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Factors Affecting Labor Productivity in the Global Construction Industry: A Critical Review, Classification and Ranking

Factores que afectan la Productividad Laboral en la Industria Global de la Construcción: Una Revisión Crítica, Clasificación y Ranking

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Scientific and Technological Research Paper

Abstract **— The construction industry plays a fundamental role in economic development and job creation, but it faces challenges of labor productivity that have been exacerbated due to the recent COVID-19 pandemic. Labor productivity is a critical component of success, as it influences the duration, costs, and efficiency of projects. Understanding the nature of factors affecting labor productivity is essential to finding solutions. This study examined the literature to identify key factors influencing labor productivity, departing from conventional analytical approaches. Through mixed-methods analysis, qualitative approaches of systematic reviews identified influential factors based on 97 documents. Subsequently, they were classified using a combination of statistical analysis and hierarchical clustering methods that encompassed both internal and external factors. The Importance Value Index allowed for the classification of the 30 most critical factors, analyzing three possible ranking scenarios. The study found that the interest in researching the topic remains relevant and has evolved over time. In recent years, greater attention has been paid to labor, management, work environment, and technical aspects. The results indicate that internal project factors, such as scheduling, planning, technical considerations, and resource management, are more predictable and controllable than external factors. Effective resource management and a comprehensive approach are essential for optimizing construction productivity. Project-level factors, as well as materials, tools, and equipment, play an important role. By synthesizing existing knowledge and identifying and classifying key productivity factors, this study offers valuable insights to construction professionals, policymakers, and researchers seeking to improve labor productivity and optimize project outcomes.**

Index Terms **— Construction productivity; Hierarchical clustering; Importance Value Index; Sectoral advancement; Systematic review.**

Resumen **—** ***La*** **industria de la construcción desempeña un papel fundamental en el desarrollo económico y la generación de empleo, pero enfrenta desafíos de productividad laboral que se han intensificado debido a la reciente pandemia de COVID-19. La productividad laboral es un componente crítico de éxito, ya que influye en la duración, los costos y la eficiencia de los proyectos. Comprender la naturaleza de los factores que afectan la productividad laboral es esencial para encontrar soluciones. Este estudio examinó la literatura para identificar factores clave que influyen en la productividad laboral, apartándose de los enfoques analíticos convencionales. A través de un análisis de métodos mixtos, los enfoques cualitativos de revisiones sistemáticas identificaron factores influyentes basados en 97 documentos. Posteriormente, se clasificaron mediante una combinación de análisis estadístico y métodos de agrupación jerárquica que abarcaron tanto factores internos como externos. El Índice de Valor de Importancia permitió la clasificación de los 30 factores más críticos, analizando tres posibles escenarios de clasificación. El estudio encontró que el interés en investigar el tema sigue siendo relevante y ha evolucionado con el tiempo. En los últimos años, se ha prestado mayor atención a la mano de obra, la gestión, el entorno de trabajo y los aspectos técnicos. Los resultados indican que los factores internos del proyecto, como la programación, la planificación, las consideraciones técnicas y la gestión de recursos, son más predecibles y controlables que los factores externos. Una gestión eficaz de los recursos y un enfoque integral son fundamentales para optimizar la productividad de la construcción. Los factores a nivel de proyecto, así como los materiales, herramientas y equipos, desempeñan un papel importante. Al sintetizar el conocimiento existente e identificar y clasificar los factores clave de productividad, este estudio ofrece perspectivas valiosas para profesionales de la construcción, responsables políticos e investigadores que buscan mejorar la productividad laboral y optimizar los resultados de los proyectos.**

Palabras clave **— Agrupamiento jerárquico; Avance sectorial; Índice de valor de importancia; Productividad en la construcción; Revisión sistemática.**

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I. INTRODUCTION

The construction industry has a crucial role in providing vital infrastructure, transportation routes, and essential housing for human development and social well-being. Additionally, it significantly contributes to the Gross Domestic Product (GDP) [1] and generates large-scale employment, offering job opportunities at various levels and sectors [2], Therefore, its performance is not only crucial for economic development but also for social stability and sustainable progress on both a global and regional scales.

However, the trend of recent decades indicates a slower growth in productivity in the construction industry (1.0%) compared to the global economy (2.7%) and other industrial sectors (3.6%) [3], Additionally, the post-COVID-19 era has brought new challenges, including labor shortages, debt, inflation, and energy transition, among others. The latest report from the McKinsey Global Institute (MGI) suggests that increasing historical productivity rates in the industry could mitigate these challenges [4].

Therefore, the study of labor productivity behavior is relevant for both the industry and academia; hence, we will conduct a background section featuring the most prominent works, tracing their development throughout the decades as a fundamental reference.

Background

Since the mid-1980s, there have been research inquiries regarding labor productivity in the construction industry, focusing on its estimation. For instance, Neil & Knack proposed a method emphasizing labor productivity units in man-hours and established a productivity index, with a reference value of 1.0 denoting standard performance [5]. On a different note, Brown explored the relationship between demotivating factors and low labor productivity in construction [6].

In the early 1990s, Thomas proposed a novel approach to modeling labor productivity in construction. Taking into account real factors observed on construction sites, he classified project, site, management, and motivational expectation factors. This classification elucidates why a team endeavors to perform and how this effort correlates with productivity [7]. Additionally, in collaboration with Sanders, they established a methodology for identifying and quantifying factors affecting masonry activity, employing standardized statistical techniques for data collection [8]

In the mid-2000s, Abdul Kadir et al. highlighted the concern of emerging countries in the Southeast Asian region regarding the identification of factors affecting construction labor productivity. To address this issue, they utilized surveys as a data collection instrument and incorporated the perception of importance using the Relative Importance Index (RII) method [9]. A similar approach was proposed by Enshassi in the Western Asian region [10].

During the 2010s decade, the study conducted by Shehata & El-Gohary stands out, with its main finding being the absence of a standard definition of productivity. This study provides a guide for the necessary steps to improve labor productivity in construction, as well as the use of benchmarks [11]. By mid-decade, Jarkas employs the RII method in a representative sample of contractors to identify and classify factors belonging to these classification groups: management; technological; labor-related; and external [12].

In the 2020s, two relevant research studies stand out. On one hand, Agrawal et al. adopt a novel approach by directly capturing the perception of construction workers, as opposed to managers or supervisors. They utilize the Relative Importance Index (RII) method to assess the significance of various factors [13]. On the other hand, Van Tam et al., through a comprehensive review of previous studies, identify critical factors influencing labor productivity in construction. These factors are categorized into six main groups, covering manpower, management, work conditions, project, and external factors [14]. Both studies employed structured surveys targeting project managers and contractors, utilizing methods such as RII and descriptive statistics for data analysis.

Theoretical framework

Construction Labor Productivity (CLP)

A commonly used generic definition is the relationship between outputs and inputs, but for the purposes of this research, which is situated partly within the project context or even at the granular level of site activity, and on the other hand, focused on labor resources, the partial factor productivity proposed by Thomas & Daily [15], Horner et al. [16], and Jarkas [17] will be employed, as shown in the equation (1):

$$CLP = \frac{\text{Output}}{Labor\ time} \quad (1)$$

CLP	: Construction Labor Productivity.
Output	: Installed units.
Labor time	: Time units per member/crew.

Research issue

The research problem arises from answering the question: What factors contribute to the low growth of labor productivity in the global construction industry? This question serves as the focal point of the study and will direct the research towards identifying critical elements contributing to this gap in Construction Labor Productivity.

Research objectives

The main objective of this study is to conduct a rigorous literature review to identify the critical factors affecting labor productivity in construction, considering their importance and frequency. Additionally, the aim is to group these factors by classifying them according to common attributes. Achieving these objectives will allow us to gain a deeper understanding of the challenges facing the construction industry and provide valuable insights for the development of effective strategies to promote growth and sustainability in the sector.

Methodological approach

The methodological approach adopted in this mixed-method study integrates quantitative analysis with qualitative evaluation of factor groups [18], aiming to provide a comprehensive and accurate understanding of the drivers and obstacles to productivity in the construction industry, with the future goal of developing strategic solutions tailored to each context.

Contribution

In contrast to surveys with Likert scales commonly employed in prior studies within specific contexts, this investigation relies on a systematic literature review and utilizes the "Importance Value Index" (IVI) to analyze the relative contribution of factors in a global context. Furthermore, it stands out for its comprehensive collection of variables, encompassing data collection instruments, analytical methods, research findings, and the inclusion of diverse industry sectors. This holistic perspective enhances our understanding of patterns and trends related to the variable under examination. Ultimately, the research introduces an innovative classification of factors, incorporating insights from the systematic review and contributions from academics and industry professionals, thereby adding distinctive value to the existing body of knowledge in the field.

Document structure and development

Regarding the document structure, the methodology to be implemented is initially described, followed by the research results and key findings. These findings comprise a characterization of the documents and the classification of factor groups. Finally, a discussion and conclusions section is presented, summarizing key points and highlighting the practical and theoretical implications of the research.

II. Methodology and Methods

A. *Study design*

The study is descriptive-analytical, of a cross-sectional nature, with a mixed-method approach [18]. It involves the collection of documents from previous research in scientific literature databases related to factors influencing Labor Productivity in Construction. These documents are subsequently processed and statistically analyzed to identify patterns and trends, allowing for the establishment of similarities, differences, common characteristics, and singularities regarding the behavior of factors influencing labor productivity in the construction industry, from a global perspective Fig 1.

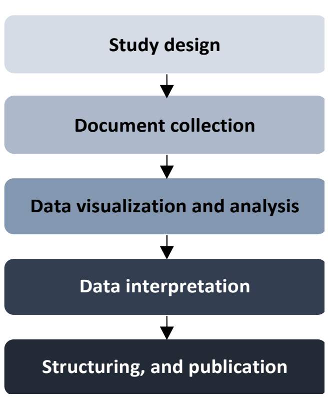

Fig 1. Research methodology flowchart.

B. *Document collection*

This phase involves a systematic review of available literature in scientific databases, using the Boolean equation: (TITLE-ABS-KEY-AUTH (factors) AND TITLE-ABS-KEY ("labor productivity") AND TITLE-ABS-KEY ("construction project")), conducted on 28/09/2022. Fig. 2 represents the initial sample of 191 documents, outlining the three proposed literature review phases, the processes, the three exclusion criteria, and the acquisition of the final sample of 97 documents.

From the final sample, 52 documents provide ranked lists of factors, while the remaining 47, although presenting groups of factors and a series of attributes to consider, do not assign them an importance rating. A total of 267 factors were identified, with a total count of 1547 occurrences within the documents.

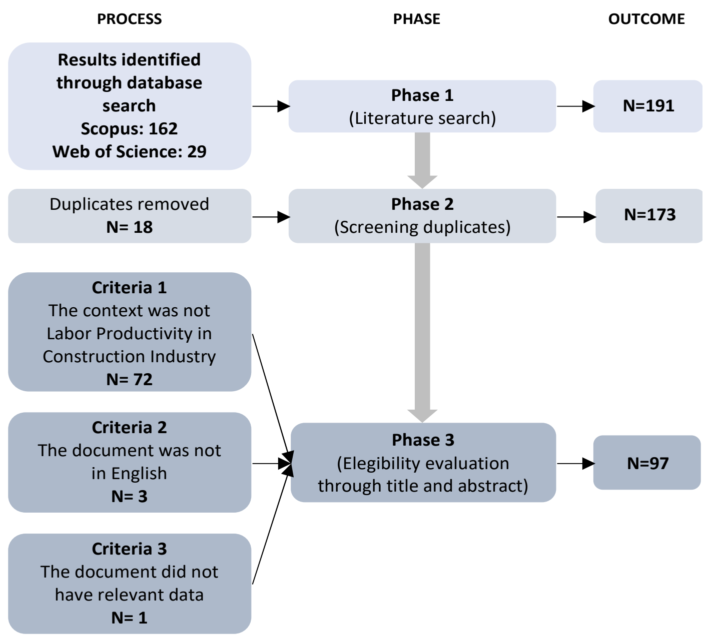

Fig 2. Scientific Literature Review Flowchart.

C. *Data visualization and analysis*

Within the dataset obtained, each identified factor constitutes a subset of data. Three possible scenarios are presented:

- *All Ranked Data Scenario:*

In this scenario, all data within the subset are ranked. Consequently, it is possible to calculate the relative importance value index for each factor.

- Mixed Ranked and Unranked Data Scenario:

The second scenario involves a mixture of ranked and unranked data. Some factors may have rankings, while others do not.

- No Ranking, Only Frequency of Occurrence Scenario:

The third scenario is where none of the data within the subset have rankings. In this case, only the frequency of occurrence is evident for each factor.

1) *Data Preprocessing*

Since there is a desire to understand the behavior of an entire dataset and achieve representativeness in the global ranking of factors, the decision is made to preprocess the data. This process involves the adoption of two data treatment techniques. The first technique, named "Outlier Removal Using Standard Deviation," is employed to detect and address values that deviate significantly from the mean of all data subsets. This enhances the overall data quality, ensuring more accurate and reliable results [19].

In the development of this first technique, a range of two standard deviations to the left (Lower limit) and to the right of the mean (Upper limit) will be considered. Within a normal distribution, this range encompasses 95.5% of the data, as illustrated in Fig 3 and expressed in equations (2) and (3).

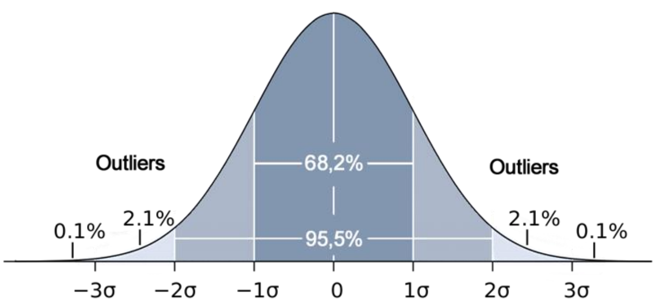

Fig 3. Normal Distribution with Two Standard Deviation Range.

Upper limit	: $\bar{X} + 2S$	(2)
Lower limit	: $\bar{X} - 2S$	(3)
In this formula		
$\bar{X}$	: Mean	
S	: Standard Deviation	

The second applied technique is "Imputation of Missing Values," implemented in the subsets of the second scenario to assign the median value of the subset's data to those missing attributes. This value is obtained after applying the first technique, and by employing this neutral value, the frequency of occurrence is considered within the analysis.

Finally, a validation of the data subset trend towards a central value is performed by calculating the "coefficient of variation" before and after the "Data Preprocessing." This validates an improvement in this metric of relative dispersion.

2) *Data analysis*

On one hand, for the characterization of the documents in the collected sample, descriptive statistics and frequency analysis will be employed. On the other hand, to rank the factors influencing labor productivity in the construction industry, the "Importance Value Index" (IVI) method will be utilized.

The "Importance Value Index" (IVI) is a method used to assess the relative importance of entities within a dataset, considering the relative contribution of key attributes, such as frequency, importance, and density, among others. In statistical analysis, frequency represents the occurrence or presence of a specific entity in a dataset, while importance may denote the relevance or impact of the entity in the analysis.

By considering these attributes in the calculation of the IVI, the relative importance of entities and their contribution to the structure and relationships in the dataset under study can be analyzed.

While its formulation is rooted in a general statistical context, its use has been extended to the study of species populations, as seen in the works of Cottam and Curtis in 1956, Cox in 1967, and Mueller-Dombois and Ellenberg in 1974.

For our study, with 267 factors or data subgroups, the subtotal of the sum-products of frequencies by their respective importance in each factor, divided by the total sum-products of all factors, yields the "Importance Value Index" (IVI) for each factor. Equation (4) illustrates the relationship for obtaining the "Importance Value Index".

$$IVI = \frac{\sum_{i=1}^{n} \mathrm{f}_i * w_i}{\sum_{i=1}^{n} \mathrm{F}_i * W_i} \qquad (4)$$

In this formula:

IVI	:	Importance Value Index
N	:	Number of subsets in study
f	:	Frequency of factors for subsets
w	:	Importance value of factors

3) *Factors Classification*

The classification of collected factors is carried out through a combination of approaches. On one hand, a statistical analysis of frequencies obtained from the sample documents is employed to discern significant patterns and trends. On the other hand, "Hierarchical Clustering" methods with "Ward" linkage are implemented using the workflow depicted in Fig 4 to generate a dendrogram constructed from a distance matrix.

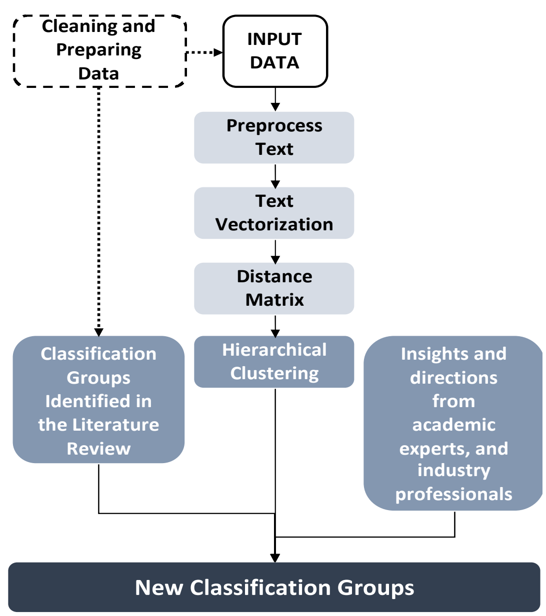

Fig 4. Workflow of the New Classification of Factor Groups.

Finally, the refinement of the classification is conducted through the consideration of valuable insights and directions from educators, academic experts, and industry professionals with extensive experience. This input provides a critical and informed perspective.

This multidimensional methodological strategy translates into a holistic understanding of the key elements involved, thereby laying the groundwork for more robust interpretations and conclusions in the study's context.

III. Results

In order to understand trends and patterns, descriptive statistics provide information of the frequency of scientific publications from 1985 to 2022 Fig 5.

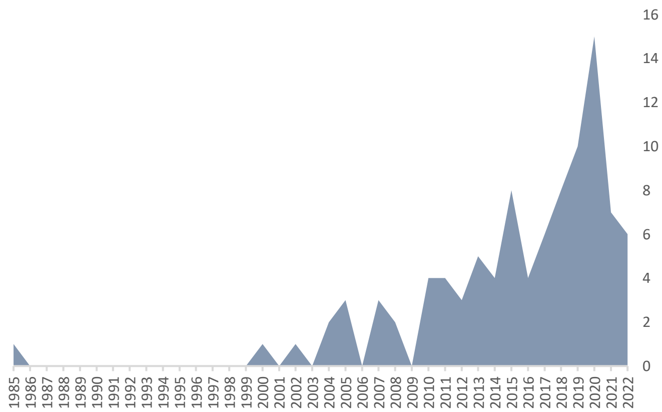

Fig 5. Frequency of scientific publications related to Factors affecting Labor Productivity in Construction Industry from 1985 to 2022.

In the first interval (1980s and late 1990s), there is observed a commencement of research with minimal activity indicating low interest, possibly influenced by global economic challenges and challenges within the construction industry. From the late 1990s through the 2000s, a gradual increase in research is noted, driven by economic recovery and increased investment in construction projects. Between the late 2000s and early 2010s, research interest continues to rise due to technological advancements in construction, environmental concerns, and sustainable construction regulations. The shortage of skilled workers also contributed. Finally, from 2013 to 2022, a substantial increase in research is recorded, attributable to the economic recovery post-2008 crisis, technological advancements such as Building Information Modeling (BIM), environmental concerns, and the COVID-19 pandemic. This keeps the topic of labor productivity in construction as relevant.

Researchers have used a range of methods to explore the factors that influence labor productivity in the construction industry, from traditional expert opinion and literature reviews to objective, quantitative analysis. These conventional approaches, while rich in empirical insights, often carry the risk of subjective bias, creating a need for more data-driven methods. Acknowledging the geographical diversity of existing studies and prone to bias ([20]; [21]; [22]; [23]), this study provides a global perspective by employing a mixed-methods approach that integrates machine learning and artificial intelligence for factor clustering and importance quantification. This is further enhanced by utilizing both Likert scale surveys and advanced quantitative techniques [24], [23] for factor ranking. By synthesizing these different methods, our approach not only leverages the strengths of each, but also minimizes their limitations, ensuring more reliable and valid results through methodological triangulation.

A. Sample Geographical Location

A broad geographic distribution has been observed among the analyzed documents, with India (11.3%), the United States (8.2%), and Canada (7.2%) standing out as the countries with the highest participation, emphasizing the diversity of national contexts under investigation, as depicted in Fig 6. The prominent position of these countries in the realm of research on labor productivity in construction may be attributed, in part, to their high level of industrialization and economic development. Additionally, the presence of educational and research institutions, coupled with the availability of financial and technological resources, drives the production and dissemination of studies in this field.

Fig 6. Country-wise distribution of scientific publications related to Factors Influencing Construction labor productivity from 1985 to 2022.

In contrast to the traditional continental division, we have opted for the geographic classification proposed by the United Nations (UN) to segment regions based on their location. This classification system consists of 7 regions grouped not only by geographical proximity but also by convergence in sustainable development goals [25], as illustrated in Fig 7.

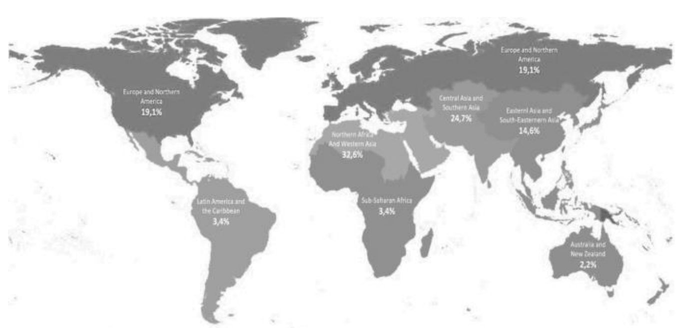

Fig 7. Distribution of Publications by Regions of Development Goals. Adapted from United Nations Statistics Division (2019), Regional Groups Report, https://unstats.un.org/sdgs/report/2019/regional-groups/".

Taking this into account, the notable representation of Western and Central Asia (32.6%) in the research corpus highlights the importance and dynamism of these areas in the context of the construction industry. Factors such as sustained economic growth, the expansion of infrastructure, and large-scale development projects, as well as the need to address specific challenges related to construction, have generated significant interest in labor productivity in these regions. The concentration of studies reflects the necessity to develop solutions and strategies tailored to the particular socio-economic and cultural contexts of Western and Central Asia.

Additionally, it is noteworthy that the region with the highest presence in research coincides with countries possessing significant reserves of oil and gas, along with a marked infrastructure development plan. This factor may have influenced interest and investment in optimizing productivity in the construction industry, given the close relationship between the construction sector and the expansion of energy infrastructure.

On the other hand, a significant presence of global review studies (8.2%) is observed, indicating an interest in assessing trends and patterns on a worldwide scale. However, the relatively lower representation of other regions, such as Latin America and the Caribbean (3.4%) and Sub-Saharan Africa (3.4%), suggests a need for more research and analysis in these contexts. The possible reason behind this disparity could be related to differences in the availability of financial and technological resources, as well as the lower prioritization of research in the construction domain in these regions.

This geographic diversity underscores the importance of addressing labor productivity in the construction industry from a global and contextualized perspective, taking into account the specific particularities and challenges faced by each region.

B. *Types of Collected Documents*

Scientific articles predominate, representing 72.16% of the total sample, emphasizing their central role in communicating findings on labor productivity in construction. Conference papers have a significant presence at 21.65%, highlighting their relevance as platforms for disseminating ongoing research or preliminary results in this field. Review articles constitute 5.15%, indicating the potential for synthesis and critical analysis of existing literature. Book chapters are less common, accounting for 1.03%. These figures provide a clear insight into the composition of available literature, underscoring the importance of scientific articles and conference papers as primary sources in research on labor productivity in the construction industry, as evidenced in Fig 8.

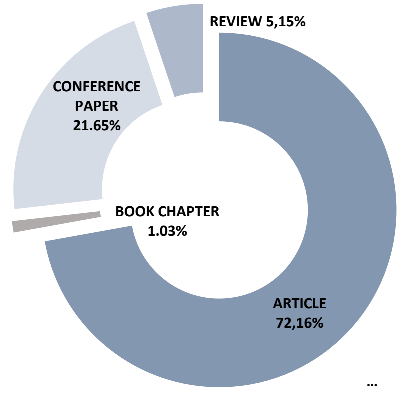

Fig 8. Types of Documents Found in the Literature Review.

C. *Data collection (Inputs)*

Various methods and instruments used for data collection have been identified, as depicted in

Fig 9. Particularly noteworthy is the literature review as the predominant source of information collection, contributing significantly with 38.05%, including review articles [26] [27] [28]. This comprehensive literature review has provided a contextual foundation for the theoretical framework of the study. Surveys have also played a relevant role, representing 28.29% of the collected data, including notable instances [29] [30] [31] [32] [33]. These findings underscore the importance of gathering perceptions and opinions of respondents in the development of research in this area. Additionally, direct on-site observations, accounting for 11.22%, stand out, exemplified by [34] [35] [36], along with interviews (9.27%) featuring [37] [38] [39] [40] [41] [42] [43] [44], providing perspectives through direct interaction with professionals and key stakeholders in the field of study. Historical records [45] [46] [47] [48] and previous research [49] [50] [51] [52] have contributed 2.44% and 5.37%, respectively, enriching the database with a temporal and comparative perspective. These results emphasize the relevance and diversity of sources and approaches employed in constructing a robust and contextually relevant information base that underpins the examined research.

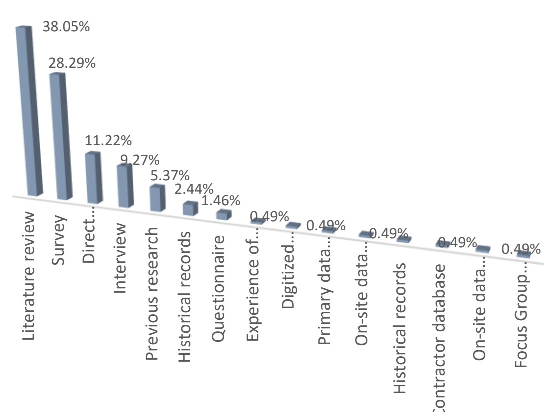

Fig 9. Methods and Instruments Used for Data Collection.

D. Tools & Techniques (Analysis)

The analysis of tools, techniques, and methods reveals trends in the study of labor productivity in construction, as observed in Fig 10. In the 2000s, statistical techniques such as correlation analysis [41] and logistic regression [53] [54] were employed, representing 11.18% and 6.21% of studies [55] [56]. Since 2010, advanced models such as Agent-Based Modeling (ABM) (1.86%) [57] [58] [46], System Dynamics (SD) (4.35%) [59] [44] [60] [61] [58] [40] [62] [49] and Neural Networks (ANN) (3.11%) [63] [64] [43] [65] [50] have emerged. The Relative Importance Index (RII) constituted 20.50% in recent years, with notable instances. [66] [67] [68] [69] [29] [70] [71] [72] [30]; similarly, methods such as Fuzzy Logic [73] [74] [75] and Genetic Algorithms [38] [75], sporadically used in the 2000s [76], resurfaced, reflecting interest in these advanced tools. The research shows a preference for sophisticated modeling approaches and comparative analysis.

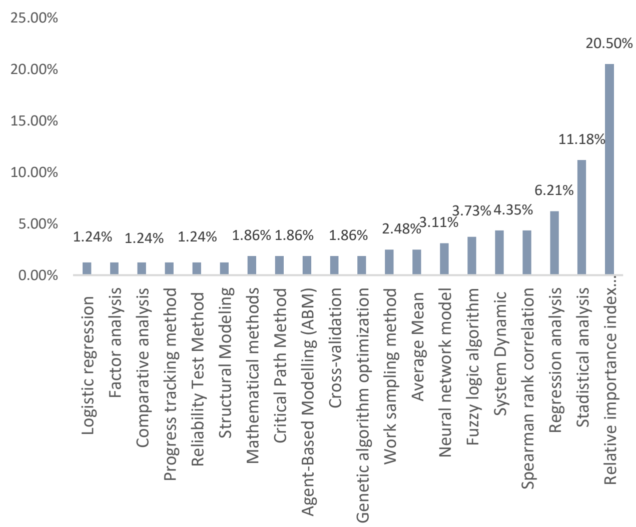

Fig 10. Tools, Techniques and Methods for Data Analysis of Factors affecting Labor Productivity in Construction.

E. Research Outcomes (Outputs)

Regarding the research results, a notable evolution in addressing labor productivity aspects in the construction industry is observed over different periods, as depicted in Fig 11.

In the 1980s, the focus was on establishing quantitative relationships between labor productivity and on-site labor costs [77]. Starting from the year 2000, with the adoption of more sophisticated techniques and tools, a shift towards formulating models to record, measure, and predict labor productivity is evident [41] [78] [79] [80] [81] [64] [75] [44] [82] [57] [83] [47] [73] [50] [62] [84], indicating a growing interest in creating quantitative frameworks to understand and optimize labor efficiency in this sector.

The identification, classification, and evaluation of factors influencing labor productivity also gain prominence, highlighting a more analytical and detailed approach in research guided by the insights of professionals and industry stakeholders, including [85] [86] [87] [33] [59] [88] [89] [90] [91] [92] [42] [65] [93] [94] [95] [74] [31] [28] [96] [97] [98] [70] [71] [68] [69] [45] [66] [99] .

Furthermore, a marked interest is evident in evaluating the impact of project changes and quantifying productivity loss at 4.95% [32] [60] [93], suggesting increased sophistication in the methodologies employed. These findings reflect a trend towards a nuanced and quantitative understanding of labor productivity in the construction industry in recent years.

Analyzing the distribution of approaches, it stands out that the identification of factors, their ranking, and classification represent approximately 70% of the utilized methodologies (26.58%, 23.87%, 18.47%), followed by modeling, encompassing around 14.41%. This analysis underscores the growing importance of quantitative and detailed approaches to understand and enhance labor productivity in the construction industry, emphasizing the need for integrated approaches considering both qualitative and quantitative factors in the pursuit of effective solutions.

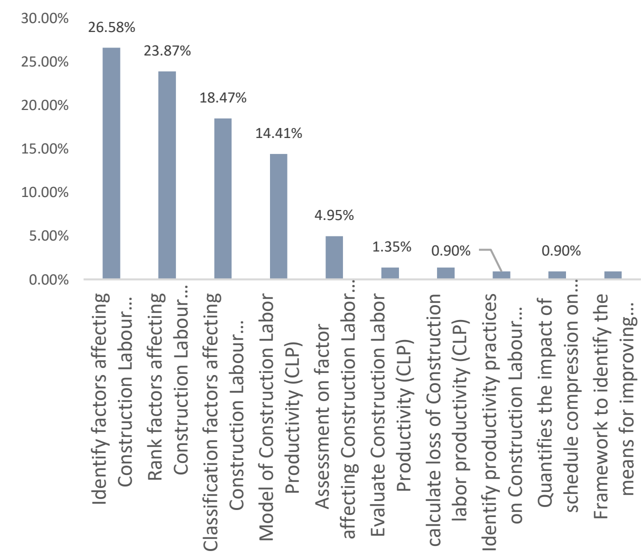

Fig 11. Outcomes of research on factors influencing labor productivity in construction as identified in the analyzed documents.

F. Sectors of the Construction Industry

Diversity is evident in terms of industry sectors represented in the analyzed documents. Primarily, "Building Construction" in general [100] [63] [101] [88] [89] [82] [92] [57] [60] [40] [102] [37] [30] [69] [67] [103], emerges as the most prominently addressed sector, representing 22,58% of the total. Following in significance are infrastructure projects, highlighted by [87] [104] [105] [97] [68], encompassing the construction of bridges, treatment plants, tunnels, hydroelectric projects, and roadways, contributing 16.13% of the total.

The "Residential" sector claims importance with 12.90% [63] [11] [64] [42] [106] [65] [107] [39] [108] [109] [66] [84], followed by a notable interest in industrial [76] and commercial [110] [11] [74], contributing together with 16.13%. It is relevant to highlight the significant presence of reinforced concrete construction with 5.38% on one hand [101] [63] , and projects related to electrical, mechanical, and metal sheeting [53] [54], contributing together with 10.75%.

The construction of high-rise buildings [42] [107] [50] [46] also holds significant representation, contributing 5.38%. Educational projects [63] [64] [50] and those related to social facilities [109], both with a 3.23% share. "Housing" projects [44] [32] and construction in the oil and gas industry [77] [43] each contribute 2.15%. Additionally, it was observed that construction consultancy [31] and high-complexity projects [83], each with a 1.08%, complete the observed sectoral distribution.

The evolution in project selection over time shows a significant trend. Between 1985 and 2010, the focus was on large-scale infrastructure such as bridges, treatment plants, and hydroelectric projects. However, from 2010, there was a shift towards the construction of residential buildings, possibly in response to demographic needs and urban development.

From 2018, a return to increased investment in infrastructure projects was observed, especially in bridges, treatment plants, and hydroelectric projects, accompanied by an increase in the construction of reinforced concrete projects. This variability in project allocation over the decades reflects the adaptability of the construction industry to respond to changing environmental demands. Fig 12.

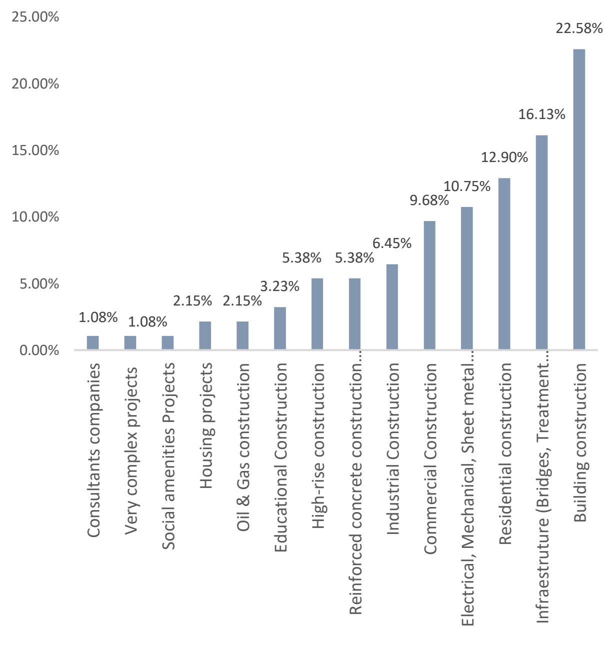

Fig 12. Sectors of construction industry represented in the consulted documents.

G. Construction Activities and Processes

The analyzed documents adopt a micro-level approach, focusing on basic construction activities [111], especially regarding labor productivity in the construction industry, as observed in Fig 13. Among the various construction processes examined, masonry [79] [11] [52] [108] [47] [38] [46] [66], encompassing the use of both clay bricks and sand-cement blocks, stands out as the most significant activity, representing 20.75% of the total. Next, works related to concrete [44] [43] [57] [32] [61] [112] [35] [38], and formwork installation emerge as crucial elements [80] [63] [101] [65] [50], contributing 16.98% and 13.21%, respectively. Similarly, structural reinforcement, including fixing reinforcements and steel [113] [86][57] [65] [38], along with excavation tasks, exhibit considerable relevance [79] [32] [60] [38] [45], contributing 9.43% each. In addition, crucial aspects such as pipe installation [76], addressing both welding and assembly, and the dismantling of main beams, each contribute 7.55%.

These results underline the breadth of areas of interest in research on labor productivity in the construction industry. To understand the underlying reasons for these findings, various possibilities can be considered. The emphasis on masonry may be related to its fundamental role in the initial phase of most construction projects and its high demand for labor. On the other hand, the prominence of works related to concrete, formwork, reinforcement, and structure can be attributed to the inclination of the documents toward vertical and residential construction in the obtained sample. These results also suggest a concern for the efficiency and functionality of building systems.

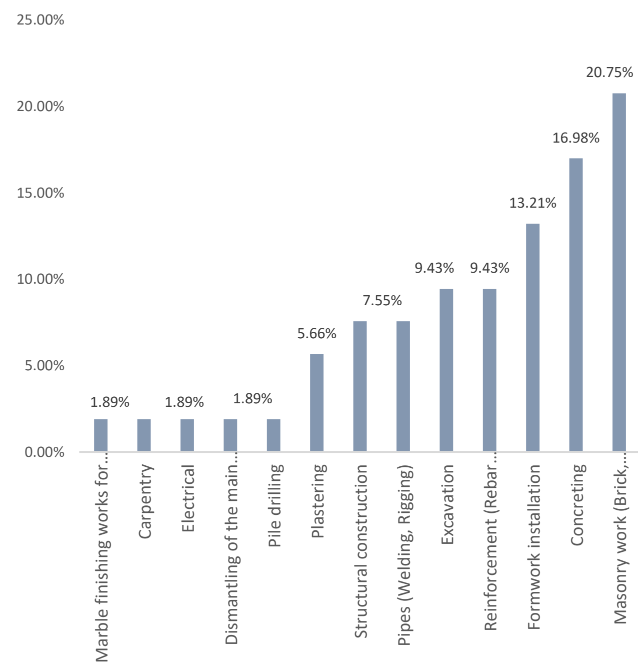

Fig 13. Construction activities and processes found in the consulted documents.

H. Identified Factor groups

In the analysis of consulted documents, various key categories were identified. "Management Factors" [11] [33] [88] [104] [89] [91] [12] [92] [32] [106] [114] [31] [108] [40] [115] [71] [72] [30] [66] and "Labor" [11] [33] [88] [89] [12] [32] [114] [74] [31] [40] [116] [30] [117] [106] [71] [72] stand out with 11.5%, emphasizing their importance in construction projects. They are followed by "External Factors" with 7.3% [90] [12] [32] [117] [74] [83] [31] [40] [71] [69], focusing on proactive management to mitigate impacts. Also relevant are "Project-Level Factors" [76] [63] [75] [91] [65] [117] [50] [71] [30] [69] and "Materials, Tools, and Equipment" [88] [104] [117] [74] [40] [115] [66] with 6.1% and 4.8%, respectively. These results highlight the need for a comprehensive approach and effective resource management to optimize productivity in construction in concordance with the clusters found by others authors [22]; [118].

When observing the evolution over time, key patterns emerge. In the Initial Period (2005-2008), the focus was on "Input Factors" and "Output Factors" [76] [28], indicating early attention to resource and result management. A "Stability Period" (2009-2016) maintained "Contextual Factors" [119] [61], "External Factors," and "Management Factors," showing sustained attention to contexts and management. From 2017, there was an increase in attention to "Labor" and "Management," focusing on their development. There also emerged a focus on "Work Environment and Technical Factors" (2019-2022), evidenced by the relevance of "Technical Factors" [33] [12] [32] [74] [31] [40] [115] [72] and "Working Environment/Condition Factors" [91] [66] [71] [69] , indicating a growing interest in labor and technical conditions.

Categories such as "Labor," "Management Factors," and "External Factors" maintained a constant presence, suggesting their ongoing influence on labor productivity. These findings provide a comprehensive view of the evolution of factors in the construction industry, useful for understanding trends and formulating strategies. However, these categories differ from other study that have used relative important index [120].

Fig 14.

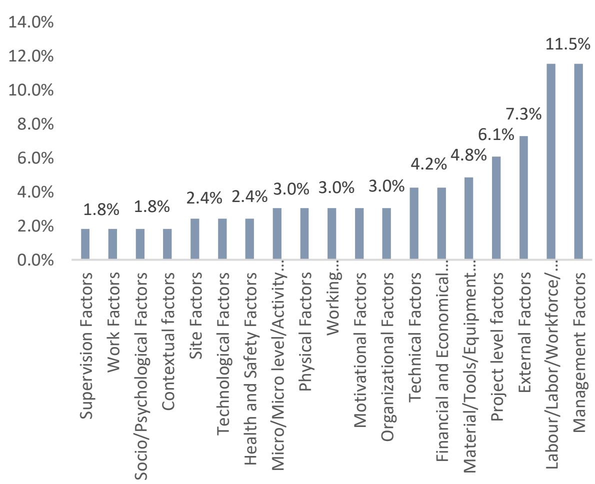

Fig 14. Classification of identified factors influencing labor productivity in construction, as found in the documents.

I. Innovative Classification of Factor Groups Influencing Labor Productivity in the Construction Industry

After identifying the diverse factor groups present in the sample, a novel classification is proposed based on the methodology outlined in Fig 4, This classification addresses the impact of these factors on the productivity of the construction industry. It is structured according to the nature and order of the factors, taking into consideration specific characteristics and attributes, which are then consolidated into related categories.

The primary classification level highlights two main categories: internal factors and external factors, as depicted in Fig 15. Internal factors (86.8%) encompass elements intrinsic to the planning and execution within the project's scope. This includes activities ranging from scheduling and planning to technical and design considerations, as well as crucial aspects of human and material resource management. In comparison to external factors, these elements are more predictable and controllable [121].

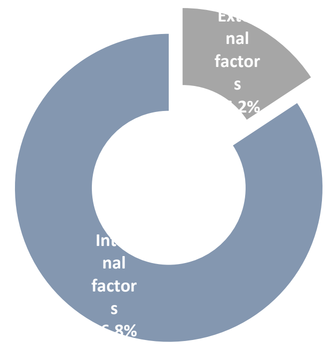

Fig 15. Primary classification level. (Global)

On the other hand, external factors (16.2%) encompass a variety of elements operating beyond the direct control of the construction company. This includes environmental factors such as weather conditions and natural disasters, as well as socio-economic, political, and regulatory variables that can significantly impact project execution. Due to their external nature and diverse sources of origin, these factors tend to be more challenging to predict and manage effectively**.**

Fig 16 presents the proposed groups in the new classification within the global context. The light grey shade corresponds to frequency analysis, while the darker represents the Importance Value Index (IVI), considering the total factors (267) and instances (1547).

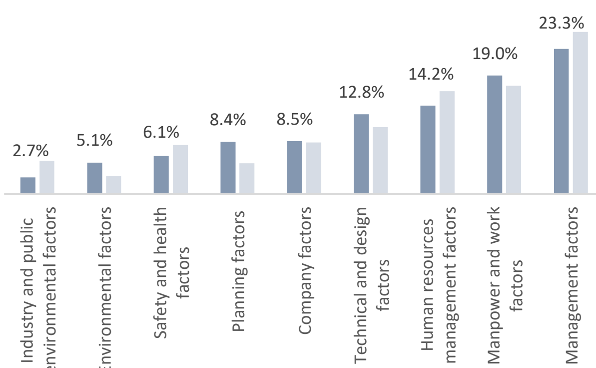

Fig 16. Revised classification of factors impacting labor productivity in construction within a global.

The Fig 17 illustrates the new classification of factor groups affecting construction labor productivity

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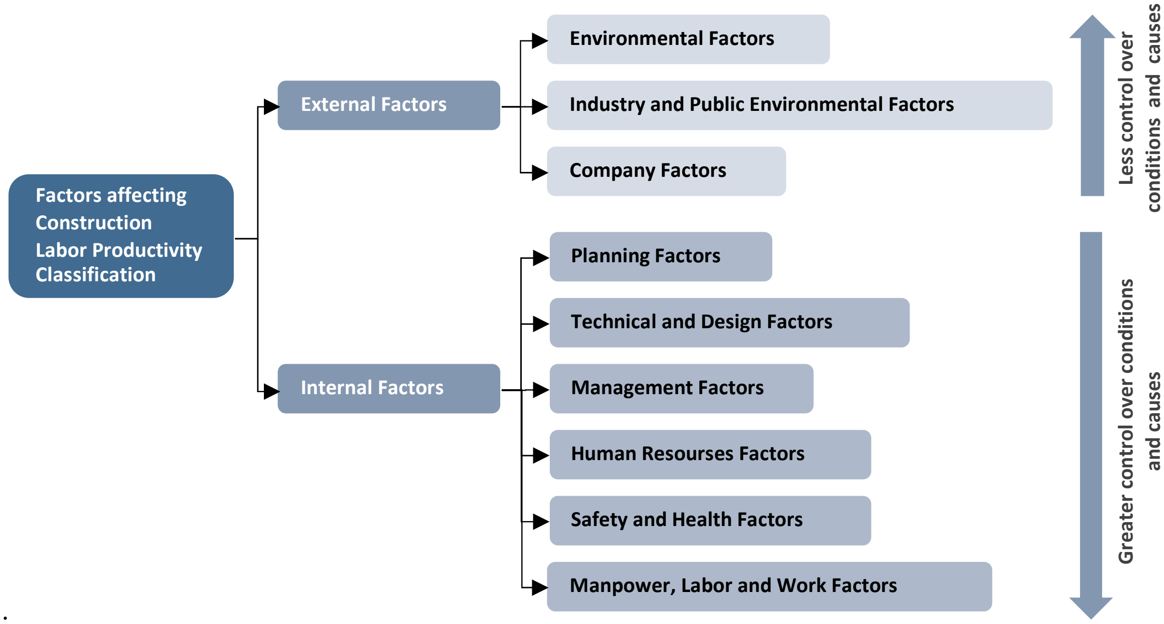

Fig 17. Innovative Classification of Factor Groups Influencing Labor Productivity in the Construction Industry

J. *Top 30 most important factors on a Global Scale*

TABLE I.

RANKING TOP 30 MOST IMPORTANT FACTORS INFLUENCING LABOR PRODUCTIVITY ON A GLOBAL SCALE.

Rank	Factor	I.V.I.	Classification I	Classification II
1	Availability of materials on site	0,0335	Internal factors	Management factors
2	level of skill labor	0,0330	Internal factors	Manpower and work factors
3	Site weather conditions	0,0281	External factors	Environmental factors
4	Rework	0,0268	Internal factors	Planning factors
5	levels of motivation and commitment of the workforce on construction	0,0244	Internal factors	Human resources management factors
6	Availability of tools and equipment on site	0,0236	Internal factors	Management factors
7	Delay in salaries payment	0,0234	External factors	Company factors
8	Financial incentive and rewards program/scheme	0,0232	External factors	Company factors
9	crew labor construction experience	0,0230	Internal factors	Manpower and work factors
10	Project planning	0,0195	Internal factors	Planning factors
11	Construction method and Building technique	0,0181	Internal factors	Technical and design factors
12	Supervisor experience	0,0179	Internal factors	Management factors
13	Communication between site management and labor and feedback	0,0165	Internal factors	Management factors
14	Turnover and labor absenteeism	0,0156	Internal factors	Manpower and work factors
15	Wages and economic conditions of workers	0,0156	Internal factors	Human resources management factors
16	Construction management team skills	0,0147	Internal factors	Management factors
17	Work planning and scheduling	0,0137	Internal factors	Planning factors
18	Working overtime	0,0126	Internal factors	Manpower and work factors
19	Availability of labour	0,0121	Internal factors	Manpower and work factors
20	Occupational Health & Safety conditions on site	0,0120	Internal factors	Safety and health factors
21	Change order	0,0119	Internal factors	Technical and design factors
22	Crew size and composition	0,0115	Internal factors	Manpower and work factors
23	Temperature	0,0113	External factors	Environmental factors
24	Physical fatigue	0,0110	Internal factors	Human resources management factors
25	Financial status of stakeholders	0,0106	External factors	Company factors
26	Design changes in the drawings	0,0105	Internal factors	Technical and design factors
27	Inspection and control delays	0,0103	Internal factors	Management factors
28	Overcrowding on the site	0,0098	Internal factors	Manpower and work factors
29	Accidents	0,0088	Internal factors	Safety and health factors
30	Incomplete drawings	0,0085	Internal factors	Technical and design factors

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TABLE presents the ranking obtained using the "Importance Value Index" (IVI) method in the "Global" context. It illustrates the top 30 most influential factors, all contributing to labor productivity within the construction industry. Notably, this ranking deviates from previous studies where material availability, although significant, does not consistently appear among the top five factors [22]; [118]; [23].

Fig 18, the internal and external factor composition is presented, this time applied to the top 30 most relevant factors. On the other hand, Fig 19 illustrates the distribution of these critical factors concerning the new classification of groups, with the darker blue shade derived from applying IVI and the lighter hue considering only the frequencies. To further emphasize the order of importance in the new factor classification, Fig. 20 exclusively displays those relevant to IVI.

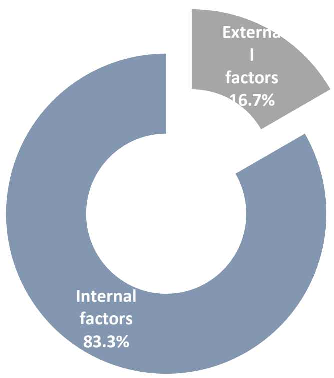

Fig 18. Internal and external factor composition is presented, this time applied to the top 30 most relevant factors.

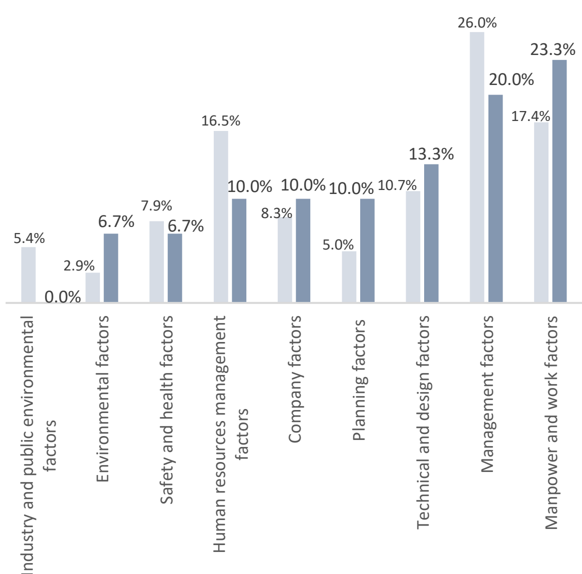

Fig 19. Distribution of 30 critical factors concerning the new classification of groups.

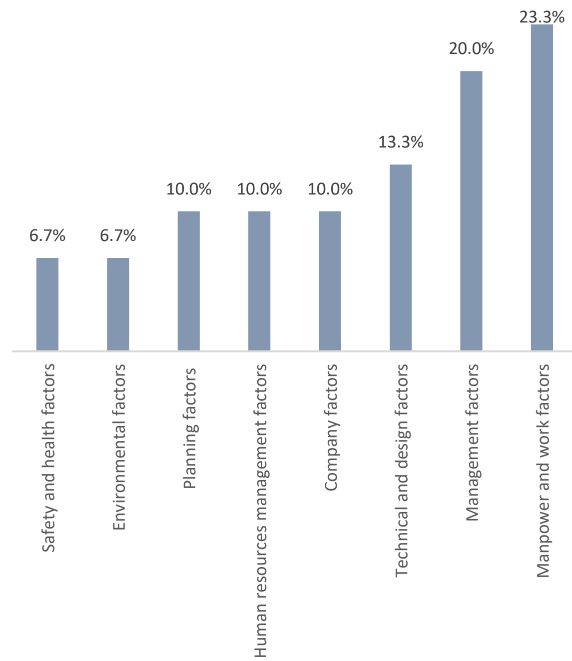

Fig 20. Distribution of 30 critical factors concerning the new classification of groups (Only IVI).

IV. Conclusions

In terms of geographical distribution and development, it is evident that the countries with the highest participation in research on the subject, according to the analyzed sample, are India (11.3%), the United States (8.2%), and Canada (7.2%). This diversity in national contexts underscores the need to tailor solutions and strategies to specific socio-economic and cultural nuances, including sustained economic growth, large-scale infrastructure expansion, and addressing specific challenges related to construction.

At the regional level, "Northern Africa and Western Asia" (32.6%), "Central Asia and Southern Asia" (24.7%), "Europe and Northern America" (19.1%), and "Eastern Asia and Southeastern Asia" (14.6%) stand out as regions with the highest research activity in the field. This concentration reflects the necessity of developing strategies adapted to diverse contexts.

Regarding information collection tools, "Literature review" (38.05%) stands out as the most relevant method, followed by "Survey" (28.29%), "Interview" (9.27%), and "Questionnaire" (1.46%). "Direct observations on site" (11.22%) illustrate the interaction between the academic and practical realms. "Historical records" (2.44%), "Contractor databases" (0.49%), and "Experience of previous projects" are also employed, highlighting retrospective and comparative on-site approaches. The combination of these methods suggests a comprehensive approach in research, emphasizing theory, practical experience, and comparative analysis.

In terms of analysis methods, the "Relative Importance Index method" (20.50%) stands out, supported by statistical methods such as "Statistical analysis" (11.18%) and "Regression analysis" (6.21%). Innovative methods like "System Dynamic" (4.35%) and "Fuzzy logic algorithm" (3.73%) indicate a search for advanced approaches to model productivity dynamics. It is crucial to note that the practical implementation of these methods may require resources and specialized expertise.

The prevalence of vertical construction is highlighted, representing a significant proportion in various subsectors. Despite the minority presence of horizontal projects, "Infrastructure" (16.13%) emphasizes its critical importance in the industry. This might reflect the need to develop essential infrastructures.

In the first-order classification of factors, internal factors predominate (86.8%), indicating their relative importance in the perception of industry stakeholders. Although external factors are a minority, they represent a considerable percentage (16.2-16.7%), underscoring the importance of balanced management.

In the second-order classification, "Management factors" (23.3%) leads, highlighting the importance attributed to project management. In the ranking of the top 30 factors, "Manpower and work factors" (23.3%) stands out, followed by "Management factors" (20.0%), emphasizing the relevance of manpower and management.

Fig 19 contrasts both scenarios, showing consistency in the proportion of internal and external factors in the two analyses.

At the individual factor level, resource management stands out, with "Availability of materials on site" ranking first and "Availability of tools and equipment on site" ranking sixth. "Level of skill labor," along with factors related to manpower, highlights the importance of training and skills. "Site weather conditions" stands out as a relevant environmental factor.

These findings suggest specific strategies, such as training for the management team, technical training programs, the development of climate risk matrices, and effective human resource management to optimize labor productivity in construction projects globally.

Following this global-level research, it is recommended to conduct a study at the level of Sustainable Development Goal Regions (SDG-R), grouping diverse perceptions and influential factors on labor productivity within each region.

Furthermore, it is advised to incorporate new tools of Artificial Intelligence (AI), particularly Machine Learning, alongside programming, in the processing and analysis of data for future research endeavors. This integration can enhance the depth and efficiency of data analysis, providing valuable insights into the complex dynamics influencing labor productivity in the construction industry.

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