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Original Research Article

Identification of Productivity-Oriented Architectural Characteristics of Heavy Industrial Complexes in Iran within the Framework of Industry 5.0 Based on Expert Consensus*

Farjad Bazghandi[1**], Majid Salehinia[2], Abbas Jahanbakhsh[1], Hossein Samavatian[3]

1. Department of Architecture, Faculty of Architecture and Urban Planning, Isfahan University of Art, Iran
2. Department of Architecture, Faculty of Architecture and Urban Planning, Hakim Sabzevari University, Sabzevar, Iran
3. Department of Psychology, Faculty of Humanities, University of Isfahan, Iran

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Abstract

Problem statement: The global transition to the fifth industrial wave has revealed the necessity of rethinking the architecture of industrial spaces. In this regard, productive architecture can, through the adaptation of spatial design to production processes, the enhancement of work environment quality, and the intelligent utilization of modern technologies, provide the grounds for increasing productivity in heavy industries. However, many heavy industrial complexes in Iran still face challenges such as physical obsolescence, a lack of coordination between spatial structure and production system, and weakness in adaptation to technological transformations.

Research objective: The present study was conducted to present a productive architectural design model in accordance with the requirements of the fifth industrial wave.

Research method: This study was carried out with a qualitative approach and by employing the two stage Delphi technique. In the first stage, initial indicators were extracted through a systematic review of research literature, and the proposed theoretical framework was formulated. In the second stage, the views of 23 experts in the fields of industrial architecture and productivity were collected, and through two phases of evaluation, the indicators were finalized based on the 80 percent consensus criterion.

Conclusion: Findings led to the identification of 19 key indicators in three main axes, including: 1) patterns of ownership and utilization of space, 2) technical, technological, and energy considerations, and 3) spatial planning and functional organization. Accordingly, the conceptual model of productive architecture for Iran's heavy industries within the context of the fifth industrial wave was explained. The results of this research can provide a basis for designing and revitalizing industrial spaces in the country and can contribute to improving productivity, sustainability, and the quality of the work environment in heavy industries.

Keywords: *Human-Centric Industry, Smart Process Automation, Workplace Spatial Quality, Delphi Method, Industrial Facility Design.*

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**Corresponding Author: farjadbazghandi1373@gmail.com, +98915009 4994

Introduction

The physical work environment in heavy industries plays a decisive role in the productivity of the workforce, the safety of the production process, and the sustainability of organizational performance. However, in many industrial complexes, the design of production spaces has been solely focused on technical requirements and equipment placement, while the human, perceptual, and functional dimensions of space have received less attention. This approach leads to the creation of environments that are not only inefficient in terms of productivity but also cause an increase in errors, occupational accidents, and a decrease in workforce retention.

Previous studies have also emphasized the direct impact of physical workplace conditions on performance, safety, and job satisfaction (Schultz, 2014, 403). Moreover, the role of architectural design in improving efficiency and reducing resource wastage in heavy industries has been highlighted (Farahnaki & Gavahian, 2013). Within this framework, the fifth industrial wave, with its focus on human-centeredness, somatization, resilience, and sustainability, offers a new perspective for redefining production spaces (European Commission, 2021, 34). Despite the importance of this approach, few studies in Iran have addressed the development of a coherent framework for productive architecture in heavy industries. This article, in response to this gap, employs the Delphi technique and expert consensus to identify and prioritize productive architectural indicators in Iran's heavy industries. The innovation of this article lies in its focus on the production sector of heavy industries and the localization of features within Iran's cultural and climatic context, in accordance with the requirements of the fifth industrial wave. The main objective is to present a practical framework for designing and redesigning industrial complexes aligned with the fifth industrial wave, aiming at enhancing productivity, product quality, and workforce retention.

Research Background

The present article examines the factors affecting productivity in architecture and in Iran's heavy industries, with an emphasis on the fifth industrial wave of the world. The background of the subject has been reviewed in three areas: industrial architecture, productivity, and productive architecture in designing productive spaces, to identify the knowledge gap.

• Industrial architecture

Industrial architecture is a branch of architecture that deals with the design and organization of production and support spaces for industrial activities. This field of architecture, in addition to focusing on technological requirements, must also consider the functional and human needs of the work environment, because spatial quality and appropriate organization of spaces have a direct effect on productivity, safety, and employee satisfaction. The history of industrial architecture shows that production spaces from primitive examples such as granaries and traditional workshops to modern factories have always evolved along with the transformation of production tools and the scale of industrial activities (Holness & Giddings, 1996, 81). In Iran, industrial architecture is used in two meanings: first, the use of advanced technologies in construction, and second, the design of buildings with an industrial function, in which architecture serves industry. Accordingly, the architecture of buildings with an industrial function, in which architecture serves industry (Bayat, 2005, 18). Accordingly, the architecture of industrial complexes includes all stages of the production process—from the entry of raw materials to the exit of the product and auxiliary services (Goodini et al., 2021, 12; Farahnaki & Gavahian, 2013, 13).

- Industrial revolutions

Industrial transformations from the eighteenth century to the present have directly influenced the architecture of production spaces. The first industrial revolution, with the mechanization of textiles and the emergence of the steam engine, laid the foundation of modern factories (Schwab, 2020, 15). The second revolution, with the introduction of electricity, the assembly line, and mass production, created a new model of industrial spaces (ibid., 63). The third revolution, known as the digital revolution, began in the 1960s with the development of semiconductors, computers, and the internet and led to a fundamental transformation in the organization of production. The fourth revolution, or "Industry 4.0," relying on somatization, integrated data, and smart factories, shifted production from mass production to mass customization (Kiani-Bakhtiari & Moosavi-Movahedi, 2021, 156). The fifth revolution emphasizes the collaboration between humans and machines and elevates production environments from purely technological structures to participatory and user-oriented settings (European Union Publications Office, 2022, 130). This trend shows that the formation of productive architecture in heavy industries results, on one hand, from functional and technological requirements, and on the other, from human interaction with the industrial work environment.

Despite the emerging nature of the concept of the fifth industrial wave, studies show that this approach involves ambiguities in how the physical and virtual worlds are integrated. This wave is built on three main pillars: human-centeredness, sustainability, and resilience (European Commission, 2021, 13). In it, technology serves human needs; circular production and the reduction of environmental impacts are pursued; and the flexibility of the value chain to face crises becomes important. Human-machine collaboration, the empowering role of robots and artificial intelligence, and the transfer of human labor tasks from repetitive work to creativity and problem-solving are key elements of this wave. Lifelong learning, interdisciplinary skills, and the creation of a work environment based on dignity and employee well-being are also essential (ibid., 16).

- **Productivity**

Productivity is one of the fundamental concepts in economic development and improving organizational performance, playing a decisive role in enhancing labor quality and the optimal use of resources. This concept has been of interest throughout history, and various definitions have been proposed; for example, Quesnay[1] introduced it, and Littre[2] defined it as the "power of production." In the twentieth century, the Organisation for Economic Co-operation and Development (1950) defined productivity as the ratio of output to production factors (Saatci, 2018, 50).

Today, productivity is considered a combination of efficiency (doing things right with the least resources) and effectiveness (doing the right things to create value for stakeholders) (Kazemi et al., 2012, 14). In Iran, the importance of productivity has also been acknowledged, and the country's fourth development plan mandated that 30 percent of economic growth be achieved through productivity improvement (Saatci, 2018, 56). In this context, human resources are regarded as the most important asset of organizations, and increasing employee productivity can also improve other production factors (Tavassoli, 2015). The alignment of individual characteristics with job requirements strengthens motivation and interest among employees and ultimately increases organizational productivity (Baqi Nasr Abadi & Shadloui, 2010, 37). Therefore, the quality of human capital, more than financial resources, has a decisive role in organizational and economic development (Gholipour, 2013, 352).

- **Architecture and productivity**

The relationship between architecture and productivity plays a fundamental role in employee performance and the quality of production processes. A suitable physical environment not only enhances productivity and work quality but also reduces employee turnover and absenteeism and increases job satisfaction. Numerous studies have confirmed this relationship: physical conditions of the environment directly affect employee performance and satisfaction (Esfandiari et al., 2017, 386). The smart and pleasant design of industrial spaces can elevate the quality of the work environment to be on par with residential spaces (Yousefzadeh & Ghodsi Far, 2017, 6). Improvement of physical facilities, spatial coordination with work activities, and elimination of undesirable factors are characteristics of productive environments (Odeleye, 1967, 14).

A comfortable, safe, and healthy work environment can lead to increased happiness and improved employee performance; their attitudes, behaviors, and productivity are also affected (Atmaja, 2018, 99). Studies show that appropriate physical environment design can reduce stress and improve work relationships (Tarantini et al., 2017, 3). Furthermore, Gensler (2006)'s indicates that improving the work environment can increase employee productivity by up to 19 percent, while only four percent of employees believe that work environment design has no impact on performance (El-Zeiny & Mahmoud, 2017, 750).

Theoretical Framework

This article is based on three conceptual foundations: the fifth industrial wave, productive architecture, and industrial sustainable productivity. In the first step, the theoretical foundations of the fifth industrial wave were examined, relying on the policy documents of the European Union. Based on the official report of the European Commission (2021, 14), the fifth industrial wave is based on three fundamental principles of human-centeredness, sustainability, and resilience, and emphasizes synergy between humans and smart technologies. In this document, the macro-direction of industrial transformations is stated as moving from mere automation towards strengthening the role of humans, environmental responsibility, and the resilience of production systems.

In this article, based on these three explicit principles and by analyzing their implications in the context of Iran's heavy industries, the operational dimensions of industrial productivity have been formulated. Thus, the concept of "productivity and productive behavior in the context of the fifth industrial wave" was defined as the dependent variable of the research, which is explained in four components: 1) More Production: In the fifth industrial wave, increased production is not merely quantitative; it moves towards mass-customized production, which requires flexibility and intelligence in production lines. Today's consumers demand mass personalization, something that is only possible by returning the "human touch" to the production process, which is the key concept of the fifth industrial wave (Ostergaard, 2018). Manufacturers need production lines that are "adaptive, intelligent, and flexible" enough to quickly meet updated demands to respond to these changing market demands (Nahavandi, 2019, 3). This shows that the ability for more production is defined not only by volume but also by the diversity and speed of response to varied customer needs. 2) Higher Quality Production: The main driver for the emergence of industrial robots, in addition to eliminating difficult and repetitive jobs, has been the "need for stable quality and production flow." Robotic automation has helped improve product quality, stability, and also the production line flow, meeting the demand for high-quality products at a lower cost (Ostergaard, 2018). On the other hand, combining the high precision of industrial automation with "human cognitive skills and critical thinking" enhances production quality globally, such that repetitive tasks are delegated to machines and the creative aspect is assigned to humans, allowing employees to take on more responsibility and increase system supervision (European Commission, 2021, 41). 3) Greater Human Longevity in the Workplace: The prosperity of a manufacturing enterprise depends not only on its economic health and technical readiness of facilities but also on the "appropriate welfare of workers." Even if an automated system is controlled by an employee, "their satisfactory performance is vital for the correct functioning of the system," because a small oversight on their part may lead to a large loss. In this regard, it is important to identify and strengthen the factors that motivate and consequently improve workers' satisfaction and morale (Odeleye, 1967, 107). In this context, new technologies and digital solutions can help "strengthen mental health and welfare culture" as an integral part of organizational culture. Furthermore, this approach is likely to bring "economic benefits and savings" due to increased productivity and prevention of long-term illness and absenteeism (European Commission, 2021, 18). 4) Higher Profitability of the Industrial Complex: For industry to become a provider of "real welfare," its goal definition must include social, environmental, and economic considerations. This approach requires "responsible innovation" not only aimed at increasing cost productivity or maximizing profit but also aimed at "increasing welfare for all involved" (Xu et al., 2021, 530). In this regard, the increasing emphasis of regulatory bodies and investors on reducing carbon emissions and environmental impacts necessitates businesses to evaluate their resource footprint. This may include analyzing the source of raw materials, the ratio of waste generated, along with assessing the environmental impacts, energy efficiency of processes, and energy sources (Lachvajderova et al., 2023, 127). Therefore, sustainable profitability in the fifth industrial wave is a result of synergy between responsible innovation, social welfare, and economic productivity.

These four components are considered the analytical interpretation of the article from the three goals of the fifth industrial wave, and they are not explicitly mentioned in the text of the European Commission's report, but rather are conceptually inferred from it.

Given that the realization of these outcomes requires a suitable physical and spatial context, productive architecture was considered as the link between the principles of the fifth industrial wave and sustainable industrial productivity. In this regard, the architectural features of the production section were defined in three categories: (1) ownership and utilization patterns of the production space; (2) technical, engineering, and energy issues; (3) spatial planning and organization of functions, as independent variables. Also, users' psychological and social characteristics were considered as intervening variables, and policy and economic factors as mediating variables, because these factors can moderate or strengthen the manner and intensity of the impact of architectural features on productivity. Based on this conceptual formulation, the theoretical framework of the article was developed, which shows the relationship between the fifth industrial wave, productive architecture, and the realization of sustainable productivity in heavy industries. This framework is presented in Fig. 1.

Methodology

The research method in this article is of a qualitative type and has been carried out using the expert inquiry method (Delphi method). This method was employed to achieve consensus among experts regarding the characteristics, indicators, and relationships affecting productive industrial architecture in the context of the fifth industrial wave. The selection of the qualitative approach and the Delphi method was due to the exploratory nature of the subject and the need to extract tacit knowledge from experts. The target population of the research included experts in the fields of industrial architecture, productivity, industrial management, and productive architecture. The sampling was purposive and based on criteria such as scientific-research background, relevant professional experience, and specialized familiarity with industrial architecture and productivity topics. To complete the expert community and increase the diversity of views, snowball sampling was used, so that initial experts introduced other qualified individuals with scientific or experiential credentials. This method is effective in qualitative studies, especially when the statistical population is scattered or uncertain. Ultimately, the final list of the research community consisted of 26 experts with diverse disciplinary, organizational, and experiential backgrounds.

The Delphi process was conducted in two iterative stages. In the first stage, a set of propositions was

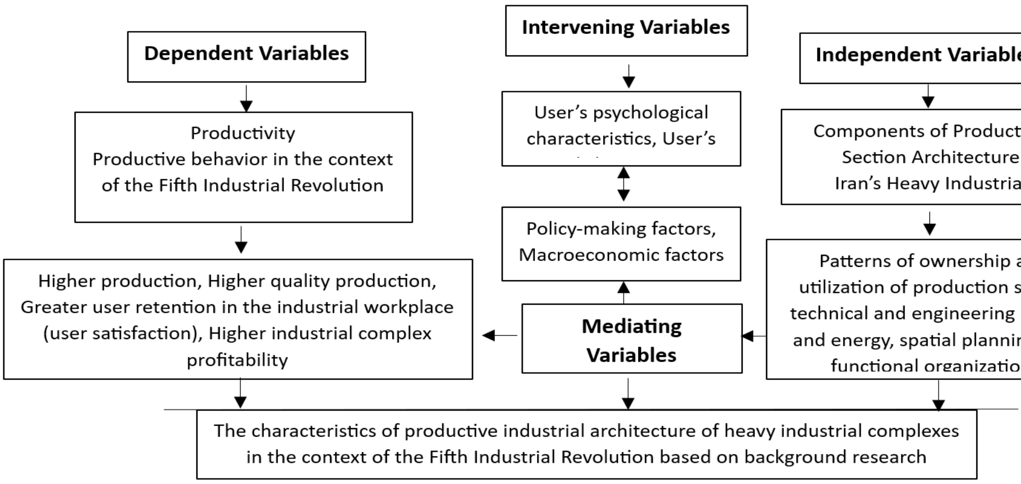

Fig. 1. Initial theoretical framework based on research background. Source: Authors.

developed based on the theoretical background and conceptual foundations of the research and presented in the form of a Delphi questionnaire to the experts. The data collection tool was distributed in two ways: electronically (email, Google Forms, and social networks) and in person. At this stage, despite the follow-ups made, 23 complete questionnaires were received and used as the basis for analysis. After analyzing the data from the first stage and measuring the level of agreement among experts, in the second stage, only the statements that had not reached consensus were resent to those same experts whose viewpoints were not aligned with the majority opinion. This iterative process made it possible to refine opinions, reduce the dispersion of views, and achieve a valid consensus. Overall, the Delphi technique used in this research has provided a suitable foundation for extracting a precise and reliable analytical framework in the field of productive industrial architecture.

- **Delphi questionnaire development process**

The Delphi method is one of the valid approaches for collecting and refining expert opinions that, through structured repetition and reaching consensus, has wide application in forward-looking and complex research (Linstone & Turoff, 2002, 36). In this paper, the Delphi method was employed to identify and validate influential features on productive architecture in Iran's heavy industries and to align it with the requirements of the fifth wave of industry. The goal was to develop a scientific and practical questionnaire for organizing production spaces and improving employee productivity. In this process, first, the key concepts of areas related to the fifth wave of industry, industrial architecture, and productivity were examined, and the main indicators were extracted. Then these concepts were organized into three main components. Accordingly, the initial statements of the questionnaire were formulated in the form of closed questions based on the Likert scale. The initial version, consisting of 100 statements, was presented to experts for evaluation of validity and clarity and, after receiving feedback, was revised, simplified, and finalized. Finally, the completed version of the questionnaire was used as the main tool for performing the Delphi method.

- **Structure of the Delphi questionnaire and its content analysis**

The Delphi questionnaire designed in this paper includes 86 closed statements in three main axes. Each statement is arranged based on a five-point Likert scale (from "completely disagree" to "completely agree") to make it possible to measure the level of experts' agreement regarding the role of features in increasing the productivity of production spaces in Iran's heavy industry.

The questions are structured based on four analytical variables (dependent, independent, mediating, and intervening), and each component has a direct link with one or more productivity indicators.

• Reason for choosing the Delphi Method (the role of experts) in designing productive architecture

Due to the interdisciplinary nature of the article's subject, including architecture, industry, environmental psychology, technology, and economics, a method was needed that could collect and bring various expert viewpoints to a consensus. The Delphi method, as one of the most reliable consensus-building approaches, by relying on the repetitive collection of expert opinions, makes it possible to utilize collective intelligence in issues lacking definite answers (Nobakht, 2017, 270). In this article, the Delphi method was used to identify and validate the physical and functional characteristics of productive architecture in production spaces of heavy industries within the context of the fifth wave of industry. Experts' feedback led to the removal of ambiguous statements, revision of wording, reordering of questions, and enhancement of the questionnaire's practicality. As a result, the Delphi method, in addition to screening and prioritizing indicators, led to the production of a valid and usable questionnaire for the Iranian industry.

• Validity and reliability of the questionnaire

In this article, the validity and reliability of the questionnaire were precisely examined. Content validity was assessed by designing the questionnaire based on prior studies and then evaluating it by four university professors and three automotive industry specialists, and based on feedback, items were modified or integrated. Face validity was also strengthened through examination of the clarity and comprehensibility of the questions by experts, and changes were made in the language and order of items. For reliability, Cronbach's alpha coefficient was calculated using SPSS, which yielded a value greater than 0.9, indicating high internal consistency and good reliability of the questionnaire.

• Execution of the first stage of the Delphi technique

The samples were selected with a focus on specialized and professional diversity to cover the variety of academic, industrial, and consulting viewpoints. The experts were categorized into four main groups:

1) Faculty members in the fields of architecture, urban planning, industrial design, and industrial engineering. 2) Senior managers and experts in the automotive industry (especially Iran Khodro Khorasan). 3) Technical and industrial design consultants active in development and production line renovation projects. 4) Faculty members in related technical-engineering fields (such as mechanics and automotive). This specialized composition allowed for an accurate evaluation of indicators from theoretical and practical perspectives and became the basis for theoretical convergence in the subsequent Delphi steps.

To implement the Delphi method, a set of qualitative criteria was considered for the initial selection of specialists, which included the following:

1) Holding a Master's degree in one of the related fields. 2) Having at least five years of executive, academic, or consulting experience in one of the aforementioned four areas. 3) Familiarity with the concepts of production space design, productivity management, production technology, or industrial organization. 4) Willingness and ability to actively participate in the multi-stage Delphi process. 5) Possessing professional credibility (based on scientific publications, management background, or participation in industrial projects).

• Preliminary analysis of responses

The composition of the participants in this questionnaire, which was distributed to a group of specialists in a targeted manner and in four specialized clusters, is as follows:

Six faculty members in architecture at reputable universities across the country, seven production managers in automotive complexes3, five experts and managers of consulting companies in the field of design and construction of industrial buildings, and five faculty members or affiliated researchers in other related fields (including industrial engineering, mechanics, or industrial design, etc.) who had interdisciplinary expertise. In total, the questionnaire was completed by 23 specialists.

In the first step of Delphi, the responses of the 23 experts were reviewed descriptively and analytically. The goal of this analysis was to measure the level of agreement and the degree of dispersion of views, which was evaluated using indicators such as the mean score (general tendency) and standard deviation (level of disagreement). Propositions with a mean of two to three or a standard deviation greater than one were selected for revision in the second step.

The first step had advantages such as simultaneous collection of academic and industrial viewpoints, a high response rate, and the ability to identify points of consensus and conflict. These are observable in Table 1. Conversely, the difficulty in attracting the initial participation of some experts and the limitation of inferential analysis were raised as challenges. Given the multi-stage nature of the Delphi method, in the second step, the consensus-building process began with the aim of refining responses and increasing the validity of the characteristics. In this step, only questions where the minority of specialists' opinions did not align with the majority were reposed. Additionally, two participants were removed from the cycle due to serious deficiencies in completing the questionnaire or inconsistent response patterns. Therefore, the final number of experts in the second step decreased to 21.

• **Classification of questions and execution of the second Delphi stage**

The 86 questions from the first Delphi step were categorized into three main groups based on the frequency analysis of responses, as specified in Table 1:

Questions with high consensus: Items for which more than 80% of the participants (at least 17 out of 21) selected the options "Agree" or "Strongly

Table 1. Responses of 23 specialists to the 86 questions of the first Delphi stage and the status of each question (rejected, accepted, proceeding to second Delphi stage). Source: Authors.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Status
1	3	12	1	4	3	Rejected
2	13	4	2	2	2	Phase 2
3	10	9	4	0	0	Accepted
4	8	10	3	2	0	Phase 2
5	9	8	2	4	0	Phase 2
6	13	5	2	3	0	Phase 2
7	6	11	1	5	0	Phase 2
8	6	9	3	5	0	Phase 2
9	2	9	7	5	0	Rejected
10	3	12	7	1	0	Phase 2
11	3	10	8	2	0	Phase 2
12	4	12	5	1	1	Phase 2
13	4	6	10	2	1	Rejected
14	3	16	3	1	0	Accepted
15	12	11	0	0	0	Accepted
16	7	9	3	3	1	Phase 2
17	5	15	3	0	0	Accepted
18	7	12	2	2	0	Phase 2
19	5	12	4	1	0	Accepted
20	10	11	2	0	0	Accepted
21	13	8	1	1	0	Accepted
22	8	13	2	2	0	Accepted
23	14	5	2	2	0	Phase 2
24	19	3	1	0	0	Accepted
25	15	6	2	0	0	Accepted
26	16	5	2	0	0	Accepted
27	18	4	0	1	0	Accepted
28	9	5	7	2	0	Rejected
29	18	5	0	0	0	Accepted
30	16	7	0	0	0	Accepted
31	12	7	4	0	0	Accepted
32	10	6	6	0	1	Phase 2
33	13	9	1	0	0	Accepted
34	17	5	1	0	0	Accepted
35	11	10	1	1	0	Accepted
36	18	4	1	0	0	Accepted
37	13	8	2	0	0	Accepted
38	14	9	0	0	0	Accepted
39	10	8	4	1	0	Accepted
40	13	8	2	0	0	Accepted
41	14	7	2	0	0	Accepted
42	6	8	8	1	0	Rejected
43	10	11	2	0	0	Accepted
44	13	7	3	0	0	Accepted

Fig. 1. Initial theoretical framework based on research background. Source: Authors.

Rest of Table 1.

Question	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Status
45	12	7	3	1	0	Accepted
46	14	8	1	0	0	Accepted
47	12	8	3	0	0	Accepted
48	12	7	3	1	0	Accepted
49	13	8	2	0	0	Accepted
50	18	3	2	0	0	Accepted
51	9	9	4	1	0	Phase 2
52	13	9	1	0	0	Accepted
53	13	10	0	0	0	Accepted
54	10	6	7	0	0	Rejected
55	10	9	3	1	0	Accepted
56	14	5	4	0	0	Accepted
57	11	8	2	1	0	Accepted
58	13	8	1	1	0	Accepted
59	8	12	2	0	0	Accepted
60	10	9	2	2	0	Phase 2
61	6	11	5	1	0	Phase 2
62	10	11	2	0	0	Accepted
63	8	12	1	2	0	Accepted
64	8	14	1	1	0	Accepted
65	13	8	2	0	0	Accepted
66	10	13	0	0	0	Accepted
67	11	9	3	0	0	Accepted
68	12	9	1	1	0	Accepted
69	7	13	3	0	0	Accepted
70	14	7	2	0	0	Accepted
71	10	8	5	0	0	Phase 2
72	11	8	4	0	0	Accepted
73	10	9	4	0	0	Accepted
74	11	8	2	2	0	Phase 2
75	11	6	3	3	0	Phase 2
76	8	13	1	1	0	Accepted
77	11	10	2	0	0	Accepted
78	10	8	5	0	0	Phase 2
79	9	11	3	0	0	Accepted
80	9	12	1	1	0	Accepted
81	12	9	2	0	0	Accepted
82	6	6	11	0	0	Rejected
83	12	9	1	1	0	Accepted
84	16	5	2	0	0	Accepted
85	13	10	0	0	0	Accepted
86	17	4	2	0	0	Accepted

Agree." These were confirmed as definitive characteristics of the theoretical framework and directly entered the final model without modification.

Questions with high disagreement: Items for which more than 40% of the votes fell into the "Disagree," "Strongly Disagree," or "Don't Know" range. These questions lacked the minimum level of professional agreement, and a total of 7 items were excluded from the analysis process.

Questions with disagreement: Including items with a consensus level of 60% to less than 80%, or significant dispersion among specialized groups. In this section, 22 questions were identified that required revision in the second Delphi stage.

Innovation in the second Delphi step of this article was the use of targeted and personalized feedback and the customization of the questionnaire. Contrary to the common approach in which the entire questionnaire is sent again to everyone, in this study, a dedicated package was designed for each expert. This package included the same propositions for which his/her view in the first stage did not align with the overall consensus. Next to each question, the statistical data from the first stage (percentage of agreement, the level of disagreements, the dispersion of opinions, and the mean score) were provided in order to enable scientific reconsideration and informed decision-making. This method, while reducing the response burden, led to greater focus by the experts on the contentious items and increased the quality of the final consensus.

• Finalization of characteristics in the second Delphi stage

In the second Delphi step, the 80% consensus criterion was considered as the final basis for finalizing the propositions. Variables (components) that, after revision, became aligned with the view of the majority of experts and obtained at least 80% approval were stabilized within the theoretical framework. In contrast, variables that still lacked consensus even after modification were definitively removed; these cases are shown in Table 2. Based on this, eight variables were excluded from the process, and 13 variables

Table 2. Comparison of the first and second Delphi rounds and the status of items admitted to the second Delphi round (accepted or rejected). Source: Authors.

Question		Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree	Status
2	1	11	4	2	2	2	Rejected
	2	11	4	0	4	2	
4	1	6	10	3	2	0	Accepted
	2	7	12	1	1	0	
5	1	7	8	2	4	0	Accepted
	2	8	10	1	2	0	
6	1	11	5	2	3	0	Accepted
	2	11	7	1	2	0	
7	1	4	11	1	5	0	Rejected
	2	4	11	0	6	0	
8	1	4	9	2	5	0	Rejected
	2	4	9	1	7	1	
10	1	1	12	7	1	0	Accepted
	2	1	15	2	2	0	
11	1	1	10	8	2	0	Accepted
	2	3	14	1	3	0	
12	1	2	12	5	1	1	Rejected
	2	2	12	0	4	3	
16	1	5	13	4	1	0	Rejected
	2	10	11	2	0	0	
18	1	5	12	2	2	0	Accepted
	2	5	13	2	1	0	
23	1	12	5	2	2	0	Accepted
	2	13	6	0	1	0	
32	1	8	6	6	0	1	Rejected
	2	8	6	1	3	3	
51	1	7	9	4	1	0	Accepted
	2	8	12	1	0	0	
54	1	8	6	7	0	0	Accepted
	2	10	9	2	0	0	
60	1	8	9	2	2	0	Accepted
	2	8	12	0	1	0	
61	1	4	11	5	1	0	Rejected
	2	4	11	1	3	2	
71	1	8	8	5	0	0	Accepted
	2	9	10	1	1	0	
74	1	9	8	2	2	0	Accepted
	2	9	9	1	2	0	
75	1	9	6	3	3	0	Rejected
	2	9	7	0	4	1	
78	1	8	8	5	0	0	Accepted
	2	8	11	1	0	0	

succeeded in obtaining expert consensus and were accepted as part of the new theoretical framework.

Findings

The findings from the two steps of implementing the Delphi technique indicate that the initial theoretical framework of the article, developed based on the research background, was evaluated, refined, and developed through the expert consensus process. Thus, the findings in this section did not merely confirm the preliminary framework but also led to its redefinition and completion.

In the first step of the Delphi technique, the features extracted from the theoretical literature were presented to the experts to assess their importance and relevance to efficient architecture in Iran's heavy industries. The results showed that some of the proposed features from the research background are not considered to have sufficient priority or efficiency in the Iranian industrial context by the experts; therefore, these items were removed from the final structure of efficient architecture features. This stage can be considered the "theoretical refinement" process of the initial framework.

In the second step, in addition to re-evaluating the features, experts were asked to propose features that had not been considered in the research background but were effective in their professional experience in achieving efficient architecture. This data was collected through supplementary interviews and the explanatory question at the end of the questionnaire. The analysis of these proposals led to the identification of several new features that were not explicitly stated in the previous literature. These added features constitute the innovative part of the article's findings and indicate the localization of the efficient architecture concept within the context of Iran's heavy industries.

• Features of architecture confirmed from the research background

This category includes features that were extracted in the initial framework development stage based on the research background and theoretical foundations.

During the two-stage Delphi process, these features were evaluated by experts in the field of industrial architecture and productivity. The results showed that some of these features align with the actual conditions of Iran's heavy industries and managed to achieve the determined consensus threshold. The acceptance of these features indicates that some of the existing theoretical foundations are adaptable to the country's industrial context and can be cited as established elements in the efficient architecture design model. These are presented in Fig. 2. Below is a list of the confirmed features:

Scattered and accessible welfare services: Clustering services such as dining halls or restrooms near production lines reduces wasted time and increases psychological satisfaction and employee efficiency.

Flexible equipment layout: The space should allow for quick relocation of machinery and improvement of infrastructure (electricity, gas, ventilation) to accelerate the organization's response to market changes and reduce line change costs.

Simple and transparent digital displays: Digital information should be in simple language, with understandable indicators, and placed at key points to reduce human error and improve output quality.

Smart processes and environmental monitoring: Real-time monitoring of machinery conditions and the work environment enables predictive management and prevents line stoppages. This feature signifies the industry's entry into the fifth wave.

Sustainable energy and materials: Experts emphasized that efficient architecture should move towards the gradual replacement of renewable energy sources. The use of solar panels, energy recycling systems, and heat-storing materials, in addition to reducing environmental pollution, decreases operational costs in the long run and enhances the organization's social credibility.

Cleansing of industrial odors and fumes: Utilizing filtration systems and local ventilation is among the main components that improve employee health and increase their psychological satisfaction. This directly impacts the reduction of occupational diseases and an increase in productivity.

Monitoring of noise pollution and thermal fluctuations: Employing high-capacity sound and thermal insulation materials ensures the quality of the work environment and prevents premature employee burnout.

Visible and improvable facilities: Unlike older models, there is an emphasis on having facilities that are accessible and visible. This design facilitates

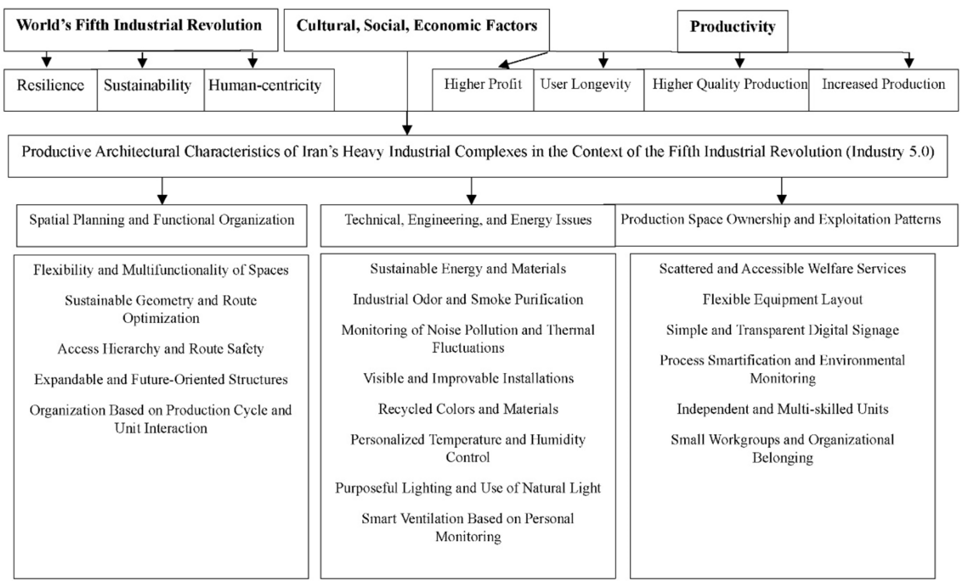

Fig. 2. Summary of findings. Source: Authors.

maintenance, allows for easier and quicker improvements without major disruptions, and reduces maintenance costs.

Recycled colors and materials: Bright colors and recyclable materials not only enhance lighting and reduce energy costs but also have a positive effect on employee morale and environmental sustainability.

Flexibility and multifunctionality of spaces: Spaces must be capable of easily changing their function so that the organization can adapt to market and technological changes. This can be achieved through lightweight structures, movable walls, and flexible infrastructures.

Sustainable geometry and optimized pathways: The design of forms and geometry must be aligned with the production cycle to ensure the shortest route for material movement is taken, thereby reducing congestion and wasting energy.

Hierarchy of access and safety of pathways: Separating paths for employees, managers, materials, and products while maintaining easy communication among them enhances productivity and prevents dual contamination and accidents.

Expandable and future-oriented structures: Structures should have the capability to expand or change use with minimal physical barriers. Utilizing modular structures and large, flexible spans ensures the organization can adapt to future changes.

- **Features identified in this research**

This category includes features that were not directly mentioned in the research background but were identified as effective dimensions in achieving efficient architecture through the Delphi technique and interaction with experts. These features were extracted through specialized discussions and the explanatory responses at the end of the questionnaire. After reevaluation and achieving the necessary consensus, they were added to the final structure. These items reflect the conceptual development of the initial framework and its adaptation to the managerial, technological, and human realities of Iran's heavy industries. They constitute the innovative findings of the article, which are presented in Fig. 2. The developed features are as follows:

Independent and multiskilled units: Designing independent stations with the ability to change roles reduces the production line's dependence on specific individuals, enhances job satisfaction, and lowers production downtime costs. This also provides a platform for "on-the-job learning."

Small workgroups and organizational belonging: Organizing employees into small groups facilitates knowledge exchange and strengthens the social capital of the work environment. This model leads to increased employee retention and reduced job burnout.

Personalized temperature and humidity control: A fundamental requirement is the design of infrastructure for localized or individual monitoring of environmental conditions. This approach increases employee comfort, reduces energy consumption, and improves their physical and psychological health, ultimately leading to long-term retention in the workplace.

Targeted lighting and use of natural light: Lighting should be designed according to the needs of each production line, while simultaneously maximizing the use of natural daylight. This measure, in addition to reducing energy consumption, enhances focus, decreases fatigue, and improves the quality of industrial spaces.

Smart ventilation based on personal monitoring: Ventilation systems should control conditions in each section based on smart sensors. This human-centered model enhances employees' lived experience and prevents production line stoppages.

Organization based on production cycle and unit interaction: Space layout should be based on the flow of materials and data. The logical co-location of units, such as placing the quality monitoring section near the production lines, increases process coordination and accuracy.

Discussion

The findings of this article indicate that the features of efficient architecture in Iran's heavy industries can be analyzed on two levels: Features rooted in theoretical literature and confirmed by experts. This confirmation strengthens the universal validity of certain design principles within the Iranian industrial context. Features developed during the Delphi process based on experts' lived experiences: This distinction shows that the proposed model is not merely a reflection of past research but a product of constructive interaction between theoretical knowledge and indigenous industrial experience. On the first level, the confirmed features demonstrate that a portion of existing theoretical foundations regarding the relationship between space design and efficiency is adaptable to the heavy industries sector in Iran.

Connection to classic human-centricity: Features such as providing adequate welfare services, considering spatial flexibility, optimizing movement pathways and facility distribution, and focusing on environmental quality (e.g., light, sound, temperature) are all aligned with the classic paradigms of ergonomics and organizational architecture. For instance, the results show strong consistency with Becker's (1981) findings on the impact of physical design on job satisfaction, as well as Esfandiari et al. (2017) 's studies on the effect of the work environment on human resource productivity. This alignment suggests that meeting basic and physiological needs of employees, regardless of the industry's nature, is a fundamental principle for enhancing performance and reducing human error.

Impact on human capital: The significance of these findings lies in transforming architecture from a passive backdrop into an active factor in human investment. Unlike traditional approaches that primarily confined productivity investments to machinery and hard technologies, this research re-emphasizes that spatial quality directly influences employee retention, organizational commitment, and ultimately, a lower turnover rate—a critical factor in industries like heavy industries that require specialized, long-term expertise.

On the second level, the features developed within the Iranian industrial context hold greater significance in terms of innovation. The most distinctive and robust part of the discussion pertains to the second-level features, which were directly extracted from the lived experiences of Iranian experts and have been less explored in the industrial architecture literature to date. These features represent the practical translation and localization of the fifth wave of industrial principles in Iran.

Personalized environmental control: This finding goes beyond standard air conditioning, emphasizing the need for individual empowerment in managing the work environment. In Iran's heavy industrial settings, where the diversity of tasks and workers' physical conditions varies, granting individuals the choice to adjust details like airflow or localized light intensity is not merely a welfare perk but a practical necessity for maintaining focus during complex tasks. This directly aligns with the human-centric focus of the fifth industrial wave.

Organization of small workgroups and multiskilled units: In global literature, these structures are often attributed to service-oriented or knowledge-based industries. The emergence of this model in Iran's heavy industries signifies a structural transformation where process flexibility, crucial for responding to specific and complex orders, is achieved by reducing hierarchies and creating self-managing, multi-specialist teams at the workshop level. This enhances organizational resilience in the face of market fluctuations.

Smart ventilation based on personal monitoring: This example showcases the successful integration of advanced technologies with physical architecture. Instead of costly, volumetric ventilation of the entire space, the focus shifts to monitoring individual environmental needs during work. This approach not only contributes to environmental sustainability and reduced energy consumption but also ensures that the highest environmental quality is provided precisely where human resources are actively engaged.

The results show that productive architecture in Iran's heavy industries has a role beyond a simple shelter; it is an active interface that bridges the physical limitations of space, the requirements of new fifth-wave industry technologies, and the cognitive-physical capabilities of the workforce. This aligns with the European Commission's (2021) view on the three pillars of the fifth wave of industry, with the difference that in this research, the physical and architectural context is defined as the primary implementer of these principles. Furthermore, the emphasis on smart technologies in environmental and process monitoring is consistent with the direction of the fifth wave of industry; a trend that, according to the European Commission's report (ibid.), places human-centricity, sustainability, and resilience at the core of industrial transformation. The article's findings indicate that achieving these principles in heavy industries requires conscious intervention in architectural design, not just technological investment. In other words, architectural design can act as an "active mediator" in the interactions between humans, space, technology, and the economy. From this perspective, a set of changes in space design may lead to the creation of work environments that better adapt to human and organizational needs.

From a theoretical perspective, this article takes a step towards developing the literature of industrial architecture in Iran and, by combining the foundations of the fifth wave of industry with indigenous expert data, provides a more comprehensive framework for analyzing the characteristics of productive architecture. From a practical perspective, the results can be used for the redesign of production lines in heavy industries, particularly the automotive industry, as a strategic and improved model for organizational and human life. However, attention to the limitations of this study in specific areas, including the lack of sample diversity and the need for further research into the long-term effects of these changes on productivity and employee satisfaction, is essential.

Conclusion

This article, relying on expert consensus and in line with addressing the practical needs of Iran's heavy industries, presents an indigenous model for the design of productive architecture. This model is the result of refining existing theoretical characteristics with the field realities of the country's industry and provides a specific set of applicable traits for the design and redesign of industrial spaces. The findings indicate that adapting a portion of the theoretical principles to Iran's managerial and executive conditions is feasible, and alongside this, novel characteristics suitable for the realities of the country's heavy industries have been identified and added to the framework.

This article demonstrates that achieving productivity in the fifth wave of industry is not possible solely through technological or financial investment, but requires the conscious design of workspaces that simultaneously impact work environment quality, production line flexibility, human resource retention, and the reduction of resource waste (time, energy, and materials). Productive architecture, thus, is elevated from a physical support role to a strategic factor in enhancing industrial productivity and provides a tangible path for redesigning production lines, spatial organization, and industrial policymaking. This framework is a practical tool for reducing time waste, improving the quality of the work environment, increasing the factory's adaptability to technological changes, and enhancing human resource retention.

Given the conceptual and consensus-based nature of this article, it is recommended that future research focus on a deeper and more specialized examination of each identified characteristic. Developing quantitative indicators to measure the impact of these characteristics on key performance indicators of productivity is a necessary next step. Furthermore, conducting field studies in active factories and transferring these characteristics from the theoretical level to the real-world context will greatly aid in the practical evaluation of their efficacy. On the other hand, the direct participation of users, production managers, and employees in the process of refining and localizing these characteristics is vital, as the lived experience of industrial users can help in correcting, prioritizing, and operationalizing the proposed model. Thus, the future research path will be guided from the stage of expert consensus towards field testing, practical validation, and the development of applied design guidelines.

Here's a word-for-word translation of the achievements and declarations:

The achievements of this research can be stated as follows:

Theoretical innovation: Introduction of an indigenous framework for productive architecture tailored to the conditions of Iran's heavy industries.

Practical achievement: Provision of a practical solution for the redesign of automotive complexes in Iran, with a focus on Iran Khodro Khorasan.

Managerial implication: Emphasis on the role of architecture in enhancing organizational belonging, job satisfaction, and employees' social capital.

At the end, the authors of this article hereby declare that there is no financial, organizational, personal, or professional conflict of interest in connection with the conduct, writing, and publication of this article. Furthermore, no entity or organization has been involved in the process of designing, collecting data, analyzing, and writing this article, and all stages have been carried out independently.

Endnotes

1. Quesnay (1766, as cited in Saatchi, 2018)
2. Littre (1833, as cited in Saatchi, 2018)
3. Bahman Motor - Pars Khodro - Zarrin Khodro - Saipa - Iran Khodro-Kerman Motor - Aryan Motor

References List

- Atmaja, N. (2018). Effect of physical work environment through productivity employees job satisfaction as an intervening variable. *International Journal of Business, Economics and Law, 7*(5), 98-104.
- Baqi Nasr Abadi, A., & Shadloui, N. (2010). نقش منابع انسانی در بهره‌وری سازمانی [The Role of Human Resources in Organizational Productivity]. *Hasoon, 26*, 35-43. [in Persian]
- Bayat, K. (2005). معماری صنعتی، معماری در خدمت صنعت [Industrial Architecture, Architecture in Service of Industry]. *Building and Computer Monthly*. [in Persian]
- Becker, F. (1981). *Workspace: Creating environments in organizations.* Praeger Publishers.
- El-Zeiny, R., & Mahmoud, A. (2017). The Interior Design of Workplace and its Impact on Employees' Performance: A Case Study of the Private Sector Corporations in Egypt. *Procedia Social and Behavioral Sciences, 35*, 746 – 756.
- Esfandiari, M., Mohd Zaid, S., Azzam, A., & Ismail, A. (2017). Influence of indoor environmental quality on work productivity in green office buildings: A review. *Chemical Engineering Transactions, 56*, 721–726. https://doi.org/10.3303/CET1756121
- European Commission. (2021). *Industry 5.0: Towards a sustainable, human-centric and resilient European industry.* Publications Office of the European Union. https://doi.org/10.2777/308407
- European Union Publications Office. (2022). *The Fifth Industrial Revolution, Towards a Sustainable, Human-Centric, and Resilient Industry in Europe.* Iran's Technology Cooperation Advisor in Vienna.
- Farahnaki, A., & Gavahian, M. (2013). *طراحی کارخانه‌های صنایع غذایی اصول و مبانی* [Design of Food Industry Factories: Principles and Foundations]. Mashhad Jihad Daneshgahi Publications. [in Persian]
- Gensler, G. (2006). *Gensler Design + Performance Index: The U.S. Workplace Survey.* Gensler.
- Gholipour, A. (2013). *مدیریت منابع انسانی مفاهیم، تئوری‌ها و کاربردها* [Human Resource Management (Concepts, Theories, and Applications)]. Publications of the Organization for the Study and Compilation of Humanities Books of the Universities (SAMT), Humanities Sciences Research and Development Center. [in Persian]
- Goodini, J.,Vafamehr, M., & Gorji, Y. (2021). *فرایند طراحی معماری در مجموعه‌های صنعتی* [Architectural Design Process in Industrial Complexes]. Tahan Gostar Publications. [in Persian]
- Holness, A., & Giddings, B. (1996). *Developing a Methodology for Investigating the Design of Award-Winning Industrial Architecture.* Nordisk Arkiturforskninng.
- Kazemi, M., Alavi, S. M. & Najafi, M. (2012). *بهره‌وری در آموزش عالی* [Productivity in Higher Education]. Marandyz Publications. [in Persian]
- Kiani-Bakhtiari,A., & Moosavi-Movahedi, A. A. (2021). The Fourth Industrial Revolution and the Fundamental Changes Ahead. *Science Cultivation, 11*(2), 155-163. https://

dor.isc.ac/dor/20.1001.1.2008935.1400.11.2.6.1
• Lachvajderova, L., Kadarova, J., Sanchis, E. J., & Rybarova, D. (2023). Industry 5.0-a sustainable human-centric solution. In *Proceeding of Conference.* Novus Scientia.
• Linstone, H. A., & Turoff, M. (2002). *The Delphi Method: Techniques and Applications.* Addison-Wesley.
• Nahavandi, S. (2019). Industry 5.0—A human-centric solution. *Sustainability, 11*(16), 4371. https://doi.org/10.3390/su11164371
• Nobakht, M. (2017). روش تحقیق پیشرفته [Advanced Research Methods]. Jihad Daneshgahi Publications. [in Persian]
• Odeleye, O. A. (1967). *Design considerations in industrial architecture, school of architecture.* McGill.
• Ostergaard, E. H. (2018). Welcome to Industry 5.0. In *Tech Magazine*. International Society of Automation (ISA). https://www.isa.org/intech-home/2018/march-april/features/welcome-to-industry-5-0
• Saatci, M. (2018). *روانشناسی بهره‌وری راهبردی (آسیب‌شناسی و مدیریت راهبردی عوامل و موانع انسانی بهره‌وری شغلی کارکنان و سازمان)* [Strategic Productivity Psychology (Pathology and Strategic Management of Human Factors and Obstacles to Job Productivity of Employees and Organizations)].Virayesh Publishing. [in Persian]
• Schultz, D. (2014). *Industrial and Organizational Psychology (Individual and Organization)* (H. Khanifar & M. Attaei, trans.). University of Tehran Press.
• Schwab, K. (2020). *Towards Industry.* Industrial Management Organization Publications.
• Tarantini, M., Pernigotto, G., & Gasparella, A. (2017). A Co-Citation Analysis on Thermal Comfort and Productivity Aspects in Production and Office Buildings. *Buildings, 7*(2), 36. https://doi.org/10.3390/buildings7020036
• Tavassoli, M. (2015). مدیریت کیفیت و بهره‌وری [Quality and Productivity Management]. Afraang Publishing. [in Persian]
• Xu, X., Lu, Y., Vogel-Heuser, B., & Wang, L. (2021). Industry 4.0 and Industry 5.0 Inception, conception and perception. *Journal of Manufacturing Systems, 61*, 530-535.
• Yousefzadeh, Z., & Ghodsi Far, S. H. (2017). ارزیابی نقش فضای معماری در ارتقای بهره‌وری نیروی انسانی [Evaluating the Role of Architectural Space in Enhancing Human Resource Productivity]. *The 6th International Conference on Economics, Management, and Engineering.* [in Persian]

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