecture can be seen in different components, such as improved peace and comfort in the living environment.

**Keywords:** Theory of Structural Architecture, Tectonical Approach, Tectonical Context, Tectonical Features, Tectonical Action, Constructive Pedagogy.

\* This paper has been derived from studies conducted in the Ph.D. thesis written under the title of "Application of Structural Architecture Design Process in a Constructive Learning Environment" by the first author and guided by the second author at Tehran University.

\*\* E\_mail: golabchi@ut.ac.ir

## 1. INTRODUCTION

Most contemporary architects insist on using intuition<sup>1</sup> in design, so forget about the capabilities of the structure and its requirements, and consider the architecture design a theoretical creation positivist architecture besides theoretical architecture is another common technique that considers various primary components in architecture design. In positivist architecture, design is a process that includes various components that must be considered to achieve an optimal design. Meaning of positivist architecture is an emphasis on the positive theories<sup>2</sup> in architecture analysis and design. Positive theories attempt to prevent personal idea-based bias to pursue the research or design process based on academic techniques (Lang 2014, 20-22). Now, architecture pedagogy does not lead students toward procedural and positivist design. Instruction is done accurately when learning is meaningful and practical for enhancing skill and ability, and this case will be possible through skill-based learning in architecture studios (Salama 2005). Educational institutions must pay attention to teaching structure to architecture students using positivist design, and the curriculum<sup>3</sup> must be revised in a way in which, architecture approaches structure-based architecture. This study of architecture that has a kind of positive view of the structure is called "structural architecture." In structural architecture, structure, and architecture are interacting with each other from the first phase of architecture. Therefore, the identification of structural architecture design requires precise knowledge and information about its principles. Although the majority of skilled architects and engineers know some of these principles, it seems that the exploration of the "Theory of structural architecture" and its accurate investigation plays a vital role in knowing this kind of architecture, especially in revising the instructional program of architecture. This theory must comprise all causal, context, and intervening conditions, as well as the strategy and consequence of the structural architecture, which is achieved in this paper, by using Grounded Theory.

### 1.2. Relationship between Structure and Architecture with Emphasis on Structure as Architecture in Structural Architecture

Lack of a suitable connection between structure and architecture causes numerous problems due to many reasons, such as over-attention paid to the structure while ignoring the architecture or paying no attention to structural requirements in determining form and space (Golabchi and Amiri 2017). Charleson (2012) considers the diverse relations between architecture and structural forms in three features of "integration,

harmony, and contrast" and refers to the structure's accountability for architecture form and paying attention to plan (Charleson 2012). Macdonald (2013) also considers some proportions between architecture form design and structure form in four groups "structure ignorance, structure acceptance, structure symbolism, and structure excellence" (Macdonald 2013, 25). In his opinion, the structure must be considered from the first stage of architectural design, meanwhile, static principles and performance must be considered to create a beautiful and resistant form (Ibid). In general, structure can affect the body, performance, and meaning of architecture, by playing some specific roles in the architecture. The structure and its action have an underlying role in creating architectural form and body playing this role through loads and powers that try to cut form and create a sustainable structure. Therefore, structure performance in architecture means paying attention to load cutting or load path<sup>4</sup>. Alami et al. (2016) point out that form has a geometrical regularity for loads transfer and flow in a structure with accurate performance, so the architecture that has a structure not only stable and safe but also has a beautiful form (Alami, Purdeihimi, and Faridani 2016, 137). In meaning scope, artistic feelings can be expressed by taking some specific measures in the structure's components (Baker 1996). Table 1 reports the important roles of structure in structural architecture based on the opinions of experts in this field.

Therefore, the purpose of structural architecture is Tectonic architecture in which, structure exists from the stage of idea creation in making the body, performance, and meaning of architecture. Architecture in works by Renzo Piano<sup>5</sup> and Norman Foster<sup>6</sup>, for instance. Tectonic emphasizes a kind of architecture that is both beautiful and useful and shapes a practical art (Baghaei 2009). When the structural concept of the work takes the executive form through construction, the visual result of this aspect of the general concept of work appears through expressive qualities that deal with the loads game but it is not possible to describe these qualities neither by using terms of construction nor structure because these qualities enact some expressions of form-load proportions. The stability and beauty factors are created indeed from the harmony between structure and architecture in an architectural work (Rezaei and Hoseini 2015). According to the mentioned points, structural architecture is architecture in harmony with the structure and structure-accepting architecture. This architecture includes some criteria and principles, which have been scrutinized in this paper by using grounded theory to extract the theory of structural architecture.

**Table 1. Important Roles of Structure in Structural Architecture**

Role of Structure in Architecture	Mission Scope	Conceptual Knowledge
Formal Scope	<p>The balance between loads shaping the form of load cutting</p> <p>Creating rhythm and repetition and harmony</p>	<p>Structure and its requirements shape the form (Alami Purdeihimi, Faridani 2016). Farshad (1974) defines the evolutionary trend of construction forms, different dimensions of the structure and its design, primary structure concepts, and different types of loads (Farshad 1974). Allen (2011) talks about the effect of load and the role of materials in creating architecture form (Allen et al. 2011). Otto and Rasch (2001) studied those forms that are optimized based on the natural loads (Otto and Rasch 2001). Salvadori (2000) explained the role and position of structure in architecture and the effect of basic concepts on structural decisions (Salvadori 2000).</p>
Define Space	<p>Define and divide the spatial scope</p> <p>Create or emphasize circulation</p> <p>Arrangement and modulation</p> <p>Create rhythm, repetition, and harmony</p>	<p>The structure is underlying and structural base on interior space (Ching 2009). The structure can be applied to define space, construct housing, make relationships between architectural spaces and circulation of individuals in spaces, create movement, expansion of volumes' combination, or modulate (Clark and Pause 2003). Moreover, structure plays a vital role in the principles of systemizing space by creating rhythm and repetition, harmony and contrast making space openness and interior division possible (Javaherian 2007).</p>
Strength	<p>Secure and smooth flow of load</p> <p>Stability and geometrical-internal sustainability, and balance</p>	<p>The useful structure is the optimal structure that has obtained its form based on the effect of load cutting. Stability means the building's strength against destruction and geometric strength concerns the number and types of connections, while internal strength means the load tolerance of Formal particles of the body under the effect of loads. Balance means a lack of movement and stillness in the whole and details of the building (Salvadori 2000, 41).</p>
Functional Scope	<p>Provide comfort</p> <p>Climate approach</p> <p>Flexibility and smartening</p> <p>Shuttering and isolation</p>	<p>The role of structure is seen in providing comfort in climate issues, such as selecting materials and suitable structure of climate and eco-friendly status that can be done based on flexibility and higher smartness degrees. Structure not only provides shutters that separate the building but also divided interior spaces from exteriors and provides proper isolation to create comfort in interior space.</p>
Provide peace	<p>Appropriate executive details</p> <p>Optimal materials and light adjustment</p>	<p>The peace of residents living in each building depends on ensuring executive details of structure, including optimum materials, accurate connections, quality of entering light, walls' details, flooring quality, and so forth (Charleson 2012).</p>
Executive	<p>Provide construction possibility</p>	<p>The structure can convert architecture from the concept and idea stage to real space (Meiss 1992).</p>
Economic	<p>Optimal use of materials and increasing speed of construction and paying attention to the economy</p>	<p>Structural systems have been created due to ease of load carrying, optimal use of materials, and paying attention to economic issues (Salvadori 2000, 41).</p>
Sustainability	<p>Bionic and environment preservation</p>	<p>Architecture with an eco-friendly structure creates sustainable architecture, which can remove many problems caused by construction in the environment.</p>

Role of Structure in Architecture	Mission Scope	Conceptual Knowledge
Meaning Scope	Paying attention to aesthetic factors Conveying meanings and feelings, and expressing artistic-ideological concepts; Transfer message; Suitable size; Diverse syntheses; Proportions and space scale; Localization and giving identity	In ancient civilizations, columns were used for decorations and inducing meanings and feelings. These columns were deployed in different directions and used some features, such as volume, weight, size, materials, role, and the distance between them making it possible to express artistic-ideological concepts or even a specific worldview (Javaherian 2007). Structural form is a creation of beauty through proper size and cutting to facilitate load flow in a structural system (Salvadori 2000, 41). In modern architecture and after that, it was possible to create and combine pure and impure volumes with different geometries, create novel forms, divide performances, and realize its specific aesthetical language using structure, and its ability to provide diverse plan-volume and façade syntheses of the building made it an influential element among architectural elements in the aesthetical evaluation of architectural works. The influence of structure on the mind highly depends on its proportions. The structure's dimensions and proportions are directly related to its tasks for load bearing; moreover, it can be a symbol of size and special scale affecting its enclosure (Baghaei 2001).

**2. METHOD**

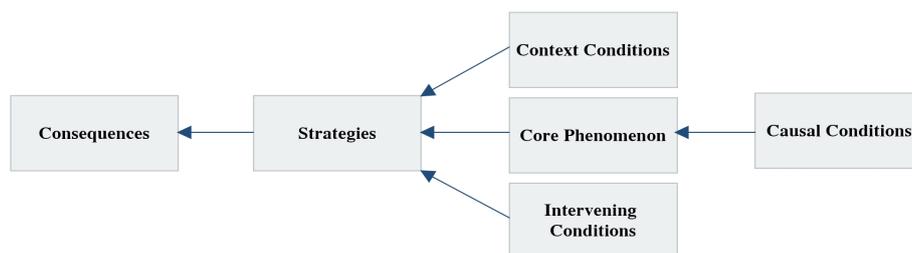
Grounded Theory<sup>7</sup> is a theory presented as an axial coding model based on the paradigm introduced by Strauss and Corbin. Figure 1 depicts this model. In this theory, researchers put the main phenomenon at the center of the investigating process and then link the obtained categories to this phenomenon. These categories include "Causal Conditions," "Strategies," "Intervening Conditions," and "Consequences" which are used to plot a diagram called coding paradigm. Strauss and Corbin consider three types of coding: open coding, axial coding, and selective coding (Lee 2001, 47).

The first stage- open coding is a process that identifies concepts in data and is analytical (Danaeifard and

Emami 2007, 80 Quoted from (Strauss and Corbin 1998; Lee 2001, 49). This stage consists of two parts: A) First-level coding (generating initial concepts): "Concepts" are basic or micro units of analysis (Pandit 1996).

B) Second-level coding (generating major categories): "Categories" are more abstract compared to concepts. Second stage- axial coding: in axial coding, the categories are related to each other in terms of the fit between the features, and as a result, a diagram is drawn, which is called "coding pattern" (Danaeifard and Emami 2007, 83-84) (Fig. 1).

Third stage- selective coding: selective coding chooses findings of coding phases and axial category and links them to other categories systematically (Strauss and Corbin 1990; Lee 2001, 127).



**Fig. 1. Axial Coding Model Based on the Strauss and Corbin Model**  
(Adopted from Creswell 2005, 401)

**3. BACKGROUND**

In the case of identifying the role and status of structure in architecture, some expert researchers such as Andrew Charleson and Angus J. Macdonald have expressed some proportions between architecture form and structure form. Golabchi (2003; 2007; 2009) introduces the load transfer

path as a way for selecting architecture forms in structure harmony. He introduced various objectives of structure design from practical needs to aesthetics. Zarkesh (2002; 2005; 2008) believe that the priority of architecture over structure in contemporary architecture has led to the creation of some structure without considering architectural concepts, and

even structural requirements or vice versa under the control of the artistic power of architecture. Many authors have emphasized the necessity of matching structure with architectural design in the architectural ideation stage. Many studies have been conducted to integrate and synthesize structure and architecture in the idea creation phase within two major parts: 1. the position of structure and its roles in the architecture design process, and 2. positive and procedural design pedagogy in the frame of constructive pedagogy design. Falahat and Kalami (2007) used the comments of Strauss and Piaget about the identification of phenomena to present a model for explaining the relationship between the two concepts of architecture and structure. Eghbali and Asadi (2007) pointed to the role of the design process in architecture matched with structure and consider this assessment a way to eliminate structure-architecture divergence. Hoseini (2019) investigated the effective factors in structural coordination of architecture and structure and found the following effective factors: geographical and environmental factors, land and adjacencies analysis, symbols of Iranian-Islamic architecture, materials, technology and structure, and building, human dimensions, architectural space, mechanic and electric installations. Ahmadnejad, Mahmoodi, and Azimi (2018) found two underlying aspects of the role of structure in architecture: mechanical and spatial aspects. The spatial aspect addresses why structure exists in architecture considering the role of structure in form and formation, and has four views (ignoring structure, accepting structure, symbolism of structure, and excellence of structure) and is shaped in the conceptual and initial design stage. The mechanical aspect considered how is structured in

architecture, which deals with load analysis and load transfer path. Haghghi, Dejdard, and Dehghan (2020) consider simultaneous learning of novel structures in the same place studio in practice as a factor in improving core components of design ability skill. Jian Ji and Adrion Bell examined methods to teach architects structure at Manchester University by using digital technologies. In the paper "Seeing and touching structural concepts in classroom education," they introduced six underlying structure concepts (equilibrium, direct force path, span and deflection, stress and torsion, structural control, and vibration) using examples and models. This method seems to be effective and attractive for students to understand structural concepts. Soleimani and Molanaei (2017) believe that methods that are based on structure-architecture convergence with emphasis on teaching non-abstract structure can improve the understanding level of structural concepts by students.

#### 4. STEPS TO EXTRACT THE THEORY OF STRUCTURAL ARCHITECTURE

##### 4.1. Open Coding of Structural Architecture

A) Generating initial concepts of structural architecture: in this phase, topics related to structural architecture are reviewed then the key points and themes are coded. These codes are presented in the frame of the concepts derived from the sentences explained about the structure in architecture. Table 2 reports this coding for generating initial concepts in structural architecture. The ID corresponding to structural architecture data is indicated with (A).

**Table 2. Initial Concepts Derived from Structural Architecture Data**

ID	Data	Concept (Code)
A1	The structure is the regular interaction between action forces (external forces) and reaction (supports and internal forces), and its function is dividing and balancing forces (Ching 2009).	Balancing forces
A2	A proper structure should be synthesized with beauty (Salvadori 2000)	Synthesized with beauty
A3	Architect engineers can have a sensual view of force transfer if they know basic structural principles (Moore 1999).	Sensual view on the force
A4	In teamwork between architect engineers and structure engineers, it is important to pay attention to creating functional designs in addition to executive issues and completing building beauty (Charleson 2012).	Response to performance, and beauty supplement
A5	The structure is the interaction between components and quality adjustment in each set of elements (Oxford Dictionary).	Organized quality and relationship between elements
A6	The structure is a science integrated with action based on knowledge about structural principles, materials, and implementation processes (Allen, Zalewski, and Boston Structures Group 2010, XIV).	The skill based on the materials, details, and construction and installation process

ID	Data	Concept (Code)
A7	The structure improves architecture, enhances architecture, and changes the size, proportions, and form by playing some roles, such as sending symbolic messages, perceptual issues, and the extent of technology and artistic affairs (Javaherian 2007).	Influencing the mind in transferring concepts and symbolic messages, technology growth, defining the scale, and improving the visual taste of the audience
A8	A structure that aims to create solid, safe, functional, and beautiful buildings can improve architecture (Baghaei 2009)	Provide beauty and function, desired performance by changing loading
A9	The structure can be just the skeleton or the icon in architecture (Panahi et al. 2013).	Load bearing and transfer and iconic function
A10	“Structural organic” means simultaneous attention to beauty and force transfer path in form creation (Panahi et al. 2013).	Structural organic and force transfer based on the form and type of materials
A11	Geometric strength and stability mean no destruction under the forces, and internal strength means load bearing rate of particles shaping the body (Salvadori 2000, 41).	Strength against external forces, geometric stability, and internal stability
A12	Structure and its components can shape and organize the architectural space. Moreover, structure type can affect the definition and division of spatial areas, the creation of routes and circulation in the space, the creation of form, and modulating design (Clark and Pause 2003).	Shaping space, organizing space, space enclosure, space division, emphasis on circulation, modulation, and arrangement
A13	Sufficient attention paid to force transfer path from the entrance to the floor point can lead to the creation of optimal artistic structures with sufficient strength (Mardomi, Soheilifard, and Aghaazizi 2015, 65).	Geometry, proportions, traditional architecture, force transfer flow, and proper materials
A14	Technology expansion contributes to the definition of architecture regarding the importance of structure as the component that creates balance (Jafari and Asadi 2017, 1).	Balance and technology
A15	An architect who knows structure would have a better view of other cases, including human capital of space, balance, symmetry, stability, attention to using, economy, attention to detail, materials, and force behavior (Macdonald 2013).	Humanizing, balance, symmetry, stability, function, economy, beauty, paying attention to details and materials, humanizing architecture, and paying attention to force behavior
A16	Creation of an architecture work requires observing economic issues, and technical requirements and paying attention to materials' features (Hashemnejad and Soleimani 2007, 25).	Economy and paying attention to details and materials
A17	The simultaneous creation of structure and architecture shapes a beautiful structural form and reinforces the structural symbols (Baghaei 2009).	Symbol and beauty
A18	Integrating architecture and structure is a combination of art, aesthetical values, technology, materials and behaviors, performance, and implementation. Structural design can be considered as a process of sorting materials in 3D space (Jafari and Asadi 2017, 8).	Beauty. Technology, and paying attention to details and materials
A19	Unity of idea, structure, and form can create memorable architectural works considering function, beauty, and economy (Sanaei and Ghasemi 2013, 1).	Function, beauty, inspired by nature, and iconic performance
A20	Technology can create icons or sculptures, knowledge, and nature symbol by revealing the structure (Alaei and Rahimi 2013).	Technology, symbols, inspired by nature, and iconic performance

ID	Data	Concept (Code)
A21	Structure creates concepts and forms for architecture within different intervals, and technology improves the beauty and creates sense and meaning (Baghaei 2009, 29).	Technology, creating meaning, giving identity, beauty, vernacular architecture, and traditional architecture
A22	Integration of structure and architecture leads to the originality of construction form and honesty transfer based on the force transfer path regarding some points, such as the usefulness of structure, balance, stability, performance, and beauty (Baghaei 2009, 33).	Beauty, usefulness, balance, stability, giving origin, wisdom, pragmatic, force transfer flow, and originality
A23	The symmetry between a structure with form and performance is seen in the architecture of Seljuks and Timurids in Iran, during the Gothic era and in the vernacular architecture of the world, which can be addressed under the titles of high-tech and eco-tech in sustainable architecture (Mohammadzadeh, Akbari, and Babazade 2017).	Function, vernacular architecture, high-tech, eco-tech, and sustainable architecture
A24	Paying attention to aesthetical issues in structures and synthesizing with architecture to shape the architecture form and space is effective in improving the quality of space, so must be mentioned in architecture pedagogy (Ibid).	Beauty, conceptualization, and Correcting the Structure of architecture pedagogy
A25	The necessity of creating buildings resistant to forces and environmental factors causes reflection on force transfer (Alami, Purdeihimi, and Faridani 2016, 124).	Safety and strength
A26	The structure is used in architecture to create scale and improve architectural form (Ibid, 137).	Scaling, safety, and qualifying
A27	The simultaneous effect of performance, beauty, and economic issues along with strength and durability can be clearly seen in the formation of natural forms. Natural forms indeed result from the gradual process of development and interaction with environmental forces and are shaped by using the minimum number of materials (Ibid, 136).	Inspired by nature and optimal form
A28	Pragmatic teaching by putting the student in conditions similar to the real world, application of workshop method in structure pedagogy, change in the curriculum of structural engineering students to make students active in the pedagogy process, expansion of discussion and negotiation, participation and collaboration between students and professors, respecting others' comments and ideas lead to efficient structure pedagogy in architecture (Momeni and Etminani 2013)	Efficient structure pedagogy in architecture
A29	Structure engineering attempts to convert concepts into forms resistant to forces, and forms that are beautiful and optimal in terms of economic issues. Moreover, the building use, operation requirements, and executive necessities must be considered (Charleson 2012)	Sustainability, economic issues, beauty, performance, executive power, and paying attention to post-operation needs
A30	Understanding structures' conduct is the first step to precise knowledge, accurate design, and safe and secure implementation of buildings (Moore 2001).	Safety
A31	Architecture is defined as enclosing and dividing space using structure (Angel 1998, 30).	Synthesis of part and whole
A32	Architecture and its design process is the process of selecting components to achieve a single whole (Seyedian and Baftiyegane 2007, 2).	Synthesis of part and whole
A33	The arrangement of single components beside each other is matched with the construction concept in a way that this arrangement creates an integrated whole beside each complete part (Grutter 2004, 582).	Synthesis of part and whole

ID	Data	Concept (Code)
A34	Cooperation and collaboration between the architect engineer and structure, as well as frequent adaptation of structural and architectural design, are required to achieve a beautiful and lasting design (Motarjem and Naghshineh 2013, 15).	Durability and conversion of architecture to heritage
A35	Unity of architecture and structure space is defined based on a harmonious whole, criteria of multiple spaces and structure include space, structure, etc. formation simultaneously in relationship with each other and with the whole, and space formation in the area of logic and structure abilities are matched with the plan (Zarkesh 2008, 22).	Unity, synthesis of part and whole, and paying attention to executive power
A36	Floating educational concepts in several fields make the structure analysis a specific discussion. Multifaceted analytical knowledge of structure confirms the complexity of its teaching and learning, results of a constructive approach to architecture pedagogy (Eizadpanah 2011, 15): - Lack of separation between structure practice from other architectural categories leads to the discovery and creation of concepts at higher levels. - Conversion of projects to the real scale makes the perception true. - Real design can be considered with minimum facilities. - Motivation, creativity, prosperity, and a sense of belonging.	Multifaceted, constructive, real scale, creativity, and discovery
A37	Nowadays, like spaces, materials make relationships with humans. In the past, human's relationship with materials also led to an identity category (Hashempoor 2011, 2).	Human-centeredness, adaptability, and identity
A38	Structure brings security and a sense of peace to a building. Engineering is indeed matched with saving in instruments and other technical factors, such as the complexity of the implementation process and future reliability of the structure, its satisfying or dissatisfying aspects (Shakeri 2017)	Security, peace, usefulness, vernacular architecture, saving instruments and materials, executive power, and future reliability of the structure
A39	Structure-architecture separation is not seen in natural structure, while they are natural organisms of architecture, structure, and beauty synthesis (Daneshgar Moghadam 2007).	Inspired by nature
A40	Using natural ideas in an artifact structure leads to the optimal use of materials and ideal structural sustainability and resistance (Molanaei and Feizi 2013, 5).	Inspired by nature, optimization, and beauty
A41	Conveying concepts is recommended by using pedagogy models and natural structure as the most effective method in teaching structure courses to architects (Amirkhani, and Okhovvat 2009, 79).	Inspired by nature
A42	Architecture is a part of cultural heritage that is transferred from one to another generation. The selected precious architectural works in the contemporary era provide some features including modern technology, flexibility, completion of architecture through other designs, the relationship between architecture and design context, and accountability of work to cultural, social, and economic needs (Mahdavinejad 2016).	Architecture as heritage, modern technology, flexibility, completion of architecture collection using other designs, relationship with the context, and cultural, social, and economic accountability
A43	Kyoto Declaration (Vito) emphasizes the spiritual and cultural aspects of architectural artworks explaining that valuable monuments are national pride, but also are considered as a subject for dialogue between civilizations and increasing cultural exchanges between them (Mahdavinejad 1996).	Dialogue of Civilizations
A44	Geometry is the joint language of architecture and structural engineering art and is the most significant index of unity and integrity in architectural work. If the geometry of the force flow system reaches convergence with the geometry of the building form, it would be stated that the design process has had a desired path (Sherbaf and Ansari 2017).	Geometry, building form's convergence with the geometry of force flow system and force flow

ID	Data	Concept (Code)
A45	Purposive teaching of modern structures courses and effective and efficient application in the design process to increase the skill of ability in architecture schools (Haghighi Dejar, and Dehghan 2020).	Architecture and structure design process, skill-based learning, and constructive learning environment
A46	Details in each part of the building must express the idea behind the design of that part. Successful details are not just arrays or decorations but point to the whole that themselves are a part of that whole (Zumthor 2010).	Paying attention to details
A47	These formal details create a relationship between large proportions of the building; accordingly, they determine the formal rhythm or well scale of the building (Ibid).	Part and whole combination and well-scaled

#### 4.2. Generating Categories of Structural Architecture

After the concepts of structural architecture are found, these concepts are categorized. Accordingly, 136 concepts derived from 47 sentences reviewed

in Table 2 have been classified into 30 categories in Table 3. This study used the cumulative categorization method, in which the content is reviewed and as a new concept appears, a new class is formed in Table 3, and similar concepts are organized under that new class.

**Table 3. Categories of Structural Architecture**

ID	Concepts (Codes)	Categories (Components)
A1, A8, A9, A11, A3, A10, A22, A15, A44, A13	Balancing forces, coordination with loading change, load bearing, and transfer, resistance against internal and external forces, sensual method when dealing with force, structural organic, balance, and force transfer flow	Balance
A2, A8, A4, A15, A17, A18, A19, A21, A22, A24	Integrated with beauty, providing beauty, and beauty supplementation	Beauty
A4, A12, A15, A19, A23, A38, A22	Response to performance, space forming, space organizing, space division, usefulness, pragmatic	Space definition
A9, A7, A17, A20	Iconic performance, symbolic messenger, and symbol	Conveying message
A7, A1, A12, A47	Scale definition, well-scaled	Scalable and scaling (proportional to scale)
A21 and A22	Giving concept, originality, and identity	Identity
A14, A18, A20, A21, A42	Technology	Modern technology
A13, A21, A23, A38	Traditional architecture, vernacular architecture	Vernacular architecture
A24, A36, A45	Revising pedagogy structure, multifaceted, constructivism, real scale, creativity, and discovery	Improving architecture pedagogy to Constructivism
A15, A18, A16, A10, A6, A13, A46, A4	Paying attention to details and materials and force transfer based on the form and type of materials	Paying attention to details such as connections, type of materials, etc.
A19, A34, A42	Heritage, building permanence, and making architecture a heritage	Converting architecture to heritage (building permanence)
A23, A20, A10, A39, A40	High-tech, eco-tech, sustainability, bionic, inspired by nature and structural organic	Eco-tech (or ecology), sustainable architecture, and bionic architecture

ID	Concepts (Codes)	Categories (Components)
A11, A15, A22, A25, A29	Resistance against external forces, internal stability, stability, and strength	Stability and strength
A30, A25, A26, A38	Safety and Security	Safety
A27, A38, A22	Optimality and usefulness	Optimality
A29, A38	Paying attention to post-operation needs and future reliability of the structure	Paying attention to post-operation needs
A35, A33, A32, A31, A47	Combination of part and whole, unity	Combination of part and whole, unity
A35, A29, A38	Executive power	Executive power
A29, A19, A16, A15, A42, A15	Economy	Economic issues
A4, A12, A15, A19, A23, A38	Response to performance, space forming, space organizing, space division, usefulness, and pragmatic	Building use
A42	Cultural, social, and economic Accountability	Consistent with beliefs
A42	Cultural, social, and economic Accountability	Philosophical message
A7	Influence on the mind when conveying symbolic messages and concepts	Improving the visual taste of the audience
A42	Completing architecture collection using other designs, relationship with the context	Synthesized with context and attention to perspectives
A42, A4	Flexibility	Flexibility
A38	Peace	Effect on life (peace and comfort)
A37, A38, A15	Human-centeredness, adaptability, security, humanizing	Adaptability and human-centeredness
A22	Wisely	Scientism and rationalism, critical wisdom
A43	Influence of magnificent building on the dialogue of civilizations	Dialogue of civilizations
A13, A44, A10, A35	Conformity of form geometry with force flow geometry, the structural organic, active form	Force cutting and optimal form
A44, A40	Form geometry, balanced	Geometry and form proportions

### 4.3. Axial Coding of Structural Architecture

In this stage, the extracted categories are reported and linked in Table 3 based on the relationship with the core phenomenon of structural architecture. The result of this stage is shown in Figure 2. It is worth noting that context conditions have been classified

into three scopes based on the Formal, functional, and semantic roles of structure in architecture. Moreover, the influence and impact of intervening conditions on the context conditions can be divided into three functional, Formal, and semantic parts, which are explained herein.

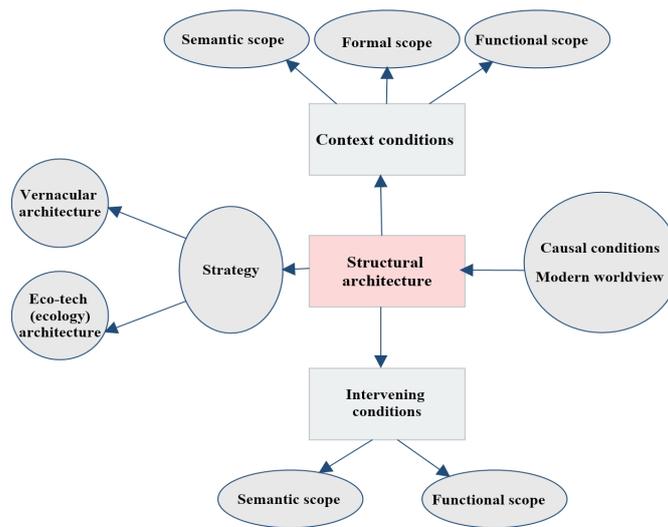


Fig. 2. Axial Coding of Structural Architecture based on the Model Proposed by Strauss and Corbin

#### 4.4. Selective Coding of Structural Architecture

In this stage, the status of each category from Table 3 is interpreted based on Figure 2 to find the best classification. This phase inserts five main headlines in axial coding, which are highlighted in bold font (red color), and inclusive approach, features, context, survey (analysis and decision), and action. "Coding paradigm for structural architecture" is derived in this phase in which, all features and tectonic contexts are placed.

**A) Tectonical Approach:** the approach is defined as attention, consideration, paying attention to something or somebody, taking a position, orientation towards a specific subject, orientation is strategic decisions, and tactics (Moein Dictionary). the approach differs from the strategy. Approach refers to an initial view and required condition to start an action not pointing to how to do it.

In structural architecture design, some categories point to the designer's approach. At the beginning stage of structural architecture design, rationalism, scientism, critical wisdom, and balance must be considered and the designer must have such categories.

Rational and scientism: scientific views and persuasion with the discovery of correctable rules was an effective step that brought humans gradually into modernity. Science and an optimistic view towards it created the intellectual base of modernity and converted nature to nature rules; it can be called the "worldview of discovery and knowledge" (Haghir and Kamelnia 2016).

Critical wisdom: while scientific thought indicates the accurate evaluation of reality and "what exists" that is recognizable experimentally, critical wisdom can reveal "what must be" directing the scientific survey trajectory in a specific way. This critical wisdom creates permanent development in architecture

eliminating the dominance of logic on the design and being trapped in repetitions opening a way for "change" and "generation."

**Balance:** balance is the main point in building static, which indicates the balance between different forces. This balance or forces balancing is one of the approaches to structural architecture design, which contributes to meeting expectations from structural architecture. Loads and forces in a building create or literary cut the shape of the structure. Designed must consider force cutting to achieve a suitable and beautiful synthesis in the form (Alami, Purdeihimi, and Faridani 2016). Farshad (1974), Edward Allen (2005), Frei Otto and Rasch (2001), and Mario Salvadori (2000) have addressed how the architectural form<sup>8</sup> is shaped through forces. In all of these works, balance is designed as the main prerequisite required to reach an optimal form in architecture. The mentioned definitions indicate that structure is a geometric discipline for the transfer and flow of forces, and balance is the most important prerequisite for this discipline.

**B) Tectonical Background- Intervening Conditions:** interference means doing initiation and stewardship in a work (Dehkhoda Dictionary 1998). Intervening variable has a context effect on dependent variables. In the theory of structural architecture, these variables and intervening conditions have been called Tectonical background. The context has been defined as the background, role, and credit, and the context of providing the field has been interpreted as an introduction to and preparing talent (Dehkhoda Dictionary 1998). Therefore, the Tectonical context includes intervening conditions that affect the arrangement of the structural architecture. For instance, culture influences beauty grading and the economy affects smartness grading. Therefore, both

of them are included in the Tectonical context. Four components of executive power, economic issues, land and adjacencies, and building use are intervening variables, especially in functional scope, while three components of ecology, ecology and climate, culture and consistency with time and building scale are intervening variables, particularly in semantic scope. It is worth noting that all components influence the Formal scope of architecture, which is formed by the performance and meaning of space design.

**C) Tectonical features:** the term "features" is the plural form of feature that means characteristic, attribute, and specification (Ibid). A feature or characteristic is a data field that provides attributes of an object and data. Statisticians use the term "variable" for feature, while data miners apply the term "attribute." A collection of features that describe an object is called Feature Vector and Attribute Vector. Features include different types of Nominal, Binary, and Numeric. Nominal features are symbols or names of objects. In a structural architecture, nominal features are used that are called Tectonical features. Tectonic features are dependent variables<sup>9</sup> that can be described as qualitative or quantitative variables. For example, beauty is a qualitative Tectonical feature, and smartness is a quantitative Tectonical feature. Tectonical features are multi-value features that have different grades, so cannot be divided into binary features. These Tectonical features include 18 options that are divided into three functional, Formal, and semantic scopes based on the studies reviewed in this research. Safety, flexibility, stability and strength and balance, optimality, attention to details such as connections, type of materials, etc. space definition, inspired by the nature and bionic, and paying attention to post-operation needs are Tectonical features in functional scope. Part-whole synthesis (unity), integration with context and perspectives, force cutting, optimal form, and geometry and form proportions are Tectonical features in Formal scope. Scale proportions, messaging, beauty, adaptability, human-centeredness, respecting nature, and sustainability are Tectonical features in semantic scope.

**D) Strategy:** strategy means map, trick, and solution (Moin Dictionary 2007). Strategy determines the activity scale to meet expectations and provides an operational project to match various variables to achieve the goal. The strategy includes two stages of survey and action:

#### 1. Tectonical Survey

The survey is Mission Statement that comprises two sections:

- Analysis: This indicates what we believe, Statement of Principle;
- Decision: this indicates where we are going to reach, Vision Statement.

Tectonical survey includes Tectonical Analysis and Tectonical Decision. Tectonical analysis addresses

our values and principles from the past to now in terms of the relationship between structure and architecture. According to the study of traditional architecture in Iran and the world, climate, and ecology must receive attention in traditional architecture. Therefore, the result of Tectonical analysis tends toward vernacular architecture. The more the architectural design is directed toward vernacular architecture in all three functional, Formal, and semantic scopes, the more hope for creating structural architecture will be. Tectonical decision clears the future trajectory for us; hence, constructability of architecture and attention to all roles that structure plays in the architecture and cooperation in providing these roles are Tectonical decision, which can be provided as ecology architecture. Ecology architecture inspired by Norman Foster's thoughts is a synthesis of responses to social, economic, technological, aesthetical, and environmental needs. The most important source for Foster's inspiration in achieving such an attitude was the cooperation and retraining thoughts of American architect, Richard Buckminster Fuller. Fuller paid attention to the organization of elements of architecture formation in the ecological system (Bani Masud 2014, 460). This architecture aims to construct flexible buildings that are adaptable to nature and geographical climate and evaluate technological development to create a human space. Nicholas Grimshaw, Renzo Piano, and Richard Rogers are the popular architect of ecology. In general, the Tectonical survey aims to promote this level of architecture to ecology architecture emphasizing vernacular architecture and increasing structural architecture.

#### 2. Tectonical Action, Tectonical Pedagogy, and Constructive Instructional Design

Like any cultural work, Tectonical action only passes through instruction and education<sup>10</sup>. According to UNESCO and the name of the 21st century a century of learning, "Quality Education for All" must be always considered in all issues. In this lieu, learning has been represented in four fields:

- Learning for knowing (permanent learning)
- Learning for doing (entrepreneurship and production)
- Learning for coexisting (respecting peace, environment, and sustainable development)
- Learning for being (citizenship and responsible and accountable existing)

Therefore, structural architecture instruction methods must be capable of providing permanent learning based on entrepreneurship and production to support the life of humans.

As the science and art of teaching-learning, "Pedagogy"<sup>11</sup> shapes one of the underlying requirements for structural architecture's education sector. In the cycle of strategic policy-making, planning, implementing, and evaluating educational programs of each discipline, the success of each country depends on the commitment to the

identification and using a cognitive load of pedagogy, as well as the financial and Formal facilities of that country.

Among pedagogic approaches, the constructive approach seems to be appropriate for developing structural architecture instruction. As explained in the Oxford Dictionary of Psychology, 2003, a constructive approach is a thought based on which, perceptions, memories, and complicated mental structures are actively created by the person in his mind, not coming from outside of the mind. This approach compares Situated Cognition with general cognition believing that learnings in a certain situation are not useful in other situations. Hence, authentic activities form the pillar of learning, and learning is considered problem-based learning (PBL) in this approach (Saif 2007). From a constructive viewpoint, certain stages are not followed for design but some other principles are emphasized, such as posing learning in relevant and

real contexts, including learning in social experiences, encouraging ownership, having comments on the learning process, presenting the experience of knowledge creation, encouraging self-awareness in the knowledge creation process, presenting experience and appreciating different views and encouraging to use various presentation methods (Fardanesh 2008, 6-7 Quoted from Fardanesh 1999).

Interactive and practical practices play a vital role in teaching structural architecture using constructive pedagogy (Schon 1987). In this education, every designer builds his/her trajectory and designs on this path based on the type of problem, the personality of the designer, and many other factors. This is a path its important parts have been shown in nine options in Figure 3: learning self-regulation, visual creativity, verbal creativity, creative thinking, exploratory paradigm, inductive thinking, active learning, critical thinking, conjecture, and falsification.

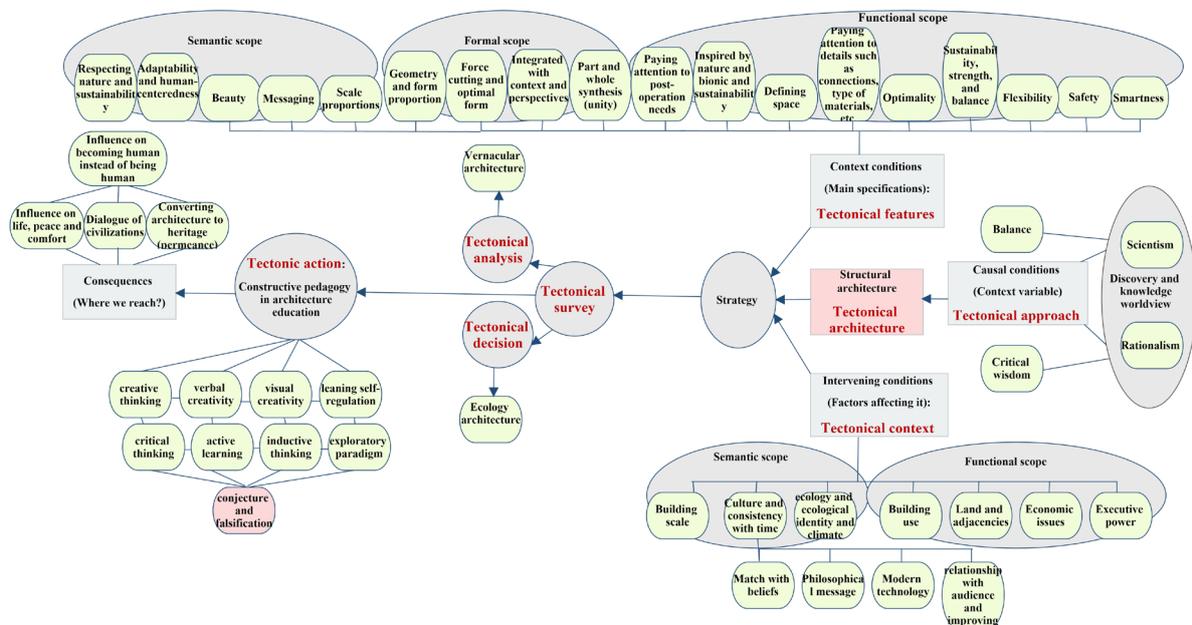


Fig. 3. Axial Coding of Structural Architecture based on the Strauss and Corbin Model

#### 4.5. Theory of Structural Architecture

Scientism and rationalism, balance, and critical wisdom are four underlying variables in structural architecture so an architecture designer can enter the field of structural architecture design just by using this Tectonical approach. Moreover, the structural architecture works must be considered and assessed only from the view of this approach. The main specifications of this architecture include Tectonical features divided into three functional, Formal, and semantic scopes. Safety, flexibility, sustainability, strength and balance, optimality, attention to details such as connection and type of materials, etc., space definition, inspired by the nature and bionic,

and attention to post-operation needs in functional scope; part and whole synthesis (unity), combined with context and perspectives, force cutting and optimal form and geometry and form proportions in Formal scope; scale proportions, messaging, beauty, adaptability and human-centeredness and respecting nature and sustainability in semantic scope are the features that designer must consider achieving structural architecture. Therefore, the structural level of an architectural design can be evaluated based on these features. Intervening conditions and factors affecting the structural architecture are included in two semantic and functional scopes consisting of the following components: land and

adjacencies, culture, ecology, building scale, building use, economic issues, and executive power. These conditions provide the Tectonical context of structural architecture. According to this context, the structural level of this architecture can be changed. Moreover, the presence or absence of these tectonic contexts and their conditions play an effective role in society's acceptance or rejection of structural architecture. Tectonical strategy includes tectonic survey and action stages. Tectonical survey in the tectonic analysis phase emphasizes the attention that must be paid to the vernacular architecture of each region regarding the structural architecture design while considering ecology design as an essential factor for structural architecture in the tectonic decision phase. In other words, the structural architecture looks for its basis in the vernacular architecture of each region and pays attention to ecology architecture. Tectonic action considers the promotion of architecture teaching to the constructive paradigm as a requirement for structural architecture teaching emphasizing learning self-regulation, visual creativity, verbal creativity, creative thinking, exploratory paradigm, inductive thinking, active learning, and critical thinking that are its principles. Moreover, the architecture design process in this paradigm passes through the conjecture and falsification path. Structural architecture leaves a positive effect by creating peace and comfort in human living space, converting surface architecture to lasting architecture, and creating a dialogue of civilizations. This case emphasizes the status and

mission of humans in life in a general attitude, which is a changing trigger not a monotone repetitive tone; becoming instead of beginning.

## 5. CONCLUSION

This study examines the roles of structure in architecture within three Formal, functional, and semantic scopes, and it was concluded that response to these three scopes could create structural architecture. These three scopes in the creation of structural architecture were identified by coding relevant data based on Grounded Theory then the components affecting each scope were classified as tectonic features and contexts. Tectonical features that were divided into 18 components express the core specifications of structural architecture. These features are variables depending on the tectonic context that are influenced by interference of context components within three functional, Formal, and semantic scopes. The intervening variables of tectonic context in teaching structural architecture design must be defined and kept fixed in students' projects comparison to control these variables. Because components of each scope differently affect the creation of structural architecture, it is recommended to use the analytical hierarchy process (AHP) in further studies. In this method, criteria or components are weighed and ranked through pairwise comparisons.

## ENDNOTE

1. Lang points to the discovery and intuition-based architecture as the first way for architecture design (Norberg-Schulz 1965). The increasing expenses of building and the variety of uses in designed environments have led to ambiguity in design regarding personal ideas (Lang 2014, 2).
2. The positive theory is based on scientific-experimental research and study on the environment and human behavior to prove the facts (Lang 2014, 15). The normative theory is based on some fixed and predetermined principles (Akrami 2003).
3. A curriculum can be defined as a plan that must be learned under the supervision of educational centers (Maleki 2014, 23). In the case of structural architecture, researchers consider curriculum revision and correction of structure courses as the first step (Mirzabeigi 2011, 62).
4. The most effective load path is a path through which, specific abilities of materials we used to achieve the maximum operation (Golabchi 2009).
5. The piano creates structure by combining art and technology (Baghaei 2001).
6. In the works of Norman Foster, the technology of construction is a powerful instrument for creating architectural space (Mohammadzadeh, Akbari, and Babazade 2017, 4).
7. Fundamental theory, data-based theory, and fundamental conceptualization theory (Danaeifard, Alvani, and Azar 2004, 130)
8. According to Herbert Read, form is the shape and arrangement of parts and is the visual aspect of the work (Read 1995), while architectural form includes parts, proportions, and size (Hushyar and Barugh 2013), comprises and conveys the concept (Giedion 1967).
9. Dependent variable: dependent variable's variations fully depend on the change in other variables, including the independent variable (Heidari 2018, 121).
10. Education is an activity that is a collection of various tasks such as determining the structure and synthesis of the learning topic, determining instruction presentation, and determining the time required for education and learning to make students aware of instructional goals (Fardanesh 2019, 10,11).
11. Pedagogy: a scientific theory of how to study teaching-learning processes (Gauthier and Tardif 2020, 5)

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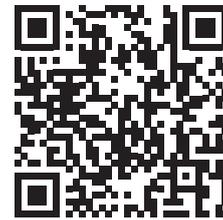
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