Interpretive Structural Model-based for Analysis of Causes of Delays in Construction Projects: The Portuguese Case

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Abstract: Delays are a common issue in construction projects worldwide, and they can frequently have an influence on time and cost overruns, among other problems. This study aims to add to the knowledge on construction project management theory and practice by identifying the leading causes of Delays in Construction Projects (DCP) in Portugal, modeling their interrelationships, and determining their main causes. The study presented herein adopted a two-phase methodology. First, based on the literature, the causes of DCP in Portugal are identified. Then the hierarchical structure of the causes of DCP is determined, using integrated Interpretive Structural Modelling (ISM), and an ISM-based Model is developed. The results show that the 16 causes of DCP taken into consideration are hierarchized in six different influence levels. The causes Bidding and contract award process and Lack of communication between parties are the most influential causes, and are thus considered to be the root causes of DCP in Portugal. Additionally, the results show that the causes of DCP can be divided into four different categories relating to Relationships and contract, Material, the Developer, and the Contractor. Finally, these results provide fundamental insights for practitioners and researchers to develop effective measures to mitigate the causes of DCP.

1 INTRODUCTION

Regardless of the type of construction project, delays are a global problem. A delay in construction is an overrun either past the date the contract parties agree upon to deliver a project or past the conclusion date stated in the contract. A project must be finished on time and meet the cost and quality requirements. Accordingly, the timely completion of a project is regarded as a significant parameter for measuring a project's success. Projects are prolonged or hastened to overcome delays, incurring unavoidable additional costs (Oyegoke & Al Kiyumi, 2017). The complexity of construction projects often makes it difficult to identify the causes of delays, which are frequently interrelated.

The Portuguese construction industry is no exception here, and delays are a disturbance for a significant number of construction projects. Accordingly, Portuguese construction companies must be alert to and comprehend the origins of delays. Such delays can be the cause of late conclusion of projects, reduced productivity, augmented costs, and even termination of the contract, all of which contribute to construction companies' ability to compete.

There has already been several studies on this issue in the literature. However, depending on the context, the origins of delays may differ. For example, they may be due to differences in culture, environment, construction methods, management system, geography, organizations involved, public policies, economic context, availability of resources, and the political climate (Zidane & Andersen, 2018). Additionally, for the most part, the existing studies focus on determining and ranking the causes of delay in construction projects and proposing some mitigation measures, in doing so, failing to understand the interrelationships. The main objective of this study is, therefore, to hierarchize the causes of

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delays in construction projects according to levels of influence and determine their root causes in the Portuguese context, with a view to improving construction project management.

This research project is structured as follows: first, a review of the literature on the causes of delays in construction projects is carried out; second, the research methods are presented; in the third section, the results are presented and analyzed; and fourth, and lastly, the conclusions and implications are drawn.

2 LITERATURE REVIEW

Given that the construction project process is a very complex one, incorporating the various stakeholders' priorities and concerns, covering numerous works, and requiring a long period to conclude, the causes of delays are multiple. Several researchers have studied the causes of delays in construction projects. Odeh and Battaineh (2002) concluded that the main causes of delays were inexperienced contractors, owner interference, delays in progress payments by the developer, slow decision-making by the developer, unsuitable planning, the low productivity level of the labor force, and difficulties with subcontractors.

A study carried out by Assaf and Al-Hejji (2006) showed that, in Saudi Arabia, contractors acknowledged that the leading causes of delays had to do with the developer, and developers and consultants considered that the highest recurrent cause of delay is the awarding of the contract to the lowest bidder. However, they all agreed that the developer changing orders during the construction phase is a fundamental cause of delay.

Fallahnejad (2013) studied the causes of delays in construction in Iran and concluded that the main causes were: incapacity of the contractors to deliver imported materials, questionable contract timelines imposed by the developer, slow provision of materials by the developer, time-consuming land expropriation due to resistance from occupants and changes to orders by the developer. For future research, the author acknowledged the necessity to define the root causes of delays and then develop mitigation measures accordingly.

Ruqaishi and Bashir (2015) determined that the main causes of construction project delays in the oil industry in Oman were: reduced site management by the contractor, difficulties with subcontractors, poor scheduling and planning by contractors, delays in the provision of materials, absence of proper communication between project stakeholders and little collaboration with vendors during the stages of engineering and procurement.

Oyegoke and Al Kiyumi (2017) studied the causes of delays and their effects on projects in Oman. They found that the primary causes were: selecting the lowest bid, the main contractor's poor financial situation, slow decision-making by the developer, and inappropriate construction planning by the contractor. As far as the major effects of the delays are concerned, the authors pointed to additional costs and project delays.

Zidane and Andersen (2018) researched the top ten universal causes of delay in construction projects. They compiled multiple studies conducted in different countries on the causes and used a global ranking index to select the "top ten universal delay causes" from the top ten delay causes for 46 individual countries. The top ten universal delay causes are changes to orders, late payments to the contractor, weak planning and scheduling, poor site management and control, poor design, inadequate contractor experience and building processes, contractor financial problems, developer financial difficulties, resource rupture, and low labor productivity and lack of skills.

More recently, Arantes and Ferreira (2020) identified the causes and the main underlying causes of delays in construction projects in Portugal. Six out of the ten most important causes of delays are also in the top ten universal delays (Zidane & Andersen, 2018). Factor analysis revealed six underlying causes: improper planning, poor consultant performance, inefficient site management, developer influence, bureaucracy, and sub-standard contracts.

Based on the literature, the leading causes of delays in construction projects reveal some variation in accordance with the type of project and the context/geography in which the project is carried out; this is aligned with the opinion of other authors (Lind & Brunes, 2015; Sambasivan & Soon, 2007; Sanni-Anibire et al., 2020). While there is a certain degree of consensus on the more significant causes of delays, these authors did find different, although related, sets of causes and present slightly different rankings for the importance of causes. However, some emerge as the most important causes (Zidane & Andersen, 2018). Moreover, to the best knowledge of the authors of this work, no studies consider the root causes of the delays based on the interrelationships between them.

The work presented here looks at the Portuguese context and emphasizes owners, consultants, and contractors in the construction industry. It intends to contribute to project management by hierarchizing the causes of delays in construction projects by influencing factors, determining their root causes in the Portuguese context.

3 RESEARCH METHOD

The present work adopted the two-phase methodology presented in Figure 1. In the first phase, the causes of Delays in Construction Projects (DCP) in the Portuguese context are identified. And in the second phase, it is established the hierarchical structure of the causes of DCP using the ISM methodology.

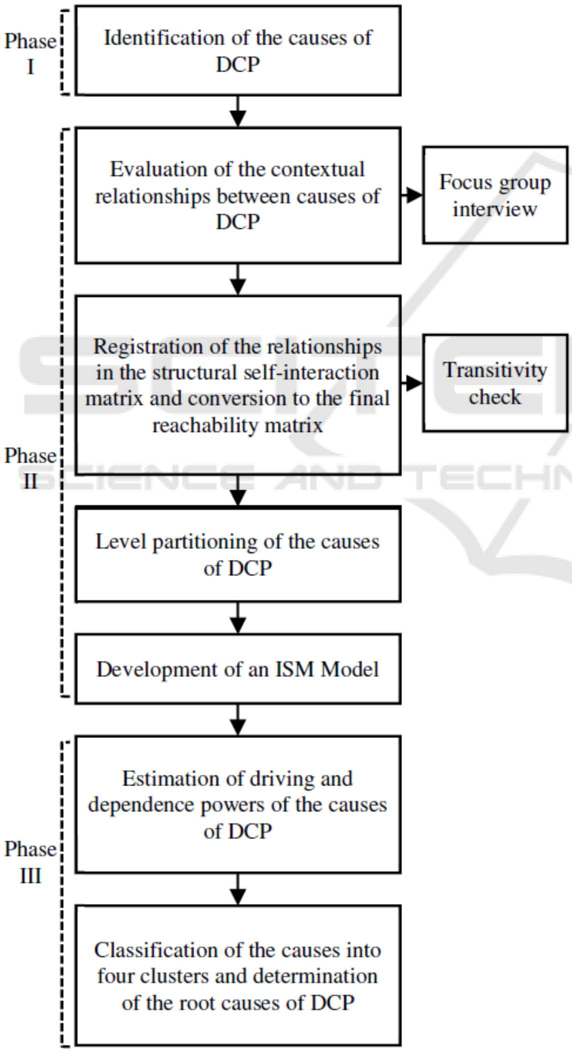

Figure 1: Methodology framework.

In phase I, a literature review is carried out on the causes of DCP in order to identify the leading causes of DCP in Portugal, as the focus group meeting experts belong to Portuguese construction companies.

In phase II, the ISM technique is used to identify and evaluate the interrelationships between the causes of DCP in Portugal, presenting a structural map of the causes and the interconnections between them, and highlighting the critical causes impelling the generation of DCP.

The ISM methodology evaluates if and how the multifaceted problem variables are linked, based on the judgment of experts (Gan et al., 2018). These judgments allow for the hierarchization of the interrelationships between the variables, and the translation of unclear mental models into visible and well-defined systems.

In the literature there are three Multi-Criteria Decision-Making (MCDM) techniques to develop structural hierarchies: DEMATEL, Fuzzy Cognition Map (FCM), and ISM. However, FCM and DEMATEL have clear limitations in comparison to the ISM methodology.

DEMATEL defines the ranking of alternatives based on their dependency but does not take into consideration all criteria, and the relative weights of experts are not aggregated to personal decisions of experts within the group assessments (Malek & Desai, 2019). Moreover, FCM requires hard optimization of all the membership functions' parameters and, sometimes, converges towards an undesired steady state. ISM overcomes these constraints; it classifies the multifaceted problem in various groups, which individually represent one segment of the problem. This is obtained through the practical experience and knowledge of the specialists. ISM provides insight into the interrelationships among different variables and assists in understanding the hierarchical way those variables are established, thus determining the order and direction of the multifaceted relationships among the variables of the complex system (Xu & Zou, 2020). These characteristics make ISM the most frequently used method in the literature and a secure approach for developing the hierarchy structural model (Malek & Desai, 2019). Furthermore, ISM can capture dynamic complexities, while other MCDM methodologies have difficulty representing real-life multifaceted problems and capturing dynamic behaviors (Shahabadkar et al., 2012).

ISM has been recently adopted in several studies related to the construction Industry. For example, Alzebdeh et al. (2015) examined ISM as a practical technique for modeling multifaceted interrelationships between factors in cost overruns in construction projects in the Sultanate of Oman. They verified that the application of ISM makes it possible to organize these factors in a hierarchical structure, demonstrating their interrelationships. Four factors were established as the root causes of cost overruns: instability of the US dollar, changes in governmental regulations, incorrect cost estimation, and weak coordination among parties involved in projects.

Gan et al. (2018) realized that few studies endeavored to investigate the complex interrelationships among barriers to the transition towards off-site construction in China. Consequently, they adopted the ISM technique to explore said interrelationships. The results show that attention should be paid to inadequate policy and regulations, lacking knowledge and expertise, dominated traditional project process, and low standardization. In particular, the findings provide valuable information for policymakers on the overall structure between barriers.

Sarhan et al. (2019) proposed a framework for implementing lean construction strategies using the ISM technique to improve performance levels in the construction industry in Saudi Arabia. They concluded that the framework constitutes considerable progress over existing frameworks, as it specifies the hierarchical relationships among the different factors that contribute to the successful implementation of lean construction, reflecting the socio-cultural and operational contexts in the Saudi Arabia construction industry. Therefore, based on the above arguments, ISM was the chosen technique for this research project.

The works of Shen et al. (2016) and Gan et al. (2018) served as guide in the implementation of ISM. In accordance with the aforementioned works, the steps to develop ISM are as follows: (i) identification and listing of the variables that comprise the system to be studied; (ii) identification of the contextual interrelationships by experts between each pair of variables and registering them in a Structural Self-Interaction Matrix (SSIM); (iii) translation of the SSIM into an Initial Reachability Matrix (IRM), which is a binary matrix representing the direct interrelationships among the variables; (iv) checking IRM for transitivity to also capture the indirect links between variables, which will be transformed into the Final Reachability Matrix (FRM), which considers all the interrelationships (direct and indirect) among the variables; (v) applying level partitioning to the FRM, ranking the elements according to their levels; (vi) drawing the ISM-based model by connecting the variables at each level, based on their IRM relationships; and lastly, (vii) presenting the ISM-based model to experts to establish its consistency.

A Focus Group Meeting (FGM) was conducted to implement the ISM. An FGM is defined as a primary research technique that collects data through group interaction on a subject set by the moderator (Morgan et al., 1996). This qualitative research approach provided detailed knowledge of a phenomenon experienced by the FGM participants. Care was taken to select experts with a view to avoiding any bias within the group; the set of experts was made up of two practitioners from each entity, namely developers, consultants, and contractors. All participants had more than ten years' experience. Furthermore, in the FGM, all experts had equal weighting in the decision-making process, and their opinions were only considered when the majority were in agreement, as suggested by Shen et al. (2016), in order to ensure consensus. The FGM was moderated by one of the authors of this paper. Particular attention was paid to the moderator's role. The moderator was well knowledgeable on construction project management, and the discussion advanced from the general to specific issues with a view to stimulating sincerity and reducing bias (Prince & Davies, 2001).

After implementing the ISM methodology, we forwarded the hierarchical structure to the experts. Later, ad hoc contacts were made with some of the experts to ensure consistency of the results.

4 RESULTS AND DISCUSSION

4.1 Causes of DCP in Portugal (Phase I)

A literature review was carried out to find and review relevant literature on the causes of DCP in general, and in Portugal in particular. The literature review was also useful for defining descriptions for each cause, which was central to guiding the FGM with the experts. We selected the causes of DCP presented in Arantes and Ferreira (2020), who analyzed the Portuguese case. Of the 46 causes they studied, only the 16 most important ones were selected for this study. The selection criterion was having a median value of the importance of the cause higher than the threshold value of 4. The main causes are presented in Table 1.

Table 1: Causes of DCP in Portugal.

No.	Cause of DCP
C1	Slow decision making by the developer
C2	Change in orders
C3	Unrealistic schedule and specifications in the contract
C4	Improper planning and scheduling
C5	Bidding and contract award process
C6	Delay in progress payments by the owner
C7	Delay in quality control
C8	Developer interference
C9	Increase in scope of work
C10	Mistakes and discrepancies in drawings
C11	Delay in obtaining permits from authorities
C12	Delay in the procurement of materials
C13	Changes in material specifications during construction
C14	Delay in delivery of materials
C15	Disputes and negotiations between parties
C16	Lack of communication between parties

4.2 ISM Methodology (Phase II)

In the FGM, the experts were asked to make pair-wise comparisons of the 16 causes of DCP in Portugal by responding to the question, "Does cause i directly influence cause j?" Four letters were used to represent the direction of the interrelationship between each pair of causes. "V" means that cause "i" influences directly cause "j"; "A" means that cause "j" influences directly cause "I"; "X" means that causes "i" and "j" influence each other; and "O" means that there is no interrelationship between causes "i" and "j". However, different experts may judge the pair-wise comparison of two causes differently. Accordingly, when consensus was not reached in this study, the interrelationships among the causes were settled by the rule, "the minority gives way to the majority" (Shen et al. (2016). The interrelationships among the causes of DCP in the Portuguese context are presented in the Structural Self-Interaction Matrix (SSIM) (Table 2).

Next, the SSIM is transformed into the Initial Reachability Matrix (IRM) by substituting "V", "A", "X" and "O" in accordance with the following rules: (i) if the (i, j) entry is "V", then the (i, j) entry in the IRM becomes "1" and the (j, i) entry becomes "0"; (ii) if the (i, j) entry is "A", then the (i, j) entry in the IRM becomes "0" and the (j, i) entry becomes "1"; (iii) if the (i, j) entry is "X", then the (i, j) and (j, i) entries in the IRM become "1"; and, (iv) if the (i, j) entry is "O", then the (i, j) and (j, i) entries in the IRM become "0". Finally, the IRM was then checked for transitivity. Transitivity means that if cause "i" is directly related to cause "j" and cause "j" is directly related to cause "k", then causes "i" and "k" are indirectly related through cause j, and if the entry (i, k) in the IRM is "0", then it must be changed to a "1*". This process converts the IRM into the FRM (see Table 3), which considers all interrelationships among the causes (direct and indirect). Table 3 also presents each cause's driving and dependence powers, which are the sum of the rows and columns of the FRM, respectively.

Table 2: Structural Self-Interaction Matrix.

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**C10**	**C11**	**C12**	**C13**	**C14**	**C15**	**C16**
C1		V	O	O	O	V	V	X	A	A	V	V	A	V	V	O
C2			O	O	O	O	V	X	X	V	V	V	V	V	V	O
C3				A	A	V	V	V	O	O	O	V	V	V	V	O
C4					O	V	V	A	A	A	O	V	O	A	V	O
C5						O	O	O	O	V	O	O	O	O	V	O
C6							A	A	A	O	O	V	O	O	V	A
C7								A	A	A	O	O	A	A	V	O
C8									V	V	V	V	V	O	V	O
C9										V	V	V	V	O	V	O
C10											V	V	A	O	V	A
C11												V	O	O	V	A
C12													X	O	O	A
C13														X	V	A
C14															V	O
C15																A
C16																

Table 3: Final reachability matrix.

	C1	C2	C3	C4	C5	C6	C7	C8	C9	C10	C11	C12	C13	C14	C15	C16
C1	1	1	0	1*	0	1	1	1	1*	1*	1	1	1*	1	1	0
C2	1*	1	0	1*	0	1*	1	1	1	1	1	1	1	1	1	0
C3	1*	1*	1	1*	0	1	1	1	1*	1*	1*	1	1	1	1	0
C4	1*	1*	1	1	0	1	1	1*	1*	1*	1*	1	1*	1*	1	0
C5	1*	1*	1	1*	1	1*	1*	1*	1*	1	1*	1*	1*	1*	1	0
C6	1*	0	0	1*	0	1	1*	0	0	1*	0	1	1*	1*	1	0
C7	1*	0	0	1*	0	1	1	0	0	1*	1*	1*	1*	1*	1	0
C8	1	1	1*	1	0	1	1	1	1	1	1	1	1	1*	1	0
C9	1	1	1*	1	0	1	1	1*	1	1	1	1	1	1*	1	0
C10	1	1*	1*	1	0	1*	1	1*	1*	1	1	1	1*	1*	1	0
C11	1*	0	0	1*	0	0	1*	0	0	1*	1	1	1*	1*	1	0
C12	1*	0	0	1*	0	0	1*	0	0	1*	0	1	1	1*	1*	0
C13	1	1*	1*	1*	0	1*	1	1*	1*	1	1*	1	1	1	1	0
C14	1*	1*	1*	1	0	1*	1	1*	1*	1*	1*	1*	1	1	1	0
C15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	0
C16	1*	1*	1*	1*	0	1	1*	1*	1*	1	1	1	1	1*	1	1

Table 4: Level partitioning results.

Causes	Reachability Set	Antecedent Set	Intersection Set	Level
C1	1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 2, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	2
C2	2, 8, 9	2, 3, 5, 8, 9, 16	2, 8, 9	4
C3	3	3, 5, 16	3	5
C4	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	2
C5	5	5	5	6
C6	6	2, 3, 5, 6, 8, 9, 16	6	3
C7	1, 4, 6, 7, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 4, 6, 7, 10, 11, 12, 13, 14	2
C8	2, 3, 8, 9	2, 3, 5, 8, 9, 16	2, 3, 8, 9	4
C9	2, 3, 8, 9	2, 3, 5, 8, 9, 16	2, 3, 8, 9	4
C10	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	2
C11	11	2, 3, 5, 8, 9, 11, 16	11	3
C12	1, 4, 7, 10, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 4, 7, 10, 12, 13, 14	2
C13	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	2
C14	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 16	1, 2, 3, 4, 6, 7, 8, 9, 10, 11, 12, 13, 14	2
C15	15	1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16	15	1
C16	16	16	16	6

After the FRM, level partitioning was carried out. For each cause of DCP, the reachability set, the antecedent set, and the intersection set were created to measure each cause's influence levels. The reachability set of cause "i" comprises all causes that are influenced by cause "i" (which are represented by "1s" in the row of the FRM corresponding to cause "i"); the antecedent set of cause "i" comprises all causes that influence cause "i" (which are represented by "1s" in the column of the FRM corresponding to cause "i"); plus, the intersection set contains the common causes found in both the reachability and antecedent sets. When the intersection set is equal to the reachability set of a particular cause, then that cause is allocated to the level of that iteration. The causes assigned to one level are then detached from the remaining reachability and intersection sets for the next iteration. The same process is applied until all the causes are partitioned into levels. Table 4 shows the level partitioning results of the 16 causes of DCP. All causes were partitioned into levels after six iterations, meaning now the ISM-based model can be represented.

Finally, a digraph is drawn up by positioning the causes vertically according to the level partitioning (Table 3) and linking the causes according to the IRM using arrows. The ISM-based model (Figure 2) shows the hierarchical structure of the causes of DCP in Portugal, emphasizing their interrelationships.

Figure 2 shows six different levels of influence. The first level of the ISM-based model is comprised of the cause Disputes and negotiations between parties (C15).

The second level directly influences the first level. It is comprised of the Slow decision making by the developer (C1), Improper planning and scheduling (C4), Delay in quality control (C7), Mistakes and discrepancies in drawings (C10), Delay in the procurement of materials (C12), Changes in material specifications during construction (C13) and Changes in material specifications during construction (C14).

The third level directly influences the second level and comprises Delay in progress payments by the owner (C6) and Delay in obtaining permits from authorities (C11).

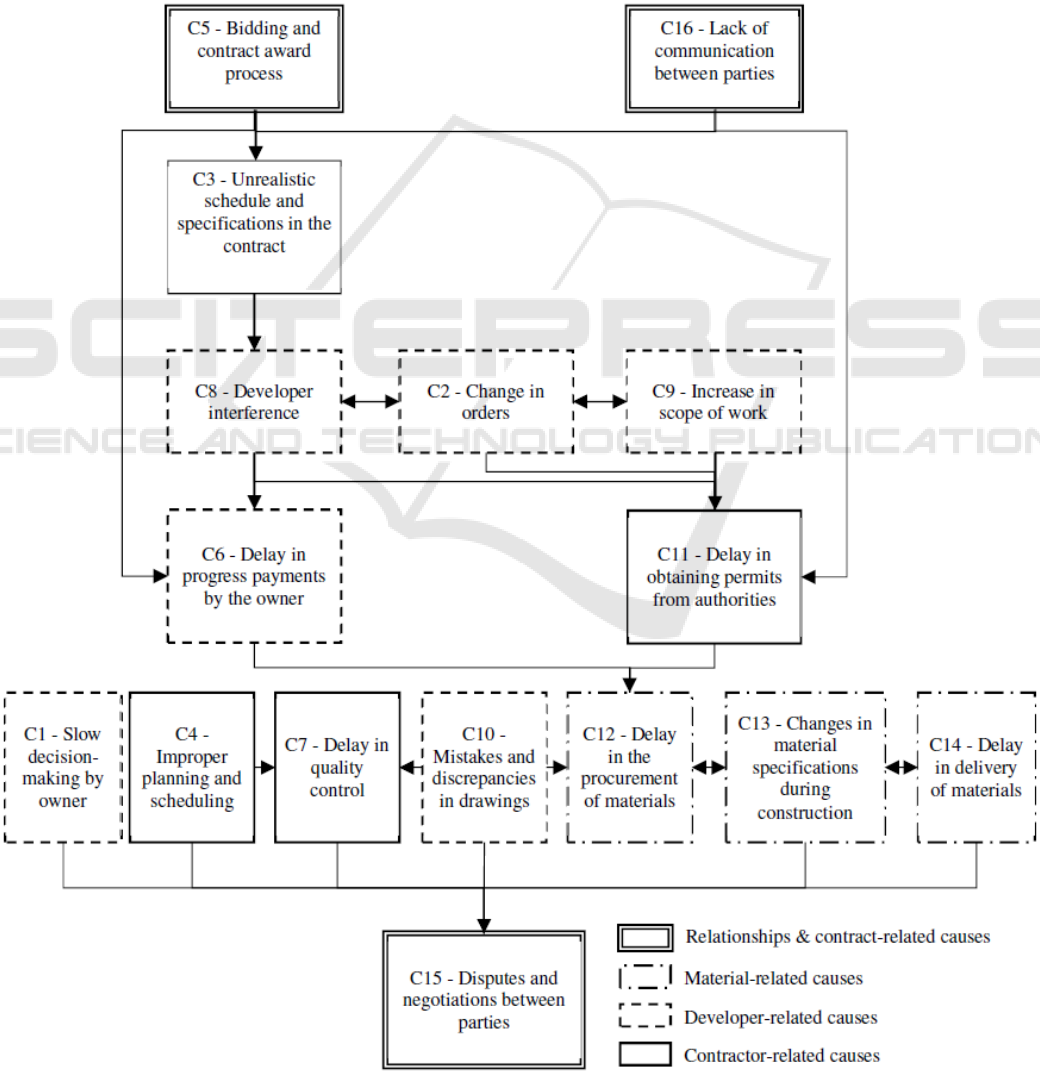

Figure 2: The ISM-based model of the causes of DCP in Portugal.

The fourth level of the ISM-based model directly influences the third level and includes Developer interference (C8), Change in orders (C2), and Increase in scope of work (C9). The fifth level contains Unrealistic schedule and specifications in the contract (C3) and directly influences the fourth level. Lastly, the sixth and final level of the ISM-based model directly influences the fifth and the third levels and has the most influence over the other causes considered, comprising Bidding and contract award process (C5) and Lack of communication between parties (C16).

From the assessment of the ISM-based model, see Figure 2, it became clear that the causes of DCP can be divided into Relationships and contract-related causes (C3, C5, C15, and C16), Material causes (C12, C13, and C14), Developer-related causes (C1, C2, C6, C8, and C9) and Contractor-related causes (C4 and C7).

4.3 Discussion

The six levels of causes of DCP presented in the ISM-based model in Figure 2 make it possible to understand their impact on DCP in the Portuguese context. According to the ISM technique, measures that lessen the causes originating at a higher level will also help lessen the causes originating at a lower level. However, corrective measures taken at lower levels will have little to no effect at higher levels. Therefore, stakeholders and practitioners from the Portuguese construction industry must pay particular care to the causes originating at level six when developing mitigation measures to DCP, given that said measures will mitigate those causes and also the causes from other lower levels.

As a result, based on the ISM-based model developed in this work, the causes of DCP that make up the sixth level of the ISM-based model – i.e., Bidding and contract award process (C5), and Lack of communication between parties (C16) – are considered to be most influential causes of DCP. These causes have already been indicated as important to DCP by other authors (Arantes & Ferreira, 2020; Assaf & Al-Hejji, 2006; Fallahnejad, 2013; Ruqaishi & Bashir, 2015), and, as such, special mitigation measures should be foreseen. This result supports the consistency and value of the model developed.

5 CONCLUSIONS

In this study, the interrelationships between 16 causes of DCP in Portugal were modeled. The ISM methodology was applied to structure the selected causes into a hierarchy and divide them into six different influence levels. Two root causes of DCP were identified: Bidding and contract award process and Lack of communication between parties. This study also reveals how the causes of DCP affect each other and provides guidelines for researchers and practitioners to develop effective measures to mitigate the causes of DCP. Moreover, the results show that the causes of DCP are essentially of four different types that can be related to Relationships and contract, Material, the Developer, and the Contractor.

Even though this paper contributes to the discussion on the causes of DCP in Portugal, namely the interrelationships between them, it also has certain limitations. Firstly, the results are dependent on the opinions of a small number of experts; and, secondly, the results may not be generalizable to other contexts. However, these limitations also constitute future research opportunities.

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