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# RELATIONS BETWEEN PRECONDITIONS, CATEGORIES AND IMPACTS OF MAKING-DO WASTES

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## ABSTRACT

Civil construction is known for its high production of waste and low productivity. Understanding the causes of making-do waste makes it possible to minimize waste in construction processes. This study aims to analyze possible causes and consequences among possible relations between prerequisites, categories and impacts of making-do waste in order to act more effectively in combating waste reducing the main problems identified that cause their occurrence. Some existing prerequisites can be determined: information, materials and components, and labor, are highly likely to occur. Concerning the categories, the following can be highlighted: component adjustment, sequencing, and storage. These combinations generally affect the seven impacts caused by making-do waste. The main contribution of this study was to analyze the possible causes and consequences of the relationship between prerequisites, categories and impacts of making-do waste. Using the dashboard developed in the Power BI platform, relations between the chosen parameters could be determined, and how prerequisites, categories and impacts interacted with other variables in the database.

## KEYWORDS

Making-do. Improvisation. Waste. Rework. Business intelligence.

## INTRODUCTION

Studies in different countries indicate that construction waste represents 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).

In the construction industry, high production costs are related to waste throughout the construction processes and should be understood as any inefficiency when using equipment, materials, labor, and capital (Formoso et al., 1997; Viana; Formoso; Kalsaas, 2012).

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In the current scenario of the civil construction sector, productivity is a constant concern for any construction company to establish itself competitively in the market, facing fierce competition and increasing demands for quality and performance by clients. The lack of a strategic vision from managers work needs interferes with productivity and causes waste related to production actions.

Koskela (1992) marked a milestone in terms of translating the principles and practices of lean production for construction, including the concept of wastes as proposed by Ohno (1988) and the Seven Wastes of TPS (Toyota Production System). Later, Koskela (2004) suggested an eighth category of waste, which is a characteristic of construction called making-do, arising from situations in which a particular task is started or continued without all the resources necessary for its execution being available or the execution of a task is continued although the availability of at least one standard input has ceased Formoso et al., 2017).

Several studies have been conducted aiming to identify causes and effects of making-do waste in construction, notably Sommer (2010) and Fireman (2012). However, few studies have sought to identify specific cause-and-effect relationships related to this type of waste.

Making-do waste can occur in different ways. There are numerous possible combinations of prerequisites, categories and impacts in the construction environment. Authors highlight that improvisation can be found at all stages of the construction site, making it difficult to identify and avoid them, 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).

Formoso et al. (2011), Leão (2014), Formoso et al. (2015), Formoso et al. (2019), Fireman & Formoso (2013), Saurin and Sanches (2014) and Kalsaas (2012) reported difficulties in identifying and classifying making-do waste, thus pointing to the need to improve the methods used.

Another gap highlighted by some authors is the need to develop more quantitative analysis and acceptable limits of classification of making-do waste (SAURIN; SANCHES, 2014). Given these gaps, this article aims to analyze the possible causes and consequences of the relationship between the prerequisites, categories and impacts of wastes related to making-do, using a dashboard developed on the Power BI platform.

# THEORETICAL FRAMEWORK

## IDENTIFICATION AND CLASSIFICATION METHOD OF MAKING-DO WASTE

Based on the classification of input flows in construction processes, Sommer (2010) proposed a method to identify making-do practices at construction sites. This proposal took into account the assumptions made by Koskela (2004), Santos (2004), Ballard (2000) and Machado (2003).

Table 1 summarizes a method of classifying making-do wastes based on identification (category), precondition and impact (evaluation) proposed by Koskela (2000), Sommer (2010) and Fireman (2012).

Importantly, the category entitled "Sequencing" emerged from Fireman & Formoso's (2013) studies but had been cited previously in a study conducted by Ronen (1992) and Santos (2004).

Table 1: Classification of making-do waste. Source: Santos and Santos (2017).

| IDENTIFICATION/CATEGORY | AUTHOR | PRE CONDITION | AUTHOR | IMPACT/ EVALUATION | AUTHOR |
|---|---|---|---|---|---|
| Access/ Mobility | Sommer (2010) | Information | Sommer (2010) Koskela (2000) | Low productivity | Sommer (2010) |
| Adjusting Components | | Materials and Components | | Decrease in quality | |
| Workspace | | Manpower | | Rework | |
| Storage: stock of materials or components | | Equipment/ Tools | | Material Wastes | |
| Equipment/tools | | Space | | Compromises safety | |
| Interim installation: water and electricity supply | | Interconnected Services | | Demotivation | |
| Protection | | External Conditions | | Lack of Terminality | Fireman (2012) |
| Sequencing | Fireman (2012) | Facilities: workspace infrastructure | Sommer (2010) | | |

In the two studies by Sommer (2010) A and B, the most affected category was access and mobility, accounting for percentages of 36% and 33%. In Amaral et al. (2019), the most affected category in the three studies A, B, and C was sequencing with 32.5%, 45.5%, and 46.2% respectively. In Amaral et al. (2020), sequencing appeared first as the most affected category with 41.55%. In Santos et al. (2020), although the most affected category was sequencing for study A, with 28.6%, the adjustments and components category can be mentioned as they accounted for 21.4%, which were the most evident in studies B and C with 35.3% and 58.3%, respectively. According to Santos et al. (2020), the category adjustments of components was observed in different situations: change of material specified in project and reuse of material previously used or that had damaged parts.

# RESEARCH METHOD

## RESEARCH CLASSIFICATION AND SELECTION CRITERIA

Data from this research, an exploratory and descriptive study, were carried out using surveys in nine construction companies in Goiânia/GO, with thirteen projects, two companies in Fortaleza/CE, and one construction company in Toulouse/France. The purpose was to identify events that cause making-do wastes.

The criteria used to select the companies were: 1) Interest in participating in the research; 2) having a Quality Management System (QMS), allowing access to information such as: standardized and documented work instructions, plans, budgets and their follow-ups, service verification forms, among others; 3) current projects that produced data collection for the research.

The companies worked with high-standard buildings and multi-storey commercial buildings. Only one company has no certification, and the others have PBQP-h - level A (a specific quality Brazilian program for the building industry) and ISO certifications. After defining the companies, they were characterized. The stage of execution in which the work was executed at the time the survey was recorded (Table 2).

Table 2: Characterization of the Enterprises.

| Company Code | Code Work | Description | Total Enterprise Area (m²) | Type of labor | No. of storeys |
|---|---|---|---|---|---|
| A | A | High-end residential townhouse | 432,00 | Own | 1 |
| B | B | High-end multifamily building | 31,128,20 | Own | 34 |
| C | C | High-end multifamily building | 30,221,85 | Outsourced | 36 |
| D | D | Medium standard residential building | 31,698,24 | Own | 27 |
| E | E | High-end multifamily building | 12,706,83 | Own and outsourced | 28 |
| F | F | High-end multifamily building | 26,341,54 | Own and outsourced | 38 |
| G | G | Shopping Center | 11,062,88 | Own | 6 |
| H | H-E1 | Medium standard residential building | 47,789,71 | Own | 28 |
| | H-E2 | High Standard Vertical Residential Condominium | 16,000,000,00 | Own | 1 |
| I | I-E1 | Medium standard residential building | 20,853,13 | Own | 27 |
| | I-E2 | Hotel/ Residential Building | 19,572,45 | Own | 28 |
| J | J-E1 | Medium standard residential building | 27,169,88 | Own and outsourced | 28 |
| | J-E2 | Medium standard residential building | 29,279,84 | Own and outsourced | 29 |
| K | K | Retrofit work | 23,219,83 | Own and outsourced | 1 |
| L | L | Medium standard residential building - 3 towers | 43,044,63 | Own and outsourced | 20 |

The analysis began with a comprehensive data collection, which involved some research tools such as: questionnaires to characterize the companies and construction sites; questionnaires to investigate the planning process; semi-structured interviews conducted with Production Managers, Team Members, Directors; documental analysis (photos, designs, drafts, notes and documents). Table 3 details the material and method used for data collection to support future discussions.

Table 3: Materials and methods used in the research.

| ACTIVITY | PARTICIPANT | DATA COLLECTION |
|---|---|---|
| Awareness of the problem | – Production managers.<br>– Team members.<br>– Directors. | – Non-participant observations at construction sites for *making-do* waste data surveys.<br>– Data survey stored in the QuizQuality management platform.<br>– Semi-structured interviews on the routines and processes (cost estimates, problems with lack of completeness, planning and monitoring). |
| Understanding of the company management and its enterprises | – Directors.<br>– Engineers responsible for the company's planning.<br>– Production managers;<br>– Team Members. | – Analysis of the short, medium, and long term planning of the enterprises. |
| Suggestion and Development | – Production managers.<br>– Team Members. | – Meetings to discuss and adjust information about the workflow and routines. |
| Evaluation and Conclusion | – Directors.<br>– Production managers.<br>– Team Members. | – Alignment meetings between the partners to present the most relevant results of the research.<br>– Discussion rounds with the focus groups to evaluate the protocol for surveying and analyzing *making-do* wastes. |

These documents were analyzed to prove the facts and obtain a correct classification of the wastes. Having this information, at the end of each follow-up, the projects and respective activities were analyzed to prove possible execution errors, which could cause or influence wastes that had been identified.

## RESEARCH AND DATA COLLECTION STEPS

The stages of the research are described below.

Step 1: Identifying making-do wastes events.

Visits were made, whose non-participant direct observations were the main sources of collected evidence. Thus, we sought to identify the events that generated making-do wastes, in order to classify, define the origin and their impacts. The wastes were separated into stages and sub-stages according to the predefinitions of NBR 12721 (ABNT, 2005).

Step 2: Defining a protocol for making-do wastes.

Based on the previous studies, data collection protocols were proposed. The causes, categories and impacts of making-do wastes were defined. The wastes were classified according to the stages and sub-stages following the predefinitions of NBR 12721 (ABNT, 2005). The impacts were classified according to the adopted parameters of decreased productivity, demotivation, material waste, rework, reduced safety, reduced quality and lack of terminality (Ronen, 1992; Koskela, 2004; Fireman & Formoso, 2013).

Based on the waste information formatting in Microsoft Excel® format, a dashboard was developed for data processing in Microsoft Power BI® to provide an interactive data analysis (Caldini; Varela, 2020). The software made it possible to perform interactive graphical analysist so as to interact and reflect on the results (Lopes, 2020). When integrating the database with Microsoft Power BI®, the parameters to be analyzed were chosen. They were divided into eight items related to the prerequisites, eight for the categories and seven for the impacts.

Stage 3: Understanding the company management and its ventures.

To this end, it was necessary to have access to information about the short, medium and long term planning and the schedule. We tried to understand if the wastes were due to failures in planning the work, what the level of control of the executing company was, in which stage the waste occurred, and what the impacts were on the initial planning.

It was identified whether the wastes originated from the subdivision of the formal or informal work packages. The formal packages are those that are planned and executed according to the initial planning and informal ones are the tasks related to the correction of previously executed work; inclusion of tasks required due to the fact that a work package was not completed in the previous (planned) week; and new work packages that were not planned for that week or in planned batches but did not follow the planned sequence (Fireman & Formoso, 2013).

Step 4: Graphical representations chosen for data analysis.

The distribution of making-do wastes were interpreted by the graphs of the hierarchical tree diagram and the analysis was done in Microsoft Power BI® (Figure 1). Based on this interpretation, the waste count can be analyzed sequentially from the prerequisites, categories and impacts of these wastes, thus enabling us to identify which prerequisites have greater influence on the occurrence of wastes.

The graphical 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 enable the analysis of the work stages and their relations with the teams with higher occurrence of wastes), and tracks (to identify the relations between the chosen parameters, and how the prerequisites, categories, and impacts interacted with the database), to present a better presentation of the analyzed results.

Step 5: Validation by the companies of the protocol for surveying and analyzing making-do wastes.

Alignment meetings between partners to present the most relevant results of the research and to evaluate the protocol for surveying and analyzing making-do wastes.

## FINDINGS AND RESULTS

The distribution of making-do wastes can be interpreted by the graphs of the hierarchical diagram analyzed in Power BI (Figure 1). Thus, it was proposed to analyze the waste count sequentially from the prerequisites, categories and impacts of the making-do wastes. This identified that the prerequisites of information and materials and components are the most influential, respectively.

In Figure 1, 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. Thus, on the left of Figure 1, it is highlighted in blue that, from the prerequisite information, the category with the highest number of wastes is component adjustment (52%), followed by sequencing (37%), as both match the fact that the information is directly related. Moreover, the highlight (in blue in Figure 1) from adjustment and components present rework as its main impact, corresponding to 57% of the wastes, and it can also be identified that the data are consistent, as the lack of information causes adjustments, and consequently, rework.

On the right side of Figure 1, the prerequisite materials and components, with the category component adjustment (44%), followed by sequencing (38%) as the category with the highest number of wastes are highlighted in blue. Moreover, the blue highlight of the component adjustment category has quality reduction (53%) as the main impact.

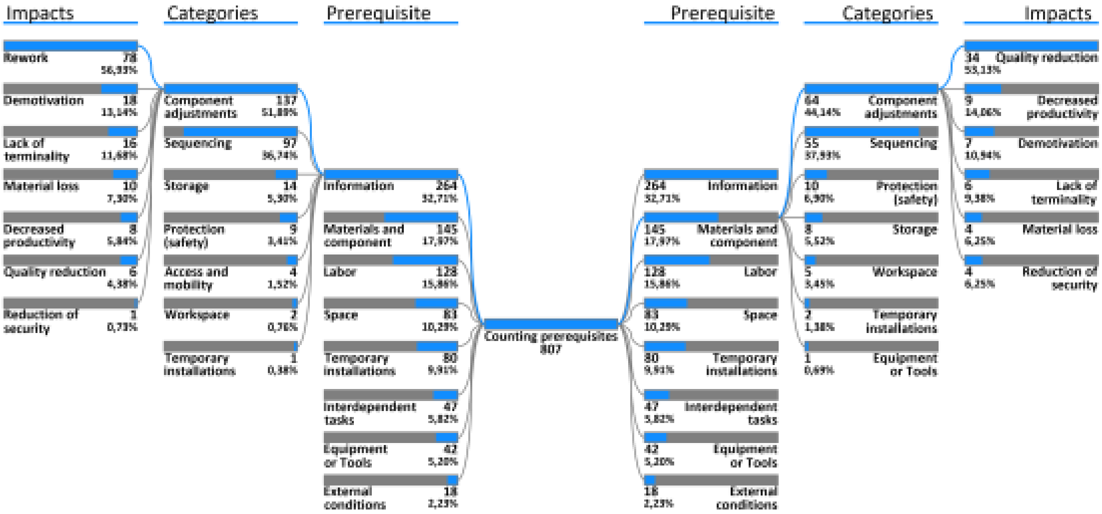


Figure 1: Diagram of the relationships between wastes by prerequisite, category, and impact.

Both present coherent analyses as materials are directly related to wastes regarding their adjustment. Appropriate materials and incorrect sequential use of materials are not necessarily used. When the adjustment of components is emphasized, it is the reduction of quality that is the main impact, accounting for 53% of the wastes. The understanding of the relationship of these topics is also coherent, because when inappropriate materials are used, there is a consequent reduction in the quality of the final service.

In Figure 2, the total wastes related to making-do are presented by the work stages analyzed, in order to present a more specific analysis. The data were highlighted in blue for the bricklayer teams (left side) and for the design team (right side), presenting 42% and 12% of the total, respectively (Figure 2), highlighted by the significance of the impacts in making-do wastes.

When analyzing the construction stages, the design team has the highest number of wastes when related to stages such as technical services (61%) and infrastructure, because it is identified that there are wastes related to exchanging information between the designers and the work and in infrastructure services. Thus, it can be identified that there are problems arising from project conceptions, as the impacts generated by the lack of technical service are related to the details and definitions that need to be passed on to the execution team. Moreover, it is identified that the infrastructure projects present deficiencies in terms of their scope and detailing, because 42% of the impacts generated by this service are due to errors in the projects and surveys made in the field by topography designers.

Meanwhile, when analyzing the stage per bricklayer team, it is possible to see that the services of provisional installations (68%), wall and panels (49%), superstructure (50%) and hydro-sanitary installations and gas (53%) are the ones that present the greatest wastes from the total corresponding to the stage, because they are intrinsically related. Thus, the team executing the service generates a greater rework of the activities already performed due to problems related to a lack of information. This is often due to errors in the interpretation of the projects, or in their preparation, as well as the lack of defining the constructive sequencing and in adjusting components, which often depend on the speed of the manpower itself.

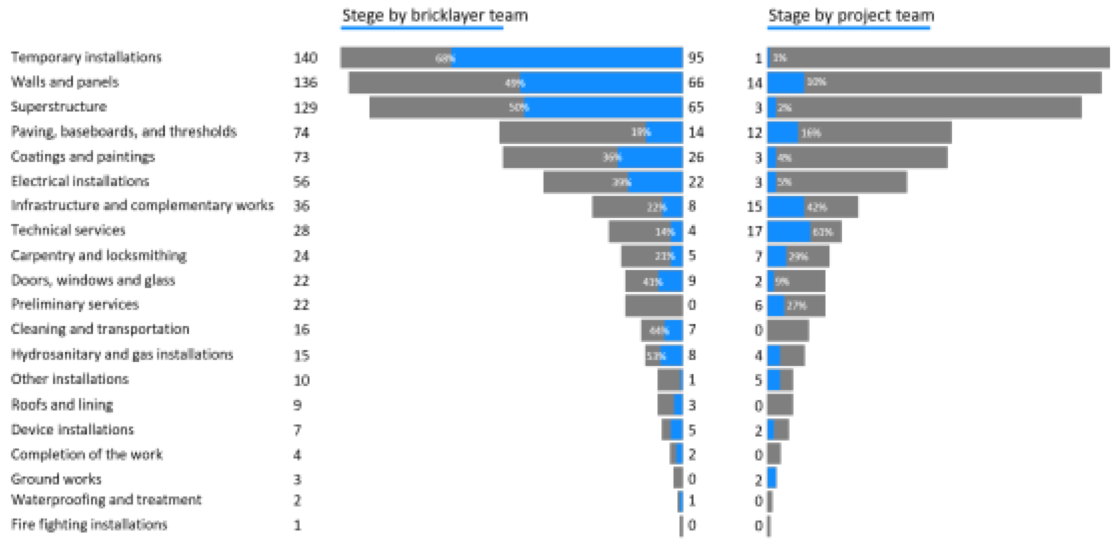


Figure 2: Analysis of the construction stages highlighted from the bricklayer and design teams.

Based on the analysis of the main occurrences of wastes, segmenting the prerequisite information (33% of the total) and the sequencing category (34% of the total), it can be observed that the information is intrinsically related to the performance of wastes in the design team and the engineering team (Figure 3), with 91% and 52%, respectively. Thus, the technical teams ended up retaining information necessary to avoid constructive problems, as well as the need for possible changes and rework. Moreover, the sequencing category directly affects the design and management teams, therefore it can be inferred that the lack of definitions of the designers and management, as well as the needs of physical progress of the work, corroborate with constructive sequence problems.

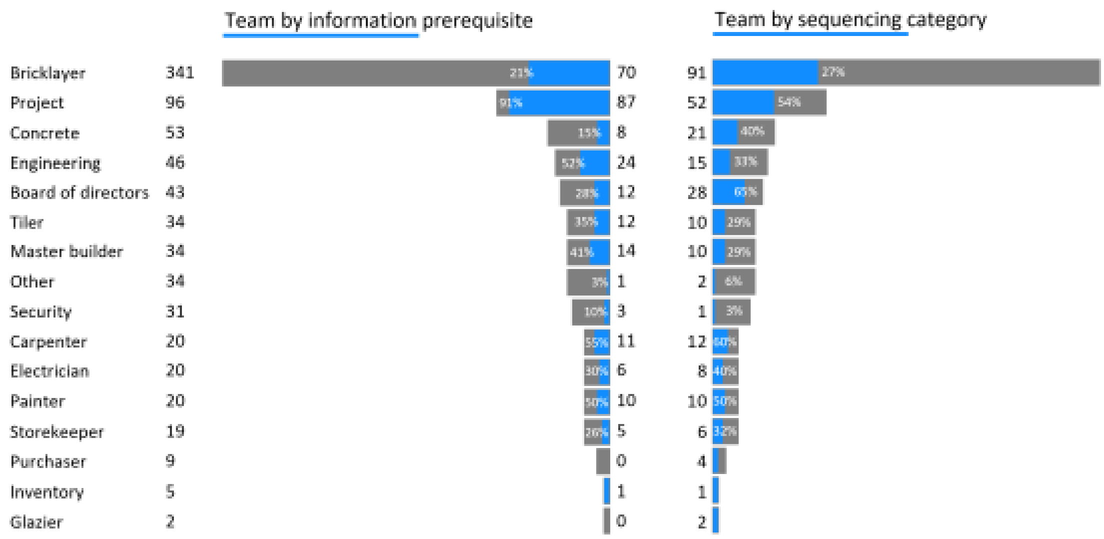


Figure 3: Information prerequisite and sequencing category analysis highlighted from the teams.

In Figure 4, making-do wastes are analyzed related to the prerequisites and impacts. Thus, it can be identified that rework (57%) corresponds to the greatest impact in all prerequisites, especially the impacts related to deficiency of information, materials and components and labor, which together account for 67% of the wastes. Thus, it is identified that in addition to the information, the materials used in the services are inadequate or incorrectly applied, generating rework, as the workforce is sometimes unqualified or not qualified with the necessary information to carry out the task.

Furthermore, it can be analyzed that problems related to information deficiency and adopting an unusual construction sequence end up leading directly to rework, representing 87% of the cases. The other impacts present a more uniform distribution throughout the prerequisites, as 56% of the rework wastes are concentrated in the bricklayer, design, and engineering teams.

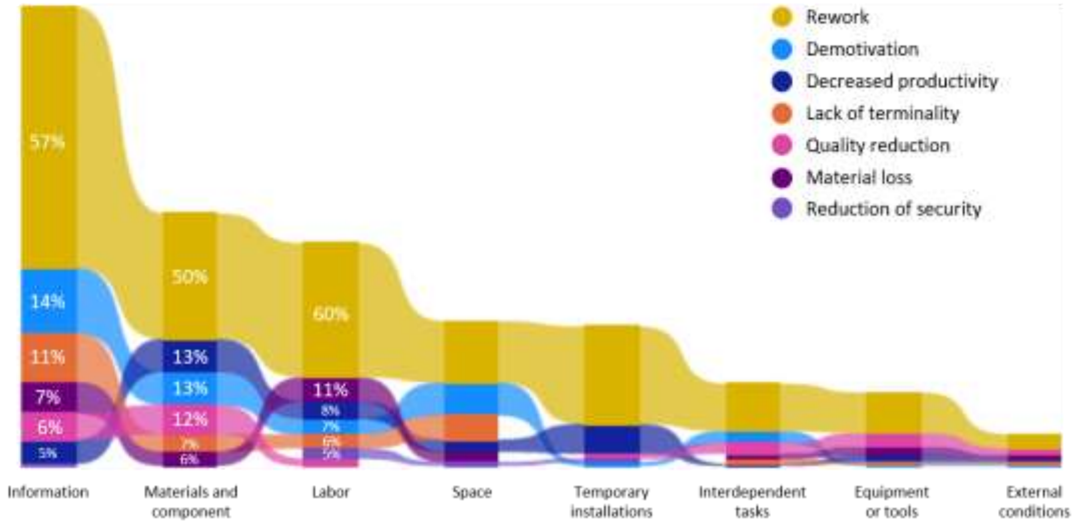


Figure 4: Waste count for prerequisites by impact.

In Figure 5, the waste counts per making-do are analyzed from the categories by impact. Considering this, it can be seen that *component adjustment* and *sequencing* present 34% of the total amount in both categories.

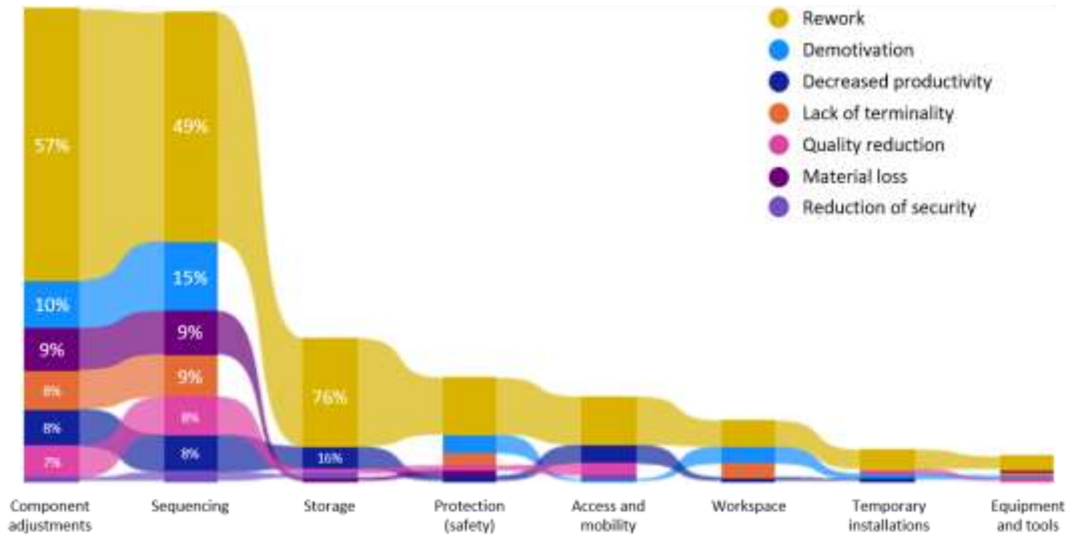


Figure 5: Waste counts for the categories by impact.

When analyzing the *component adjustment* and *sequencing* categories, it can be observed that the impacts are also related to the *information and materials and components* prerequisites, presenting a greater synergy between these variables. Considering this, it can be inferred that the execution team ends up having to determine definitions that will impact on wastes related to making-do. Thus, it is identified that *rework* is the item that represents the largest number of wastes in all categories of analysis, and it can be highlighted that *storage* presents high rates of wastes, as unnecessary transportation takes place at the construction site. Meanwhile, the other impacts are distributed in the other categories.

Table 4 shows a summary consisting of the categories, prerequisites and impacts that most influenced making-do wastes. Thus, it was identified that the database presented the main prerequisites similar to those reported in the literature, as is the case of information and materials and components. In the case of the category as component adjustment and sequencing it can be related to the improvisation character, also due to the lack of information reported as a prerequisite, of the construction companies reported in the database. The main impact is identified as rework, which is characterized by improvisation and inadequate execution of the services identified.

Table 4 – Comparison between researches related to making-do wastes.

| | OUR DATABASE | SOMMER (2010) | FORMOSO (2017) | ELIAS AND BRANDÃO (2018) | BRAGA (2018) |
|---|---|---|---|---|---|
| **MAIN CATEGORY** | 34.08% Component adjustments. 33.83% Sequencing. | 34.50% Access and mobility. | 34.50% Access and mobility. | 41.40% Sequencing. | 37.18% Protection. |
| **MAIN PREREQUISITE** | 32.71% Information. 17.97% Material and components. | 81.50% Installations. | 81.50% Workspace infrastructure. | 27.30% Information. | 27.47% Installations. 20.00% Material and components. |
| **MAIN IMPACT** | 55,51% Rework. | 72.00% Reduced safety. 72.00% Materials waste. | 70.50% Material waste. 65.00% Reduced safety. | 24.00% Rework. | 45.12% Reduced safety. 26.67% Quality reduction. |

# CONCLUSIONS

The relationships between the chosen parameters were observed, and how the prerequisites, categories and impacts interacted with the other variables in the database using the dashboard developed in the Microsoft Power BI® platform.

Regarding the prerequisites, the *information* item (33%) is the one that presented the highest number of associated wastes and was strongly related to the *component adjustment* and *sequencing* categories. Thus, the *component adjustment* and *sequencing* categories presented, in both variables, 34% of the total analyzed, which were the categories with the main bottlenecks in solving problems with *making-do* wastes.

The technical department should detail all the necessary information for the production teams at the design stage. In addition, the supply management must supply all the production and internal logistics' needs to reduce wastes related to sequencing and adjustment of components.

The limitations of the research are related to the sample analyzed, and there may be an expansion of data and inclusion of the analysis in different countries, states, and construction typologies. Considering this, the database may present a greater variability of samples to better understand the most diverse situations and civil construction companies. Future research may focus on expanding the sample to other regions, through institutional collaborations, either nationally or internationally. In addition, the database can be used to develop a model to help identify prerequisites and categories by detecting existing impacts in the construction site.

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