

Dominant Design Innovation in Building Projects

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Abstract. Dominant designs consist of outstanding innovation that promotes meaningful paradigm shifts, regarding the economic, social, and cultural aspects. Likewise, the Dominant design innovations are considered a technological reference in their sector. In regards to the civil construction sector, there are few reports in the literature about innovation, especially in building projects. Some of these reports do not demonstrate expressive participation of civil construction in the 4.0 industry. Additionally, the changes' perception of the civil construction activities is soft by the sector workers. This paper aims to demystify the vision concerning the low level of innovation in the civil construction sector related to building project activity. To do this, we researched the literature references on the topic of Dominant design innovations in building projects. Then, the Dominant design innovations were identified and characterized. Thus, the paradigm shifts were listed. As a result of this paper, we found innovations classified as Dominant designs in building project activity. We also noticed some innovations presented potential in turning Dominant designs. However, they were still not classified as Dominant designs due to their absence of paradigm shifts. Hence, Building Information Modeling (BIM) and Lean Construction presented these features. Finally, this paper contributed to the importance of reporting the Dominant design innovations for monitoring trends in specific economic sectors.

Keywords: Dominant Design, Innovation, Building Project

1 Introduction

Throughout history, technological and process innovations in the civil construction sector, especially concerning architecture and building projects have emerged. Despite that, there is a lack of perception of innovation consequences in civil construction [1, 2]. This image is a consequence of the low adherence of the civil construction sector in the 4.0 industry, especially regarding building projects. Additionally, there are a myriad of processes, technologies, and methods without the perception of significant changes in the XX and XXI centuries [3]. A hypothesis concerning the low level of the perception of the innovation's effects in the building projects area is the absence of radical innovations classified as Dominant design.

Dominant design means a notorious innovation occurring in a specific economic sector that modifies its approach. Likewise, the consequences of the approach changes promoted by the Dominant design innovations are named Paradigm shifts. Therefore, they can be limited to the sector where the Dominant design occurs or is widespread in society. Consequently, a Dominant design innovation becomes an innovation of reference in its economic segment [4–6].

This paper aims to verify if the civil construction sector is truly innovative, especially regarding the building projects area. To achieve this, we intended to figure out, identify, classify, and characterize the radical innovations in building projects founded in the scientific literature. Additionally, we checked whether these radical innovations fit into the Dominant design concept. If not, we evaluated the potential of the innovation in becoming Dominant design.

Therefore, this paper is sorted in the following structure. First, the introduction includes the Dominant design concept and the paper's purpose. Second, we presented a brief theoretical basis for dominant design innovations and their relationship with the civil construction sector. In the same section, the method was explained. Besides that, we detailed the exploratory research made in the literature and the evaluation of its results. Hence, the criteria applied to the literature research were explained, as the ones to classify and evaluate the innovations found in the literature. Then, the results and their discussions were exhibited. In this section, we presented the answers to the questions made for verifying whether a radical innovation in building projects fits into the Dominant design concept and its Paradigm shifts. Beyond that, we evaluated its potential to become a Dominant design. Finally, the conclusions.

2 Theoretical Aspects and Method

2.1 Theoretical Aspects

According to [6], innovations classified as Dominant design depend on human factors, such as qualified workers in companies. Additionally, there is uncertainty concerning the company's size. [6] demonstrates evidence that large companies are more intense in producing Dominant design innovations than small ones. On the opposite, there are arguments in favor of the small. The first argument is that large companies are intensive in capital, which is a relevant factor in producing innovation and spreading it [5]. However, the stability of the large companies and the necessity of joining into the market represent the evidence in the literature regarding the innovation production by the small companies. [6] shed lights on the innovation status in its lifecycle. It is noteworthy that the innovations at the beginning of their life cycle are not classified as Dominant designs due to the uncertainty related to their acceptance. Moreover, the effects consequent from their adoption would not be evaluated, even consolidated. Hence, the Paradigm shifts are inexistent.

About the scope of this paper, civil construction companies are typically characterized by large companies with regional presence. Even the ones that act in building

projects. Besides that, in their market area, they are subject to intensive regulatory conditions, which constrain innovation production [3, 7].

Despite that, the literature pointed out drivers that are favorable to produce innovation in civil construction companies. Among them, there are companies' organizational structure and the role of the consumers in stimulating companies' innovation. Regarding the first aspect, [8] cited the differences between the civil construction industry and the manufacturing of product development procedures. The product development routine in manufacturing follows the firm-theory principles, concerning the development of innovative products, whether in civil construction seems complex systems [5, 6]. Likewise, civil construction companies produce innovation as a consequence of problem-solving routines during the process of product development. Typically, they are incremental innovations. Beyond that, incremental innovations are not associated with Dominant designs, and they do not provide paradigm shifts. Different from the radical innovations.

Regarding the consumers' role in the civil construction industry, mainly in building projects, there are controversial aspects about their participation in innovation development, especially in radical innovations. Despite they are considered a positive driver in innovation development, according to [8], [1, 3] pointed out evidence concerning the level of consumers' knowledge basis to participate in product development in civil construction. The main factor for consumers to choose a product in civil construction is the price. Thus, the authors conclude that consumers can accept innovative products only if it means savings for them[3].

The literature presented some aspects and arguments that shed light on the vision concerning the lack of Dominant design innovations in civil construction. Nevertheless, it does not mean that civil construction, in regards to the building projects segment, does not produce innovation, as we investigated following the method that will presented in the next section.

2.2 Method

The method deployed in this paper is exploratory research, which is described in Fig. 1.

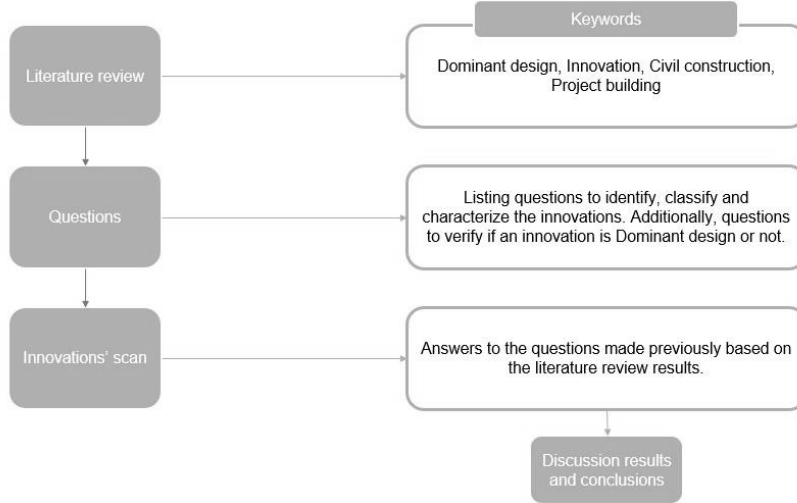


Fig. 1. Method's structure.

First, we structured the research problem as demonstrated in **Table 1**.

Table 1: Research problem structure

Question	Independent Variables	Dependent Variables
Is truly there a lack of innovation in civil construction and innovations classified as Dominant design?	References Topic Technologies	Paradigm shifts

Then, we carried out the literature review by applying the PRISMA method [9]. Besides that, we chose Scopus and Web of Science as research databases. To search for references, we inserted the following keywords in English as input in the mentioned databases:

- Dominant design;
- Innovation;
- Civil construction;
- Projects;
- Buildings.

Likewise, the keywords were sorted in logical order with the AND operator. Moreover, their synonyms were associated as well. In this sense, we prioritize the synonyms in the logical operations by using the operator OR. Due to the exploratory feature of this paper, we did not conduct keyword research in specific parts of the references, such as the title, abstract, and others. Furthermore, we sorted the keywords according to their purpose in the research in both bases. For instance, “Dominant Design” is a keyword

associated with the target of this paper. We intend to figure out Dominant Design innovations in project buildings. Hence, “Dominant Design” corresponds to the criteria applied to the sort of innovation found in the literature. In this sense, “Innovation” and “project building” are keywords associated with the research problem and its domain, respectively. Thus, they represent the questions and research objects. The acronym deployed in the keywords structure is denominated TQO (Target, Question, and Object). Beyond that, we applied the filters to journal papers and the study area. Hence, it was selected only civil engineering and IT. Furthermore, we limited the papers’ language. In this sense, it was constrained to English, Spanish, and Portuguese. We did not opt to limit the papers’ publication year because we intended to research the literature on Dominant design innovations produced throughout history. Next, we pointed out questions elaborated according to the Dominant design concept based on [4, 10] to scan, classify, and characterize the innovations found in the literature research. Thus, the questions are listed below:

- Is there any technological innovation classified as a Dominant design in building projects?
- Which are the Dominant design features in building project innovations throughout history?
- What kind of Dominant design has lasted more time throughout history?
- How have the paradigm shifts affected the process and activities involved in project buildings?
- What are the paradigm shifts related to the current Dominant design in building projects?
- Which are the paradigm shifts promoted by the longer Dominant design innovations throughout history?

After that, we deployed the literature review, which is presented in the following section.

3 Exploratory Research

We started the literature research by sorting the logical operation of the keywords as input, according to the acronym TQO. Table 2 presents the construction steps of the keyword input to insert in the two databases utilized in this research.

Table 2: TQO keyword structure. Input databases.

	T (Target)	Q (Question)	O (Object)
Objective	Dominant design of innovation in building projects		
Extraction	Dominant Design	Innovation Civil construction	Building Project
Combination	Dominant Design	Innovation	Building Project
		Innovative Technology	Building Projects
		Civil Construction	Building
		Construction	Buildings

Composition with operators	Dominant AND Design	(Innovation OR (Innovative AND Technology)) AND ((Civil AND Construction) OR Construction)	(Building AND Project) OR (Building AND Projects) OR (Building) OR (Buildings)
Final composition	(Dominant AND Design) AND ((Innovation OR (Innovative AND Technology)) AND ((Civil AND Construction) OR Construction)) AND ((Building AND Project) OR (Building AND Projects) OR (Building) OR (Buildings))		

As a result of the literature review, we obtained six journal papers in the Scopus database and 56 in the Web of Science. After applying the filter settings described in Section 2, we obtained 59 papers.

4 Results and Discussion

After the literature research, we analyzed the papers found and sorted them according to the research problem to answer the listed questions presented in Section 2.2. Consequently, the innovations mentioned in the papers were characterized.

4.1 Innovations characterization

Table 3 identifies the variables mentioned in the papers that discussed innovations in project building. Some papers were not identified in Table 3, due to their content. They did not treat innovation in building projects as their main topic.

Table 3: Identification and characterization of innovations found in the literature.

Topic (independent variable)	References (independent variable)	Technology related to the innovation (independent variable)	Dominant design? (dependent variable)	Paradigm shifts (dependent variable)
Sustainability	[10–12]	Energy production in buildings, recycling materials, resources and leftovers	Yes	Energy savings, leftovers, construction waste reduction, changes in consumption

		management, low-carbon emissions technologies			habits, and building uses
Interior design	[2]	Room distribution inside the houses and buildings	Yes		Changes in family structure and social habits.
Automation and 4.0 industry	[7, 8, 13–15]	Automation for doing repetitive activities, machines for producing pieces, and resources for construction	No		Productivity increasing, changes on the tasks and work distribution, new occupations
Building projects practices	[16–18]	Project design, rendering, communication, and management software. Data science.	CAD yes, BIM no		Emerging of associated technological innovations, productivity increase, changes in communication, working process, and environment.
Materials	[19]	Alternative and technological construction materials with specific physical properties	No		Changes in buildings' lifecycle, building physical properties changes, such as heating, lighting, and acoustic.
Process innovation	[1, 3, 6, 20–22]	Strategies, methods, and techniques directed to project management.	No		Changes in management, execution and hiring projects, and financial structure. Changes in working distribution.

4.2 Innovations' scan

Based on the results presented in the 3.1 Section, we answered the questions mentioned in Section 2, to evaluate the Dominant design features of the innovations found.

- Is there any technological innovation classified as a Dominant design in building projects?

Innovations in civil constructions occur frequently in process, with the adoption of new concepts concerning processes and technological innovations. Among the technological innovations more notorious in the second group are materials, drawing utensils, and Computer-aided Design software (CAD)[17]. In the first group, there are architectural aspects, such as layout planning and execution in interior and exterior building design [1, 2], process management on-site and sustainability [12, 18, 23].

The sustainability concept is considered a Dominant design innovation in civil construction due to the necessity of natural resources and energy savings. Beyond that, building projects with sustainability certification are commercialized with higher value than regular ones. Despite that, we obtained the literature research with the settings described in Section 3, five journals. Furthermore, the first paper that listed the paradigm shifts regarding sustainability was [11]. In this sense, the author mentioned the deployment constraints in energy management and savings. This paper was fundamental to energy efficiency studies in buildings.

Whereas the existence of consolidated Dominant design innovation is found in the literature research, some references indicate innovations that are not still a Dominant design. Due to the incipient adoption, there were not possible to generate Paradigm shifts. Nevertheless, they have the potential to become it. In this context, there are Building Information Modeling (BIM) and Lean Construction. Likewise, there are significant barriers to widespread deployment and consolidation. At this moment, it has not been possible to assertively affirm which one of these innovations will be a Dominant design due to the uncertainty concerning the environment civil construction has emerged. Beyond that, it is emerging new artificial intelligence technologies and innovation in processes in a short period. Hence, it brings difficulties in monitoring the innovation trending and their ability to promote Paradigm shifts. However, BIM deployment has brought in building projects, modeling, and technical data integration in the building graphic model [23].

Among the Dominant design innovations, such as sustainability and the ones that have the potential to be, there are construction automation and 3D printing. Similar to BIM and Lean construction, construction automation and 3D printing are not Dominant designs, but they present the potential to become them. Besides that, their potential Paradigm shifts are similar to the sustainability and building project practices, as demonstrated in **Table 3** [7, 13]. Hence, they could be associated with these innovations to boost the paradigm shift effects. However, construction automation and 3D printing did not turn into Dominant designs due to regional and regulatory issues in countries, which limit its widespread use. A particular feature of the civil construction sector is the difficulties in standardizing management practices,

processes, activities, and results inherited from the project building design[1]. These aspects are constraints to the arising of Dominant design innovations in robotics and automation for project buildings.

- Which are the Dominant design features in building project innovations throughout history?

The dominant design innovations in building projects consist of avoiding affecting project details. Moreover, they present holistic characteristics and aim to save costs and efficiency enhancement. Due to these features, CAD software and manufacturing on-site building construction are considered Dominant design innovations in building projects and civil construction. Regarding CAD software, this innovation allowed project designers to design projects with accuracy and precision rather than drawing utensils.

- What kind of Dominant design has lasted more time throughout history?

According to the references resulting from the literature research, we noticed that sustainability and layout alterations in interior design last most. Nevertheless, there is evidence of Dominant design in construction methods such as modular construction and materials designed that was not detected in the literature research set as demonstrated in Sections 2 and 3. Furthermore,[1] mentioned that materials design innovations should not be considered Dominant design, due to the regional and climate aspects, which influence in the value perception of these innovations. In this context, the authors affirmed materials fit well in buildings in some areas and others not.

- How have the paradigm shifts affected the process and activities involved in project buildings?

CAD software directly affects productivity in building design. Likewise, it has clarified the communication through the building modeling. Additionally, it has brought accuracy and precision, as mentioned before. Nevertheless, a prominent paradigm shift propitiated by CAD software was the emergence of BIM. Hence, it introduces data integration to the 2D project drawing and the 3D modeling. Interior design layout and sustainability have influenced environmental and social aspects concerning furniture design and building users' behavior.

- What are the paradigm shifts related to the current Dominant design in building projects?

The paradigm shifts promoted by sustainability consist of waste reduction, behavioral changes in the habits of the building users, costs, and energy savings[1]. mentioned that materials design innovations should not be considered Dominant design, due to the regional and climate aspects, which influence in the value perception of these innovations. In this context, the authors affirmed materials fit well in buildings in some areas and others not.

- What are the paradigm shifts related to the current Dominant design in building projects?

The paradigm shifts promoted by sustainability consist of waste reduction, behavioral changes in the habits of the building users, costs, and energy savings[2]. Besides that, they referred to the behavioral changes, not only in habits but in social

and family structure. Family structure and social changes take time to appear in the results rather than other paradigm shifts, such as waste reduction.

As a result of the literature research, we observed that it returns a few innovations that fit into the Dominant design concept. However, the results returned a meaningful number of innovations with the potential to become them.

5 Conclusion

This paper scanned innovations in building projects that fit into the Dominant design concept. As a result, we figured out a few Dominant design innovations that produce significant Paradigm shifts. We noticed there is a lack of Dominant design innovations, which significantly shifted paradigms in social, economic, and behavioral aspects. Currently, the most expressive is sustainability in building projects and CAD software. Moreover, the layout design has been the Dominant design that promotes the most significant Paradigm shifts, directly affecting society and cultural aspects, such as family structure.

However, there are more innovations currently with the potential to become Dominant designs. Besides that, they have not expressively affected the building project sector due to their incipient adoption. Hence, it has not taken time enough to notice their effects. Then, their Paradigm shifts. Among them are technological innovations related to materials design innovations, 4.0 industry and automation, BIM, and Lean construction.

A contribution of this paper is the importance of diagnosing the innovation according to the concept of Dominant design application for monitoring innovation trends. With trend monitoring it is possible to evaluate the effects produced by innovations and their Paradigm shifts. Additionally, it permits to identification of innovation trends at the beginning of their lifecycle. Based on the innovation diagnosis it is possible to acquire information to develop incremental innovation. Beyond that, it is possible to comprehend the consumers' preferences from the literature reports about the acceptance of the innovations. This paper directed the innovation diagnosis to the building projects segment in civil construction. Nevertheless, it might be deployed in other economic sectors, which is suggested in future research.

Among the limitations of this paper were the constraints directed to the literature research. Despite the area of study filters, we unfortunately figured out results without the research context. Moreover, we noticed that old innovations in building projects were not listed on a scientific basis. Except for the Dominant design innovations related to interior design, which lasted long throughout the history of the building projects.

As a conclusion of this paper, we can affirm that the vision concerning civil construction lacking innovation is inadequate. In this paper, we demonstrated that there are Dominant design innovations that have lasted long periods throughout history. Moreover, there are a significant number of innovations emerging in the last years with the potential to become Dominant design. Therefore, the potential of promoting paradigm shifts is meaningful, as demonstrated in this paper, especially regarding productivity aspects.

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