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RESULTS OF THE CAUSES AND IMPACTS OF MAKING-DO WASTES IN PRODUCTION IN FORTALEZA, CEARÁ, BRAZIL

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ABSTRACT

This report aims to present the possible relationships between the prerequisites, categories, and impacts of *making-do* wastes from the non-conformity data provided by the Quizquality of six companies participating in INOVACON. From the analysis of the missing prerequisites related to the city of Fortaleza, it was possible to see that labor (52.75%), materials and components (26.69%), and interdependent tasks (5.90%) presented the most associated wastes. The main categories related to wastes are component adjustments (53.84%), sequencing (21.01%), and storage (9.76%). The highlighted prerequisite information for the Goiania cases was motivated by the absence of projects, blueprints, studies, or procedures that should provide necessary information to execute work packages which were unavailable, unclear, and/or incomplete. Based on these results, the determined actions are the need to improve information management to cooperate so that there are no errors arising from incomplete projects or difficulty in passing on necessary information to the employees responsible for performing the service/work.

KEYWORDS

Making-do, prerequisites, categories, impacts and work packages.

INTRODUCTION

It is a common goal among the academic and technical communities to make the construction industry more competitive. To this end, it becomes necessary to increase controls at all project stages and to increase the performance of processes and products, as well as to reduce production, material wastes, and impacts on the environment (ADEWUYI, IDORO and IKPO, 2014; ANSAH, SOROOSHIAN and MUSTAFA, 2016).

Thus, companies have developed actions that provide improvements in construction processes to avoid the occurrence of failures, losses, accidents, and/or rework, thereby ensuring

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improvements at the organizational level, cost reduction, meeting deadlines, minimizing errors, as well as in quality and productivity. Studies conducted in different countries indicate that losses in construction represent a relatively high percentage of production costs (FORMOSO et al., 2002; FORMOSO et al. 2017; HWANG et al., 2009; KOUSHKI, KARTAM, 2004; LOVE, LI, 2000; LEÃO, 2014; LEÃO et al., 2016). High production costs are related to losses throughout the construction processes and should be understood as any inefficiency in the use of equipment, materials, labor, and capital (VIANA; FORMOSO; KALSAAS, 2012).

Moreover, productivity is a constant concern for any construction company in the current landscape of the construction industry to establish itself in the market competitively. Companies face great competition due to increasing demands from customers who want products with adequate quality and satisfactory performance. Nevertheless, management strategies have been adopted by construction companies to improve organizational and construction performance. In this sense, the implementation of lean construction based on the Toyota Production System (TPS) and Total Quality becomes an answer to the culture of improvisation in construction sites and can be proven by several implementations around the world.

Toyota created a loss classification aimed at making wastes visible and facilitating identification of their causes to foster a "zero waste" culture among its employees called the "Seven Wastes" (Shingo, 1989). According to Ohno (1988), waste or loss refers to all production resources which only increase costs and do not add value to the product, explained through the seven major categories of wastes adopted by the STP.

Soilbelman (1993) states that the reduction of wastes must consider that there is an acceptable level of wastes, which can only be reduced through significant changes in the level of technological and managerial development of the company. Accordingly, the referred author classifies wastes as unavoidable (or natural waste) and avoidable, in which the occurrence costs are substantially higher than the prevention costs. Thus, several theories arise or evolve in this context. However, it is known that an important increment for lean construction was the designation by Koskela (2004) of a new category of wastes called making-do, added to the widely known and applied list of Ohno (1988) and Shingo (1989).

THEORETICAL REFERENCE

The terms unfinished work, work in progress, buffer, rework, work completion, and work stoppage have been reconceptualized in a trajectory of lean history to be associated with making-do. Nevertheless, it is important to note that these terms already existed before the evolution of lean construction theory. Likewise, Ronen (1992) and Koskela (2000) already presented the theoretical basis for the making-do in their works, highlighting that the latter was based on the former to establish the complete kit (prerequisites to perform a certain task). Koskela, Bolviken, and Rooke (2013) point out making-do as a central waste in construction for being the possible main cause of other wastes.

Since then, studies related to ways to use the concept of making-do loss to minimize or eliminate activities which do not add value to the process have been developed, either in various stages of the life cycle (from project conception to maintenance), such as in: project preparation (Koskela et al., 1996; Grosskopf; Menezes; Santos, 2004; Neve; Wandahl, 2018); construction site logistics (Ghanem et al., 2018, Perez et al., 2015); the supply chain (Taggart, Koskela, and Rooke, 2014); production slack (Fireman, Saurin, and Formoso, 2018); developing or augmenting methods or tools, virtual or otherwise, to facilitate the identification of these wastes (Sommer, 2010, Fireman, 2012, Leão; Formoso; Isatto, 2016); or by identifying other wastes in a cause and consequence discussion concerning making-do waste (Koskela et al., 2019; Formoso et al., 2011; Fireman; Formoso; Isatto, 2013; Santos; Santos, 2017; Pérez, Costa, and Gonçalves, 2016; Pérez; Costa, 2018).

Several studies have been conducted seeking to identify the causes and effects of making-do waste in construction, notably those by Sommer (2010) and Fireman (2012). However, few works are dedicated to identifying specific cause-effect relationships associated with this type of waste. In one such study, Spohr and Isatto (2018) argue that the associations between causes and effects of making-do are quite diverse, with some being very close and central, while others are quite diverse and peripheral, suggesting that managerial attention aimed at reducing making-do wastes should focus on a more central set of effects. However, due to the small number of cases studied, the results obtained in that study do not enable a broader generalization to identify the associations between each of the causes and effects individually considered, or specific mechanisms which govern such relationships, pointing out a gap to be explored.

According to Koskela (2004), making-do waste occurs when a job site activity is started without having all the necessary prerequisites, or when its execution continues even if one or more prerequisites are no longer available. Ronen (1992) called this set of prerequisites a complete kit and states that there are two consequences, technical and behavioral. In addition to these consequences, Koskela (2004) added the safety waste caused by making-do; this safety waste is the result of abnormal manufacturing conditions.

The waste identification method proposed by Sommer (2010), and then complemented by Fireman et al. (2013) and Santos and Santos (2017), presents three groups. The first is used to identify missing prerequisites in work packages, the second is to identify the most affected waste categories, and the last assesses the impacts of waste.

Next, the work packages to be executed are defined in planning, and making-do wastes are identified when there are no working conditions, and therefore alternatives or improvisations are used so that the work is not interrupted. The method application must consider that these wastes may or may not generate some impact on production, not jeopardizing the execution of the packages. Therefore, it is necessary to first identify which activities can lead to these or other wastes in the production process (SOMMER, 2010).

It is noteworthy that wastes by making-do can occur in different ways, and there are numerous possible combinations of prerequisites, categories, and impacts in the construction environment. Some authors have highlighted that improvisations are present in all of the construction site stages, thereby making it difficult to identify and avoid them, and requiring strict control of construction processes, investments in cultural change conducive to improvisation and standardization (AMARAL et al., 2019; SANTOS et al., 2020, FORMOSO et al., 2002; JOSEPHSON; HAMMARLUND, 1999; HORMAN; KENLEY, 2005; FORMOSO et al., 2017; OHNO, 1997). Moreover, some authors reported difficulties in identifying and classifying making-do wastes, pointing to the need to improve the methods used. In addition, the need to develop more quantitative analyses and the acceptable limits of making-do wastes is also highlighted in the literature by several authors (SAURIN; SANCHES, 2014; AMARAL et al., 2019; SANTOS et al., 2020, JOSEPHSON; HAMMARLUND, 1999; HORMAN; KENLEY, 2005; FORMOSO et al., 2002; FORMOSO et al., 2011; FORMOSO et al., 2015; FORMOSO et al., 2017; FORMOSO et al., 2019; LEÃO, 2014; FIREMAN & FORMOSO, 2013; and KALSAAS, 2012).

On the other hand, it is noteworthy that only surveying making-do wastes does not provide enough information for the manager to completely prevent these wastes from occurring in their next undertaking or task. The targeted analysis of impacts is also important to facilitate feedback to the manager, as it allows the manager to prioritize the necessary corrections toward the most efficient work possible.

Leão et al. (2014), Formoso et al. (2015), Fireman et al. (2013), Saurin and Sanches (2014), and Kalsaas (2012) reported difficulties in identifying and classifying making-do wastes, pointing out the need to improve the methods used and develop more quantitative analyses and the acceptable limits of making-do wastes, as well as highlighting the need to prioritize decision-making by the manager; this means instead of the manager concentrating their efforts to correct all the intercurrences identified on-site, they may concentrate energy, resources, and management on the stages that contribute greater impact to achieve better results in the most critical points of the work concerning making-do.

OBJECTIVE

This report aims to present the possible relationships between the prerequisites, categories, and impacts of making-do wastes from the non-conformity data provided by the Quizquality of six companies participating in Civil Construction Industry Innovation Program (INOVACON).

METHOD

Table 01 characterizes the companies participating in these analyses. The group of companies defined in the sample are part of the INOVACON and subsidized this survey stage.

Table 1: Characterization of the construction companies.

Company Code	Code Work	Description	Current Phase Execution	Total Employment Area (m²)	Nr. of Floors
M	M-E1	Medium standard residential building - 3 towers	Concluded	9,444.6	23
N	N-E1	High Standard Vertical Residential Condominium - 2 towers	Running	2,860.0	15
	N-E2	High-end Vertical Residential Building	Running	2,390.0	19
	N-E3	High-end Vertical Residential Building	Running	2,480.0	30
O	O-E1	Low-rise residential building - 11 towers	Running	18,700.0	4
	O-E2	Medium standard residential building - 3 towers	Running	12,200.0	7
P	P-E1	Low-rise residential building - 11 towers	Running	26,145.0	5
Q	Q-E1	High-end Vertical Residential Building	Running	2,420.0	23
R	R-E1	High-end Vertical Residential Building	Running	2,350.0	20

IMPLEMENTATION STEPS

The research steps are detailed below.

Step 1: Definition of protocol for identifying making-do wastes.

Protocols for data collection were proposed based on previous studies. The causes, categories and impacts for making-do wastes were defined. The wastes were classified according to the steps and sub-steps following the NBR 12721 presets (ABNT, 2005). The impacts were classified according to the adopted parameters of reduced productivity, lack of motivation, loss of material, rework, reduced safety, reduced quality, and lack of finishing (RONEN, 1992; KOSKELA, 2004; FIREMAN et al., 2013).

Step 2: Diagnosis performed in Fortaleza/CE/Brazil based on the export of QuizQuality.

Preliminary analyzes of a database with 156,762 compliance and non-compliance data from the companies were conducted. From the 8,842 non-conformities analyzed, 6,339 instances of data were classified. The analysis period covered the years 2020 to 2022. The data refer to seven construction companies from Ceará, using data stored in the QuizQuality management platform, developed by the company Aval Engenharia.

Step 3: Dashboard enhancement for analysis of interactions between parameters.

The data were integrated into Microsoft Power BI® and the analyzed parameters were chosen based on the information classification on wastes, being divided into eight items related to prerequisites, eight to categories and seven to impacts (Table 2). Then, the parameters from this group (presented in Table 02) which highlighted the information were chosen to obtain a more specific and detailed analysis of the database.

Table 2: Parameters analyzed for making-do wastes.

Prerequisite	Categories	Impacts
Information	Access/mobility	Decreased productivity
Materials and component	Component adjustments	Demotivation
Labor	Workspace	Loss of material
Equipment or Tools	Storage	Rework
Space	Equipment/Tools	Security reduction
Interdependent tasks	Temporary installations	Quality reduction
External conditions	Protection (security)	Lack of finishing
Temporary installations	Sequencing	

Source: The authors.

The distribution of wastes by making-do could be interpreted by the hierarchical tree diagram graphs with the analysis carried out in Microsoft Power BI® (Figure 1), and the counting of wastes from this analysis can be sequentially analyzed from the prerequisites, categories and impacts of these, thus enabling to identify which prerequisites have the greatest influence on the occurrence of wastes.

The graphic representations chosen for data analysis were: hierarchical tree (to obtain a Diagram with the relations between the wastes by prerequisites, categories, and impacts), funnel (to analyze the construction stages and their relationships with the teams of works with the highest occurrence of wastes) and ranges (to identify the relationships between the chosen parameters, and how the prerequisites, categories and impacts interacted with the database), as they better present the analyzed results.

The 156,762 compliance and non-compliance data from the companies were analyzed according to the distribution shown in Table 3. From the 8,842 non-conformities analyzed, 6,339 instances of data were classified. The reduction of the database for the classified data is justified by the absence of response or inconclusive answers for the Quizquality fields: "characteristic description", "problem response" and "correction action response", making it impossible to classify the data according to the spreadsheet used by the research group. Table 4 shows three cases that make it impossible to tabulate the data.

Table 3: Database extracted from QuizQuality.

Company	Database	Analyzed Data		Classified Data	
M	63,618	6,367	10.01%	4,770	7.50%
N	63,601	1,887	2.97%	1,077	1.69%
O	26,923	512	1.90%	460	1.71%
P	41	41	100%	15	36.59%
Q	34	34	100%	17	50%
R	2,545	1	0.04%	0	0%
	156,762	**8,842**	**5.64%**	**6,339**	**4.04%**

Table 4: Examples from the analyzed database that were not classified.

Item	Feature Description	Problem Answer	Response Action Containment
1	*Shafts* Compartmentalization with drains	Locked Hydraulic *Shafts*	Not defined
2	Painting Walls and Frames - Stains	Room 01 - Stains on the wall	Repaint wall
3	Operation	Does not turn on	Repair

It was necessary to individually analyze each non-compliance provided by the companies to classify the data, which were subsequently tabulated in Microsoft Excel®. Then, a Microsoft Power BI® dashboard was developed from this data to provide an interactive data analysis and the parameters to be analyzed were chosen. These in turn were divided into eight items related to prerequisites, eight to categories, and seven to impacts for making-do wastes.

Step 05: Alignment meetings between partners.

Alignment meetings were held with all the companies participating in the study to present and discuss the results and analyzes, and to establish new theoretical frameworks aimed at reducing wastes in the production process, including new concepts and classifications about wastes.

TEAMS AND STEPS INVOLVED

The non-conformities found had a concentration of 54.33% of the data related to the coating and finishing stage, and 19.03% for installations and appliances, as shown in Table 05. It is believed that this percentage (54.33%) is related to the more complete recording of non-conformities in the final inspection stages, with repair needs for receiving the housing unit by the client since all the identified problems must be solved, thereby resulting in a greater recurrence of non-conformities described/detailed by the team involved in filling in this data.

Table 5: Wastes by classified stages.

Step	N.º	%
Coating and finishing	3,444	54.33%
Fixtures and fittings	1,206	19.03%
Structure	723	11.41%
Walls and panels	538	8.49%
Completion of the work	404	6.37%
Initial Services	22	0.35%
Covers and protections	2	0.03%
Total	**6,339**	**-**

Problems in the main stage of cladding and finishing were identified in the wooden doors, such as damage and malfunctions in the stops and jambs, requiring adjustments and/or replacement. Additional problems were identified in floor trims, malfunctions and/or changes in tone and/or the presence of stains on the ceramic tiles.

Regarding the teams involved, we conclude that the carpenter, bricklayer, tiler, janitor, plumber, and painting teams presented the most non-conformities, with 22.68%, 16.26%, 14.45%, 13.87%, 9.69%, and 8.69% respectively.

These teams were mainly related to the coating and finishing stages and to installations and appliances, suggesting a need for monitoring and training of these teams so that there is a reduction in these non-compliance occurrences.

ANALYSES OF THE PREREQUISITES, THE CATEGORIES, AND THE IMPACTS OF MAKING-DO

From the analyses of non-conformities in the database, it was found that labor (52.75%) and materials and components (26.69%) were the prerequisites that showed the most associated wastes. The labor wastes were related to execution problems in the coating and finishing stages (57.12%), involving the mason (27.06%), carpenter (21.02%), and tiling (15.40%) teams, directly impacting the execution and completion of the services.

The wastes related to materials and components were linked to problems in the supply and use of the material, being associated with the "covering and finishing" (51.06%) and "installations and appliances" (16.84%) stages from applying non-compliant materials (e.g., damaged window frames; ceramic coating with stains or changes in tone), materials in insufficient quantities (i.e. electrical material), or materials with higher performance than those specified or requested in the project (i.e. steel).

The prerequisites of labor and materials and components were related to the highest impacts of rework (41.63%) and lack of completeness (33.27%), which are intrinsically related to the characteristics of the most recurrent stages (Figure 01).

The analysis of the non-conformities shows that labour, materials, and components are the main prerequisites related to the associated wastes, with 52.49% and 26.6%, respectively (Figure 01). The adjustment of components category can be understood as adjustments made on-site to speed up the service or simply adapt it to what should be done, justifying its relationship with the stages of "coverings and finishing" and "structure", corresponding to 42.31% and 19.87% of the cases identified, respectively, as well as "installations and appliances" and "panels", corresponding to 19.13% and 13.18% of the cases identified, respectively. The impact of this category on the structure, wall and panel stages occurs more frequently since the laborers end up making decisions on-site without consulting those responsible for their work.

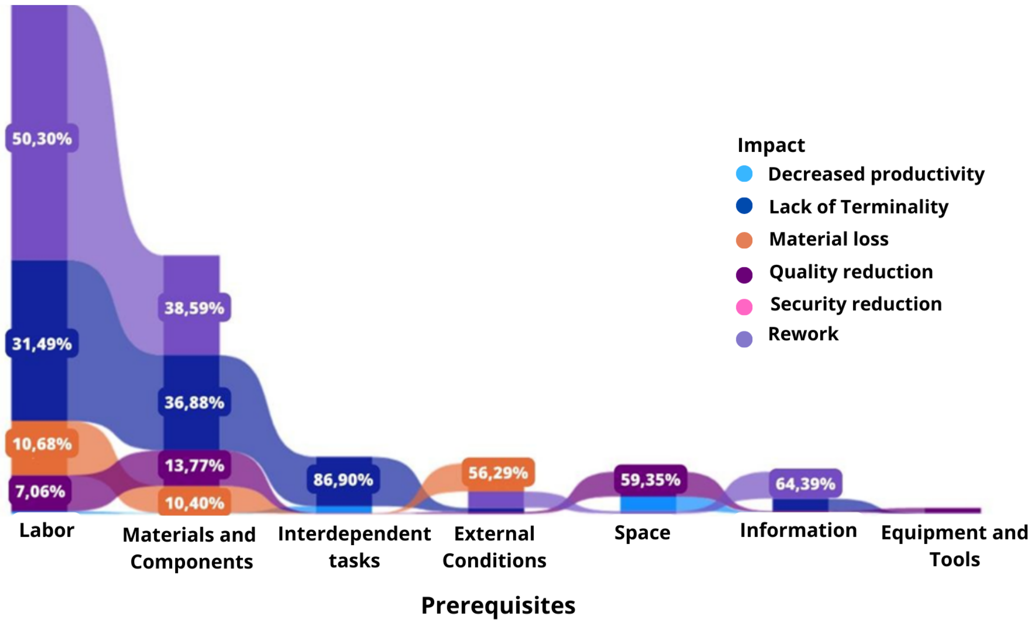

Figure 01: Correlation of wastes between prerequisites and impacts.

Next, the "sequencing" category has "coatings and finishing" (47.52%) as its main associated stage, and "lack of completeness" (70.12%), "rework" (19.07%), and "reduction in quality" (8.11%) as its main impacts. The main prerequisite regarding company "M" was labor (47.34%), followed by materials and components (31.97%) and external conditions (6.96%). The categories of greatest influence were component adjustments (44.03%), sequencing (23.94%), and storage (12.91%). The main impacts were in rework (39.12%), lack of completeness (33.48%), and material loss (12.52%).

The main prerequisite found when analyzing company "N" was labor (69.55%), followed by materials and components (11.42%) and interdependent tasks (9.66%). In addition, the categories of greatest influence were component adjustments (84.77%), sequencing (10.31%), and access/mobility (3.25%). The main impacts were rework (46.80%), lack of completeness (33.61%), and material waste (10.96%).

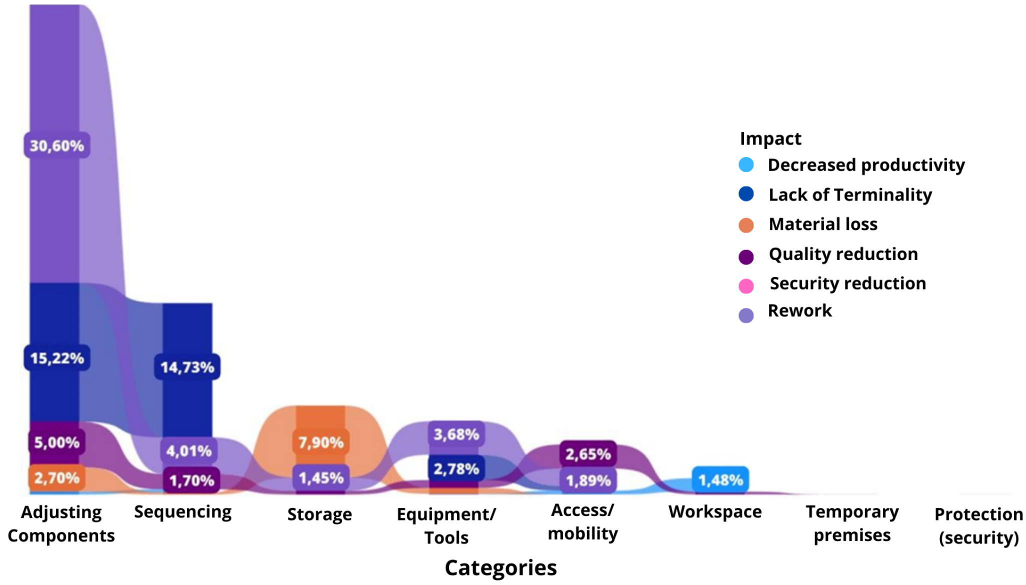

Figure 02: Correlation of wastes between categories and impacts.

The main prerequisite found for company "O" was labor (71.09%), followed by information (10.43%) and interdependent tasks (9.35%). In addition, the categories of greatest influence were component adjustments (81.96%), sequencing (15.65%), and work area (1.09%). The main impacts were rework (56.74%), lack of completeness (31.52%), and reduction in quality (8.04%). Next, the main prerequisite found by analyzing the data from company "P" was labor (33.33%), followed by materials and components (26.67%) and information (20.00%). Moreover, the categories of greatest influence were component adjustment (53.33%) and sequencing (46.67%). The main impacts were presented by rework (4.00%), lack of completeness (33.33%), and material waste (20.00%).

Next, the main prerequisite for company "Q" was equipment and tools (58.82%), followed by labor (29.41%) and materials and components (11.76%). The most influential categories were component adjustments (88.24%) and equipment/tools (11.76%), while the main impacts were presented by quality reduction (82.35%), rework (11.76%), and productivity decrease (5.88%).

From an overall perspective, it is concluded that the prerequisites of greatest influence among the companies are labor (52.75%), followed by materials and components (26.69%) and interdependent tasks (5.90%). Furthermore, the categories with the highest occurrence are related to component adjustments (53.84%), sequencing (21.01%), and storage (9.76%). The main impacts were rework (41.63%), lack of completeness (33.27%), and loss of material (11.50%).

DISCUSSION

The hierarchy diagram graph shows the relationships between the prerequisites, categories, and impacts. The center represents the total number of impacts recorded in the database, while the total value is highlighted in blue, and the quantities and lines under analysis are different from each other on both sides (Figure 3). In Figure 3, two diagrams are shown, split between the left and right-side diagrams, of the relationship between the prerequisites, categories, and impacts. The center represents the total number of impacts recorded in the database, while from the total value (center) the quantities and lines are highlighted in blue, which are different from each other for both sides.

From the analysis of the missing prerequisites related to the city of Fortaleza, it is possible to see that labor (52.75%), materials and components (26.69%), and interdependent tasks (5.90%) presented the most associated wastes. The main categories related to wastes are component adjustments (53.84%), sequencing (21.01%), and storage (9.76%). In addition, rework (41.63%), lack of finishing (33.27%), and material waste (11.50%) represent the main impacts related to wastes (Figure 3).

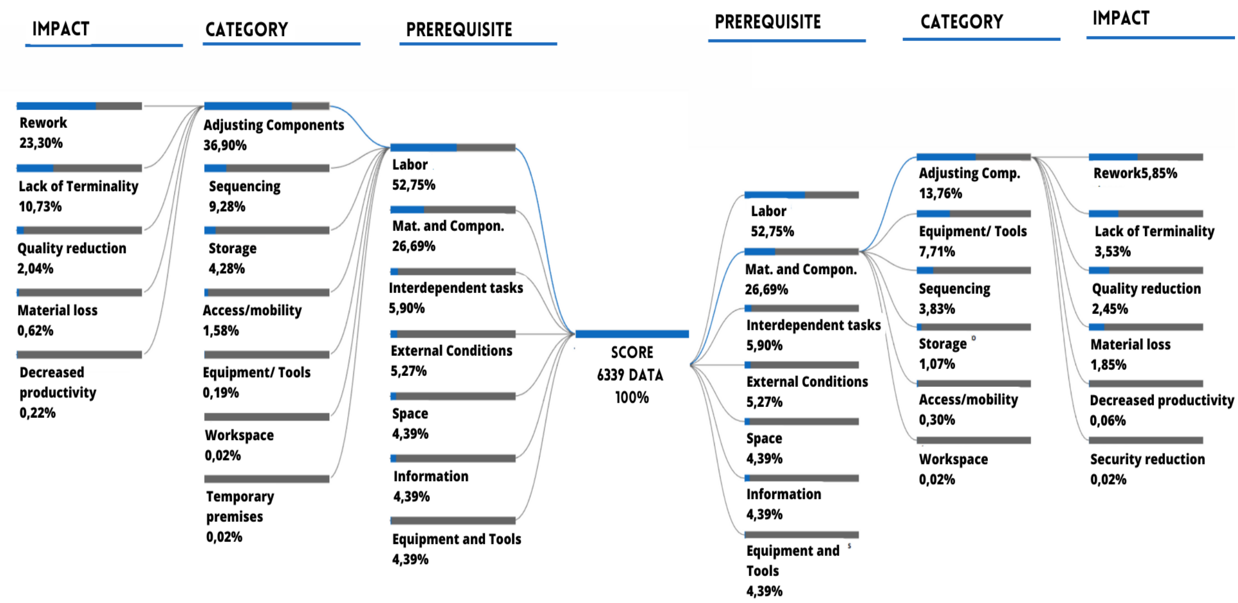

Figure 3: Diagram of the relations between wastes per prerequisite, category, and impacts - Fortaleza Results.

The teams involved in the analyses were: carpenter (22.68%), bricklayer (16.26%), tiler (14.45%), laborer (13.87%), plumber (9.69%), and painter (8.69%); while the percentages show the team that presented the highest non-conformities. Through these data, the labor prerequisite can be justified by its unavailability in terms of quantity and/or skills needed by the work teams, specifically the carpentry (22.68%), bricklayer (16.26%), and tiling (14.45%) teams, who contributed to the impact of wastes mainly related to rework. With this in mind, we suggest actions aimed at identifying the need for requalification, monitoring the services performed, the need for adequate dimensioning of the construction management, and better selection and supervision of the companies outsourced for the execution of the services.

CONCLUSION

The aim of this work was to identify associations between each of the causes and effects considered individually, or the mechanisms which direct such relationships; as a result, it is concluded that making-do wastes can occur in different ways, and there are numerous possible combinations between prerequisites, categories, and impacts on the construction environment. Different enterprises, regions and cultures have different prerequisites. Uniformly using average results and implications is not applicable.

Improvisations are present at all the construction site stages, making it difficult to identify and avoid them, requiring strict control of construction processes, investments in cultural change conducive to improvisation and standardization. Only surveying wastes by making-do does not provide enough information for the manager to prevent them from occurring in their next undertaking or task, but it does provide a more robust and interactive analysis of information to minimize them.

With the study it is concluded that instead of the manager concentrating their efforts on correcting all the intercurrences identified in the construction site, they will be able to concentrate resources and management in the stages, teams, and processes which most contribute to greater impacts, or those which are more significant in terms of costs or delays in the works in order to achieve better results. From this particular study, these efforts should be directed towards requalifying the workforce, investments in materials and components which are compatible with the dimensions established in projects, and investments in medium-term planning in order to eliminate interdependent tasks; and lastly, it is still extremely important to analyze the risks linked to the impacts of rework that are directly associated with the decrease in productivity, the waste of material and the lack of terminality and quality reduction.

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