Factors affecting construction productivity in Brazil: comparison with recent international research
Factores que afectan la productividad de la construcción en Brasil: comparación con investigaciones internacionales recientes

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Abstract

Executing projects according to its estimated cost and schedule is fundamental to guarantee the economic and financial viability of the businesses associated with them. In this context, the estimated duration of an activity is very important for the development of the project schedule and budget. Therefore, determining the main factors that contribute to labor productivity becomes imperative. This research identified the main factors affecting labor productivity in construction projects around the world. Then, it was verified the pertinence of these factors to the Brazilian industry. The 56 factors identified were prioritized, according to the importance index, and categorized into four main groups: management, labor, external and technological. Factors such as: poor material management, lack of construction manager’s leadership, site supervision inefficiency, strikes and lack of tools are at the top of the list. It was also observed the balance between the management, technological and external groups. Finally, when compared to researchers carried out in other countries, there is a reasonable correlation between the results identified by this research and those found by previous researches.

Keywords: Labor productivity; construction productivity; metrics; project performance and construction best practices

Resumen

Ejecutar los proyectos de acuerdo a su costo y cronograma estimados es fundamental para garantizar la viabilidad económica y financiera de los negocios asociados a ellos. En este contexto, la duración estimada de una actividad es muy importante para el desarrollo del cronograma y el presupuesto del proyecto. Por lo tanto, es imperativo comprender los factores que contribuyen a la productividad laboral. Esta investigación identificó los principales factores que afectan la productividad laboral en proyectos de construcción en todo el mundo. Luego, se verificó la pertinencia de estos factores en la industria brasileña. Los 56 factores identificados fueron priorizados, según el índice de importancia, y categorizados en cuatro grandes grupos: gerencial, laboral, externo y tecnológico. Factores como: mala gestión de materiales, falta de liderazgo del gerente de construcción, ineficiencia en la supervisión del sitio, huelgas y falta de herramientas están en la parte superior de la lista. También se observó el equilibrio entre los grupos gerencial, tecnológico y externo. Finalmente, cuando se compara con investigaciones realizadas en otros países, existe una correlación significativa entre los resultados identificados por esta investigación y los encontrados por investigaciones anteriores.

Palabras clave: Productividad laboral; productividad de la construcción; métricas; desempeño de proyectos y mejores prácticas de construcción

1. Introduction

The need to execute projects according to its estimated cost and schedule is fundamental to guarantee the economic and financial viability of the businesses associated with them. However, significant variations of cost and schedule in engineering projects have been a cause of increasing concern for many construction companies in Brazil and worldwide. According to (Chanmeka et al., 2012), these variations are caused by several reasons, being the inadequate planning, deficient scope definition and low productivity the most representative. Among these, low productivity is the main factor (Kaming et al., 1998).

Therefore, understanding the factors that contribute positively or negatively to labor productivity performance becomes imperative and receives emphasis in the academia and the industry (Hasan et al., 2018).

For these reasons, in the last decade an extensive research work has been conducted in several countries, among which can be mentioned: (Singh, 2010), (Dai and Goodrum, 2011), (Soekiman et al., 2011), (Ghoddousi and Hosseini, 2012), (Jarkas and Bitar, 2012), (El-Batreek et al., 2013), (El-Gohary and Aziz, 2014), (Hughes and Thorpe, 2014), (Alghonamy, 2015), (Jarkas et al., 2015), (Hiyassat et al., 2016) and (Hasan et al., 2018).

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Despite the importance of the topic, this issue deserves attention as there is no previous research in this sense in Brazil. Furthermore, research conducted in other countries may not reflect the real condition of Brazilian industry due to geopolitical, environmental, weather, and economic differences among different countries. In this context, this article identifies, through literature review, the main factors affecting labor productivity in construction projects around the world. Then, it evaluates, through field research, the pertinence of these factors to the Brazilian industry. The identified factors were cataloged and prioritized, according to the importance index recommended by (Lim and Alum, 1995) and categorized into four main groups: management, labor, external and technological as proposed by (Jarkas and Bitar, 2012). At the end, the factors identified in Brazil are compared to recent international research. It is expected that, with the adequate comprehension of these factors, future studies can evaluate how to mitigate or attenuate them, thus maximizing the results of the Brazilian construction industry.

2. Productivity

Usually involving the concepts of measurement, analysis and interpretation of data, the study of productivity dates back to the 18th century and was initially mentioned by Quesnay in 1766 in the publication Journal de l’Agriculture (Tangen, 2005).

Although the consensus among most researchers, the fact that labor productivity has fundamental importance for the development of a business or industry, this term is rarely precisely defined due to its multidimensionality, being function of the context or perspective of use. (Singh et al., 2000) understand that this diversity comes mainly from the fact that this theme is addressed by different areas of knowledge, such as: economics, management, and engineering.

According to (Del Gatto et al., 2011) the mathematical concept of productivity comes from the production function adopted in economics and initially proposed by (Solow, 1957). The basic structure of the production function, (Equation 1), focuses on four variables: product (Q), capital (K), applied labor (l) and technology (t).

\[ Q = f(K, l, t). \] (1)

(Solow, 1957) justifies that the variable \( t \) appears in \( f \) to consider the influence of technical variations that may affect production. After defining the variables that compose the production function, the author proposes to start the analysis considering a specific case where the technical variation is neutral. Next, he mentions the need to add a variable that considers the changes in the outputs according to the changes that occurred in the work shifts. In this case, the production function assumes the form represented mathematically by (Equation 2), where the multiplier factor \( A_t \) measures the accumulated effect on shift changes.

\[ Q = A_t f(K, l). \] (2)

(Equation 3) correlates a given output \( Q \) with the inputs used in production, \( f(K, l) \), where \( A_t \) is the productivity index. In this case, the index presented is called the Multi-factor Factor Productivity (MFP) (Pieri, 2010).

\[ MFP = A_t = \frac{Q}{f(K, l)} \] (3)

Finally, if only one input factor is considered, there will be a Partial Factor Productivity (PFP), as it showed in (Equation 4).

\[ PFP = A_t = \frac{Q}{f(K)} \text{ or } \frac{Q}{f(L)} \] (4)

When applied to the construction industry, the inputs considered will be: labor, energy, materials and capital, in the form of tools and supplies (Nassir, 2013). The outputs are the deliverables necessary for the mechanical completion of a project or project task.

According to the input and output data, (Jarkas and Bitar, 2012) classified the partial productivity factor in labor productivity (LP), capital productivity (CP) and equipment productivity (EP).

The LP (see (Equation 5)), measures the productivity of specific activities by monitoring field activities and is usually expressed as the number of outputs (Q) over the amount of labor (L).
The CP (see (Equation 6)), is given through the correlation between the profit (P) provided by a business compared to the capital invested (K) for its realization. By comparing inputs and outputs expressed in the same unit, this index is dimensionless.

\[
\text{CP} = \frac{P(\text{$/unit$})}{K(\text{$/unit$})} 
\] (6)

Finally, EP (see (Equation 7)), cited by (Jarkas and Bitar, 2012), measures the effectiveness of the use of equipment applied in a given project. Considering that in large industrial projects, equipment to support construction and assembly represents an important portion of the total cost, it is of great value to monitor and control their productivity. This index compares the outputs (Q) with the number of hours of equipment applied (MH).

\[
\text{EP} = \frac{Q(\text{production units})}{\text{MH}} 
\] (7)

The concepts of global productivity, intrinsic productivity and unproductivity must be considered when measuring the time required to perform a task (Tabim, 2013). Global productivity is defined as the sum of the time to perform the required processes, added to the time of all support work needed to execute the given processes and the unproductive time. Intrinsic productivity is the productivity inherent to the process at its effective moment of execution. Finally, unproductivity is characterized as any activity outside of the direct work measured by intrinsic productivity.

3. Research method

This is characterized a descriptive research because it aims to determine the characteristics of the behavior of contributing factors to the Brazilian construction industry. Regarding its nature, this work is classified as field research. (Gil, 2008) mentions that most of the field studies consist of preliminary evaluation, architecting the research project, pretesting the research tools, data collection, analysis of the collected data and report releasing. The initial evaluation was carried out through literature review while the other items compose the field research itself.

3.1 Literature Review

Due to the upraise of search engines, it is observed that the quality and reliability of published knowledge has become an aspect to be managed (Trinta, 2011). According to (Araújo, 2006), bibliometric analysis is the appropriate tool for this purpose, and it’s divided into bibliographic research and analysis of results. (Farias Filho, 2012).

The bibliographic research identifies the previous studies that strongly represent the objective of this research. To this end, an exploratory search was conducted through the portal of the CAPES where 217 articles were identified. Through the selected articles, the most used keywords in the academic environment related to the research topic were identified.

After obtaining the keywords, Boolean search logic was used as input to the search engines CAPES, Scopus and Web of Science. At the end of the initial search, 3410 articles were identified and cataloged in the Zotero™ software.

Then, the duplication check function available in the software was used. Also, as part of this initial filter, articles that lacked the necessary information for bibliometric analysis were removed from the library. The second filter was performed by reading the titles of the articles, considering the alignment with the research objective and the possibility of academic and professional contribution. Finally, a detailed reading of the abstracts of the articles was carried out, resulting in the maintenance of 258 articles in the database.

The bibliometric analysis considers four main research focuses: article, authors, scientific journal and theme. In the article topic, the number of citations received was the metric used to evaluate its relevance and quality. The author topic sought to identify the importance of a particular researcher for his research area. The indicator adopted to point out this representativeness is the H index, which is a bibliometric index that aims to quantify the productivity and impact of scientists.

The scientific journal topic identifies the importance of the vehicle publishing the article. For this purpose, the productivity index of the journal was used. The criteria adopted for this analysis was the SJR index. The last topic analyzed was the theme. This topic aimed to identify the significance of the article to the research, for which the keywords, abstracts and a superficial reading of the articles were assessed.
In addition to the search and selection criteria for the articles, a final analysis was carried out through a detailed reading of the 66 articles initially selected. This reading aimed to ensure that only articles in total concordance to the object of this research would be considered. Additionally, a specific search for articles was carried out. As a result of this bibliometric analysis, 69 articles were classified and selected to compose the framework of this research.

3.2 Field Study

The field study phase started with the preparation of the closed questionnaire, prepared based on the analysis of the articles identified in the literature review. According to the methodology proposed by (Gil, 2008), this questionnaire was directed to a small group for validation. To determine the number of surveyed people, the universe of 108 companies participating in the ABEMI (Brazilian Association of Industrial Construction) was considered. Statistical sampling was determined by calculating the sample size for finite populations according to (Equation 8).

\[ n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}} \]  
\[ (8) \]

Where \( n \) is the sample size, \( N \) is the universe. The variable \( n_0 \) is determined by (Equation 9).

\[ n_0 = \frac{(Z(k))^2}{4d^2} \]  
\[ (9) \]

Where \( Z(k) \) is the statistical value of the required confidence level and \( d \) is the acceptable margin of error. For the purpose of this research, 95% and 5% were used respectively. Thus, the number of surveyed people required is approximately 84. When answering the questionnaire, the surveyed person was asked to inform the relevance of certain factors on productivity in projects where he or she has worked. This measurement was given on a scale of 1 to 5, being expressed in the research as “no effect”, “little effect”, “moderate effect”, “strong effect” and “very strong effect”, respectively.

The collected data was prioritized according to the importance index technique, presented by (Lim and Alum, 1995) and described in (Equation 10).

\[ II = \frac{5(n_5) + 4(n_4) + 3(n_3) + 2(n_2) + n_1}{5(n_1 + n_2 + n_3 + n_4 + n_5)} \]  
\[ (10) \]

Where \( II \) represents the importance index, \( n_5 \) represents the number of respondents who consider that it has a “very strong effect”; \( n_4 \), a “strong effect”; \( n_3 \), a “moderate effect”; \( n_2 \), a “little effect”; and \( n_1 \), “no effect”.

4. Results and discussion

Ninety-five questionnaires were answered and used as the basis for the analysis of this research. After calculating the importance index, the factors were ranked in descending order for each of the main groups, as proposed by (Jarkas and Bitar, 2012).

4.1 Management Group

The contributing factors belonging to the main management group are highly representative in the results obtained through field research. It’s important to mention that the 3 most influential factors in this group (poor material management, lack of construction manager’s leadership and site supervision inefficiency) are the factors of greatest influence in the research. The relationship among the 18 factors that compose this group can be seen in (Table 1).

Table 1. Importance indices and ranks of management group factors.
The second most important factor is the lack of construction manager’s leadership, with a 0.82 index attributed to it, which also indicates a great impact.

With an importance index of 0.80 the site supervision inefficiency is identified as the third most important factor. This factor is strongly related to the crew composition factor, which has an importance index of 0.68. For the respondents, the perception of this effect also shows that continuous supervision of work is necessary to optimize labor productivity. According to (Jarkas and Bitar, 2012) the site supervision inefficiency encourages employees to engage in unproductive activities, take frequent unscheduled breaks, or even leave workplaces during working hours to attend to personal issues.

4.2 Technological Group

(Table 2) shows the 12 contributing factors that are part of the main group called technological. The 3 main factors are rework, inconsistency among the various project documents and changes to drawings and project specifications.

| Factor                                             | II  | Rank |
|----------------------------------------------------|-----|------|
| Poor material management                           | 0.87| 1    |
| Lack of construction manager’s leadership          | 0.82| 2    |
| Site supervision inefficiency                      | 0.80| 3    |
| Inappropriate tools and equipment                  | 0.79| 4    |
| Lack of periodical meetings with crew and leaders  | 0.74| 5    |
| Non-provision of transport means                   | 0.72| 6    |
| Inefficient equipment                              | 0.70| 7    |
| Lack of training                                   | 0.70| 8    |
| Unrealistic scheduling of labor performance        | 0.69| 9    |
| Physical fatigue of operatives                     | 0.68| 10   |
| Payment delay                                      | 0.68| 11   |
| Crew composition                                   | 0.68| 12   |
| Insufficient lighting                              | 0.67| 13   |
| Lack of proper break areas and lunch rooms         | 0.64| 14   |
| Lack of recognition program                        | 0.60| 15   |
| Proportion of subcontracted work                   | 0.59| 16   |
| High number of workers                             | 0.57| 17   |
| Working overtime                                    | 0.50| 18   |

Table 2. Importance indices and ranks of technological group factors
Rework was identified as the factor with the greatest contribution in the research, with an importance index of 0.78.

For people surveyed, with the goal of avoiding rework, it is necessary to implement rework reduction programs. An example of these programs is the CII’s RT252, which proposes the following methodology: identify the reworks, define the root cause of each rework, document each rework event and communicate the lessons learned to the project teams, develop an action plan to eliminate the root cause, implement the action plan, check the effectiveness of each action plan. Once a consistent methodology is implemented, the search for reduction must be continuous until acceptable levels of rework are achieved.

The inconsistency among the project documents ranks second, with an importance index of 0.77, which is directly related to the scope changes that figure as the third factor with the greatest contribution in this group, with an index of 0.76.

4.3 Labor Group

The third main group of factors contains the labor related items. (Table 3) shows the 10 contributing factors in this group. The factor with the highest importance index, 0.78, in this category is the lack of commitment by employees followed by dissatisfaction and absenteeism with importance indices 0.73 and 0.72 respectively.

| Factor                                                                 | II   | Rank |
|------------------------------------------------------------------------|------|------|
| Rework                                                                 | 0.78 | 1    |
| Inconsistency among contract documents                                 | 0.77 | 2    |
| Drawing and specifications alteration (change order)                   | 0.76 | 3    |
| Lack of coordination among disciplines                                 | 0.75 | 4    |
| Method of working                                                      | 0.72 | 5    |
| Delay in responding to requests for information                        | 0.71 | 6    |
| Assembly interference                                                  | 0.70 | 7    |
| Inspection delay by the engineering or quality representatives         | 0.68 | 8    |
| Low quality of raw materials                                           | 0.68 | 9    |
| Construction site/facility layout                                     | 0.66 | 10   |
| Design complexity level                                                | 0.64 | 11   |
| Construction method                                                    | 0.63 | 12   |

Table 3. Importance indices and ranks of labor group factor
When analyzed in the general context of the research, these factors occupy the seventh, fourteenth and fifteenth positions respectively, not having a great influence. No factors were found in the open fields of the research that justify the appearance of these items at the top of the list. However, when analyzing some problems pointed out in the management group, some of the reasons can be inferred, being them: lack of periodical meetings with crew and leaders, which ranked fifth in the management group with an importance index of 0.74, physical fatigue of operatives, which ranked tenth in the same group with an index of 0.68, and payment delays and lack of recognition program, with an index of 0.68 and 0.60 respectively.

4.4 External Group

Among this group, only three contributing factors are included in the list of the 20 most relevant factors in the general context of this research. Strikes are the most representative, in the first position of the group and in the fourth position in the general context. The complete list with the factors belonging to the main group of external factors can be seen in Table 4 and includes 16 factors with an index of importance ranging from 0.80 to 0.48.

| Factor                                      | II  | Rank |
|---------------------------------------------|-----|------|
| Lack of commitment by employees            | 0.78| 1    |
| Labor dissatisfaction                       | 0.73| 2    |
| Labor absenteeism                           | 0.72| 3    |
| Alcoholism and similar problems             | 0.72| 4    |
| Lack of labor experience                    | 0.72| 5    |
| Accidents and safety incidents              | 0.72| 6    |
| Labor dishonesty                            | 0.70| 7    |
| Violation of safety precautions             | 0.64| 8    |
| Labor personal problems                     | 0.64| 9    |
| Misunderstanding among employees            | 0.62| 10   |

Table 4. Importance indices and ranks of external group factors
According to the surveyed people, several factors can be considered when analyzing the main reasons for strikes (factor with the highest importance index in the group, 0.80). Among them, the most cited are, again, related to the management group, notably those listed as the root cause for the problems pointed out in the labor group. However, factors such as: political conditions, number of projects running in the same demographic area and legal conditions.

In addition to the strikes, the item classified as the third most important, the high rate of labor turnover, with an index of 0.73 shall be highlighted as well.

According to comments made in the research, reasons for the high turnover include, but are not limited to relationship problems with supervision, poor expectations of salary raise, inadequate working conditions and job opportunities offered by other companies.

When the groups are compared, the equilibrium between them can be seen. This equilibrium is given both in number of factors and in the importance index attributed to them. The management group has four factors present in this list with an average index of 0.82, while the technological group contains 3 factors obtaining an average of 0.77, followed by the group of external factors with 2 items and an average of 0.78. The labor group, on the other hand, has only the factor of lack of commitment by employees in the list of the 10 most representatives, in the seventh position, with a representativeness index of 0.78.

5. Comparison of results with previous research

The contributing factors identified through this research were compared to 22 relevant studies of the last decade and conducted in countries such as: Australia, Bahrain, Chile, Egypt, USA, India, Indonesia, Iran, Jordan, Kuwait, New Zealand, Oman, Palestine, Qatar, Thailand, United Kingdom and Yemen.

The selected articles were published in journals of significant representation in the area of construction, such as: Journal of Construction Engineering and Management; International Journal of Construction Management; Engineering, Construction and Architectural Management; International Journal of Engineering and Advanced Technology; Australasian Journal of Construction Economics and Building; Construction Innovation among others.
(Table 5) correlates the twenty factors of greatest impact identified by this research with the factors identified by: (Durdyev and Mbachu, 2011), (Rivas et al., 2011), (Soekiman et al., 2011), (Ghoddousi and Hosseini, 2012), (Jarkas and Bitar, 2012), (Jarkas et al., 2015), (El-Batreek et al., 2013), (Gundecha, 2013), (Ibrahim, 2013), (Jarkas and Radosavljevic, 2012), (Soham and Rajiv, 2013), (Thomas and Sudhakumar, 2013), (El-Gohary and Aziz, 2014), (Hughes and Thorpe, 2014), (Ghoddousi et al., 2015), (Heravi and Ismadoost, 2015), (Porntepkasemsant and Charoenpornpattana, 2015), (Hiyassat et al., 2016), (Naoum, 2016) and (Alaghbari et al., 2019).

| Factor | Main Group | II  | # Citations |
|-------|------------|-----|-------------|
| 1 Poor material management | Management | 0.866 | 19 |
| 2 Lack of construction manager’s leadership | Management | 0.816 | 15 |
| 3 Site supervision inefficiency | Management | 0.805 | 15 |
| 4 Strikes | External | 0.798 | 6 |
| 5 Inappropriate tools and equipment | Management | 0.788 | 13 |
| 6 Rework | Technological | 0.781 | 12 |
| 7 Lack of commitment by employees | Labor | 0.776 | 10 |
| 8 Inconsistency among contract documents | Technological | 0.767 | 13 |
| 9 Drawing and specifications alteration (change order) | Technological | 0.760 | 13 |
| 10 Lack of utilities (water, power) | External | 0.760 | 5 |
| 11 Lack of coordination among disciplines | Technological | 0.748 | 8 |
| 12 Lack of periodical meetings with crew and leaders | Management | 0.736 | 7 |
| 13 High rate of labor turnover | External | 0.734 | 5 |
| 14 Labor dissatisfaction | Labor | 0.732 | 16 |
| 15 Labor absenteeism | Labor | 0.725 | 7 |
| 16 Method of working | Technological | 0.722 | 9 |
| 17 Non-provision of transport means | Management | 0.720 | 5 |
| 18 Alcoholism and similar problems | Labor | 0.720 | 4 |
| 19 Lack of labor experience | Labor | 0.715 | 15 |
| 20 Accidents and safety incidents | Labor | 0.715 | 7 |

It is observed that the 3 factors identified as the most relevant in Brazil have great adherence to research conducted abroad. The poor material management has a common place in most studies. However, labor dissatisfaction and lack of labor experience, which have an II of 0.732 and 0.715 respectively, are frequently cited in recent studies and it was not identified as a significant impact in Brazilian projects.

The factors that are not among the 20 most relevant in this research were also mentioned in other studies, such as: weather and delay in responding to requests for information.
6. Conclusions

The analysis of the responses to the questionnaire led to the creation of a list containing 56 contributing factors to the performance of labor productivity in construction of industrial projects in Brazil. These factors were classified in order of influence and grouped according to the main groups of management, technological, labor and external.

Although the importance index attributed to each group is, in general, well distributed, there is a great influence of the management group in the result of labor productivity performance in projects in Brazil, with the three factors of greatest contribution belonging to this main group.

When compared with studies carried out in other countries, in most cases, there is reasonable adherence between the results identified by this research and those found by previous researches. It is well known that this assessment must take into account social, environmental, geographical and political factors, as these explained some of the differences found.

Future research can be divided into two main strands: (1) further study in order to understand the divergences found in the comparison between international studies and the study carried out in Brazil. Notably, the factors “labor dissatisfaction”, “lack of labor experience”, “weather” and “delay in responding to requests for information” must be evaluated in greater depth. (2) Quantify the impact caused by each factor so that they can be taken into account when estimating the cost and schedule of new projects and, thus, are avoided or mitigated.

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