Generation of Early Warnings in the Identification of Changes in Deliverables in The Execution Stage of Construction Projects

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ABSTRACT

In construction projects, changes continue to present themselves as a challenge that influences the normal development and success of the construction processes and stages of execution. Most of these changes are due to events and causes that in many cases could have been avoided. In this research, through a qualitative and documentary methodology, an extensive theoretical review of the causes of change and the impacts on cost and time was carried out, which, once analyzed and filtered, allow the most important causes and their impacts to be described and presented at a general level. Similarly, in the development of the research, the classification and level of importance of these types of changes and causes was validated through the implementation of a collection instrument, thus contrasting the findings of the review with the real context of the construction sector in Colombia. This information allowed the generation of a model for the generation of early warnings in order to prevent these changes in the execution stage of the construction process.

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I. INTRODUCTION

Internationally, different studies and proposals have analyzed the performance of construction projects, in order to generate correlations, identify particular causes and common factors that affect both positively and negatively their different stages or life cycles. However, there is a common theme that reveals deficiencies and/or problems in projects, changes, which manifest themselves in orders, requests or actions that imply an adjustment, an addition or elimination of some component, some task or work package and that in effect may have some consequence on the baseline time, cost or scope.

Therefore, the construction industry is constantly seeking to improve the planning and management of projects in order to reduce the levels of uncertainty and allow control of tasks without deviations from the plan and the development of activities in the execution stage. However, projects continue and will continue to face several challenges that originate the need to make changes to adapt and respond, especially in the execution stage. This stage was the focus of this research, which sought to delve into those aspects that generate or influence the origin of requests and change orders.

The purpose of this research was to investigate in the existing literature and to go deeper into those causes that generate changes that have been identified and compiled in different types of construction projects, as well as to review the extent to which they have impacts on cost and time.

On the other hand, it was important to contrast and confront the results of the theoretical collection with the close environment involved in construction projects, in order to validate the relevance of the subject and focus the results together with good practices at the project management level with the purpose of becoming a reference and comparison document that contributes to the decisions and/or actions to be taken, thus facilitating the early identification and mitigation of those changes that most often impact construction projects.

Changes in construction projects are common (Motawa, 2005; Anees et al., 2013) and inevitable (Hao et al., 2008; Paz & Lay, 2009; Alsuliman & Bowles, 2012; Hwang & Low, 2012; Zhang, 2013; Yana et al., 2015) and can occur throughout the life cycle of the project (Padala et al., 2020) and are even inherent to the projects themselves (Casas & Giraldo, 2014). In other words, even with a high degree of theoretical planning for a project, there will always be some change. This can be understood since there are many factors that can influence the parameters or characteristics that compose or define a certain construction project. Factors that may be under certain control since they depend on the same organization or the team that plans and/or executes the project and factors that, although they may be known in advance, there is no control over them and that may be very changeable, which may eventually generate some consequence in the projects.

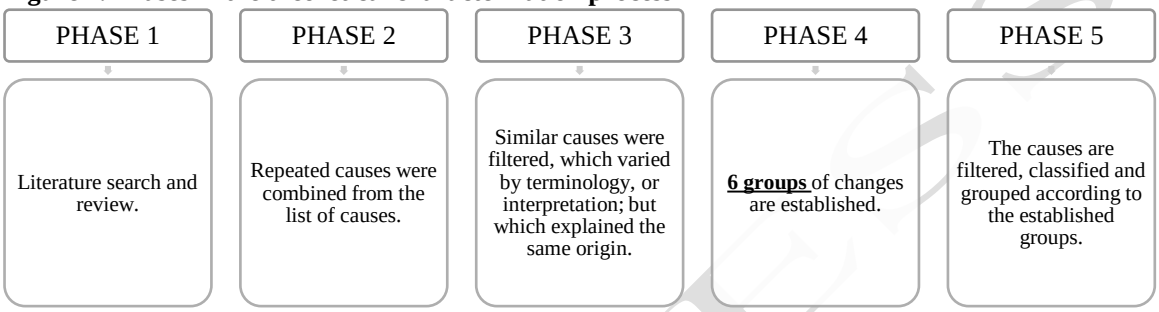
In this sense, a construction project may arise from a need, an idea or an opportunity, and by means of determined resources and different coordinated and planned actions, it seeks to create an infrastructure that in itself is or provides the best possible solution, the required service or the use for which it was created. That is why it is based on different standards and institutions of project management that are unique and unrepeatable (Association for Project Management, 2019; International Organization for Standardization, 2012; Project Management Institute, 2017). Therefore, we can understand that the changes that are generated in the projects also imply a specific modification of different factors, aspects and situations, which will depend on the object or process and at what moment the change is being generated.

II. METHODOLOGY

This research began with a review of the existing literature related to the management, models, types, causes, impacts and effects of changes in construction projects. The compilation started with a search in the different databases of scientific journals, articles and academic papers that are available online. Using the search filters of the databases, Boolean, proximity and truncation operators; using descriptors and keywords.

In order to understand the magnitude of many of the factors that are directly or indirectly related to changes in construction projects and according to the methodology described for the theoretical characterization, the following phases are developed:

Figure 1. Phases in the theoretical characterization process



Source: Own elaboration

An information gathering instrument was also developed for people who are involved in or have responsibility for decisions and/or actions that prevent, generate, accept, reject and/or manage changes in construction projects. The instrument was created based on the review and analysis of existing literature, which in turn made it possible to support and investigate the causes of changes in projects during their execution stage.

For the characterization of the respondent's profile, we sought to know the years of experience in the construction sector. Likewise, we sought to identify the sector of economic activity in which they may have been involved, whether in the public, private and/or public-private sector, the type of projects they have been part of, taking as reference some of the occupancy groups according to the Seismic Resistant Standard NSR 10 and the types of concession projects carried out through the National Infrastructure Agency-ANI. In order to learn even more about the respondent's experience, we also sought to consult the nature or modalities of works in which he/she has been involved, taking as a reference the classification of construction licensing modalities of the Ministry of Housing, City and Territory. Another aspect that was involved in order to complement the characterization of the respondent's profile and experience was the size of the company in which he/she was linked and/or performing his/her role (Ley 905 de 2004, Artículo 2).

For the selection of the population and taking into account the place of development and presentation of this research, the number of companies, both natural and legal persons, that are active as of the third quarter of the year 2022 and that are linked to the construction sector in the city of Tunja is taken as a reference. According to the database of the Chamber of Commerce of Tunja, (2022) indicates that the city of Tunja has 71 companies with the following classification: *F4390-Other specialized activities for the construction of buildings and civil engineering works*. Based on the result (71 companies), the calculation is used to obtain the random sample number using the following formula, (Torres, 2008):

$$n = \frac{N * Z^2 * p * (1-p)}{e^2 * (N-1) + Z^2 * p * (1-p)}$$

Thus resolving:

$$n = \frac{71 * 1.65^2 * 0.5 * (1 - 0.5)}{0.05^2 * (71 - 1) + 1.65^2 * 0.5 * (1 - 0.5)}$$

$$n = 56.48 \approx 57$$

According to the result, the appropriate population sample to be surveyed was 57 experts, so that 90% of the time the results would capture the data of interest, with a margin of error of ± 5% in the number of the sample. For the validation of the causes of changes and the impacts on time and cost, a survey-type instrument was developed that includes two sections. The first section sought to capture the profile and experience of the respondent participating in the study. The second section sought to identify from the respondent's criteria the impact in terms of percentage of increased time and cost of the types of changes that are considered most relevant in construction projects. It also sought to know from the experience of the respondent the frequency of occurrence of some causes that trigger changes in construction projects.

The impacts in terms of time and cost for the types of changes, as well as the causes of changes were classified by the Relative Importance Index (RII) method using the following formula, (Waty & Sulistio, 2022):

$$RII = \frac{5 * n_5 + 4 * n_4 + 3 * n_3 + 2 * n_2 + 1 * n_1}{W * N}$$

Table 1. Parameters Relative Importance Index (RII) Method

n_5	Number of respondents who selected scale 5
n_4	Number of respondents who selected scale 4
n_3	Number of respondents who selected scale 3
n_2	Number of respondents who selected scale 2
n_1	Number of respondents who selected scale 1
W	The largest scale
N	Total number of respondents

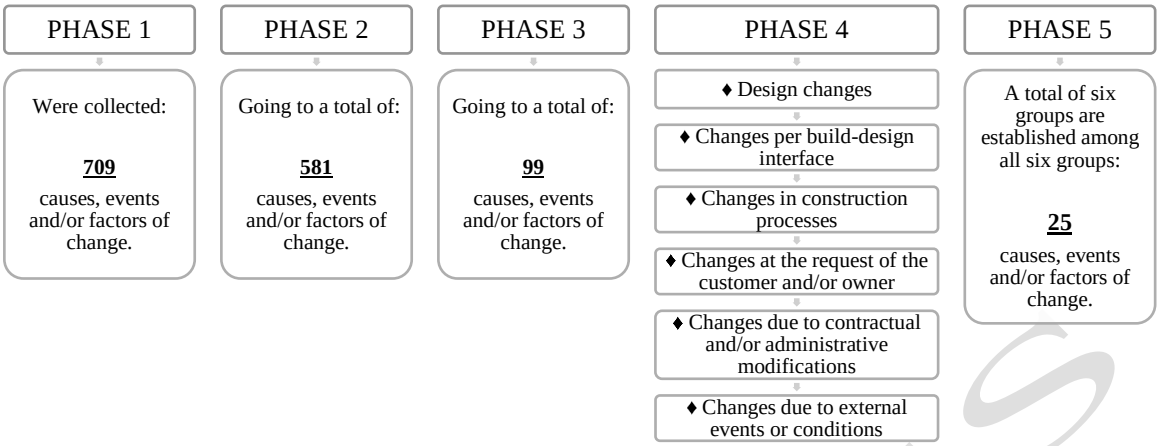
Source: Own elaboration

III. RESULTS

CLASSIFICATION AND CAUSES OF CHANGES IN CONSTRUCTION PROJECTS ACCORDING TO THEORETICAL CHARACTERIZATION

According to the methodology described for the theoretical characterization in the development of the phases, the following findings of the factors that are directly or indirectly related to the changes in the construction projects are evidenced as illustrated in Figure 2.

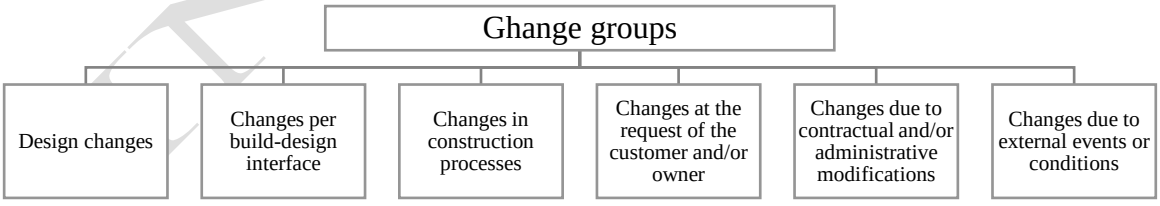
Figure 2. Theoretical Characterization Results



Source: Own elaboration

According to Figure 2. In **Phase 1**, applying the methodology described for the theoretical characterization, it was possible to collect 709 factors or causes of changes during the execution stage of construction projects. In **Phase 2**, a first analysis was carried out for each one, in order to combine the repeated causes, thus reaching a total of 581 causes of change. In **Phase 3**, a second analysis was carried out to group the similar causes, which were described differently either by the use of words of the area or region, or the interpretation when translated; but which coincided or explained the same origin of some change in the construction projects. In **Phase 4**, groups of types of changes were established as shown in Figure 3. Classification of changes and in **Phase 5**, according to the established groups, each of the causes or events that trigger changes were filtered and grouped in the corresponding group, according to their origin, the context, the elements and/or individuals involved and the result of this new analysis were 25 causes of changes in the construction projects during the execution stage, which are listed in Table 2. Classification and causes of changes in construction projects according to theoretical characterization.

Figure 3. Classification of changes



Source: Own elaboration

Table 2. Classification and causes of changes in construction projects according to theoretical characterization.

ID	Group	ID	Causes

GR 1	**1. Design changes**	CS 1	1. Design modifications proposed by the consultant, by the contractor, by influence of user requirements or needs, by opportunity for improvements or optimizations.
		CS 2	2. Errors, omissions, insufficient clarifications, contradictions or non-compliance with rules and regulations in the designs and/or engineering studies.
		CS 3	3. Lack of engineering design details and specifications.
		CS 4	4. Lack of integration and overlapping of designs.
GR 2	**2. Changes per build-design interface**	CS 5	5. Inconsistency between designs, reports, studies and site conditions or location of existing service lines.
		CS 6	6. Construction processes not taken into account in the design process.
GR 3	**3. Changes in construction processes**	CS 7	7. Construction errors, omissions and reprocessing, lack of standardization of construction methods.
		CS 8	8. Safety, space and access conditions of the work sites.
		CS 9	9. Poor procurement and inventory processes, delays and non-compliance of suppliers and/or contractors, substitution of materials or procedures.
		CS 10	10. Overlapping of the design and construction phases; overlapping of design and construction phases; overlapping and simultaneous activities; changes in the schedule or construction schedule that are too limited, inadequate or unrealistic; changes, adjustments or errors in the planning.
		CS 11	11. Weaknesses in the direction, coordination, communication, approvals and decision making of the working groups; and internal conflicts.
		CS 12	12. Inadequate interpretation of reports, designs, details and studies.
		CS 13	13. Inadequate labor productivity, lack of experience and knowledge, lack of availability of specialized and qualified personnel.
		CS 14	14. Difficulties and increased complexity of unfeasible or unrealistic works, constructions or activities.
GR 4	**4. Changes at the request of the customer and/or owner**	CS 15	15. Requests, modifications, new requirements from the client and/or owner.
GR 5	**5. Changes due to contractual and/or administrative modifications**	CS 16	16. Budget constraints or limitations, financial difficulties and/or shortcomings, inadequate estimation of quantities and costs, value engineering studies.
		CS 17	17. Lack of standards, construction manuals and procedures, execution controls, lessons learned bank.
		CS 18	18. Flaws, errors, omissions, contradictions in the contractual documents and procedures.
		CS 19	19. Modification or new project objectives, policies, internal organizational strategies.
GR 6	**6. Changes due to external**	CS 20	20. Changes or new requirements of governmental policies, regulations and building codes, environmental, urban planning, etc.
		CS 21	21. Environmental problems or impacts, adverse or catastrophic weather and natural conditions.

	events or conditions	CS 22	22. Opposition and complaints from the community of neighbors, damage and interference from third parties, unsafe conditions (disturbances, conflicts, vandalism, etc.)
		CS 23	23. Economic and financial situation of the construction sector or all sectors at regional and/or global level.
		CS 24	24. Lack of availability of technologies, equipment, tools, materials, supplies and personnel.
		CS 25	25. Requirement, request, additional need from third parties with high influence on the project.

Source: Own elaboration

The materialization and/or request of a change will always have an effect, since in order to manage it or as a consequence of it, "there will be an increase in services due to the need to adapt the productive system to the proposed change" (Carvalho et al., 2021) and the more changes generated in a project, the higher the probability that they will become deliverables and/or costly projects and that more time will be required for their construction (Halwatura & Ranasinghe, 2013).

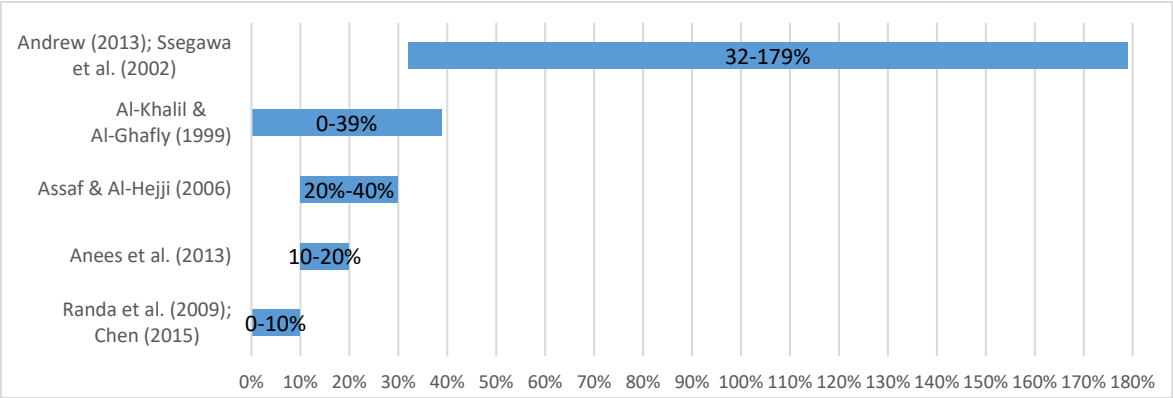
A change implies a new scenario, in which impacts are produced which can be negative or positive, according to the type of change, the magnitude of the change, the moment and the reasons that originate it. Changes generally imply negative impacts, since they alter work plans, established ideas and procedures, calculated times and costs, among others, however, changes can also originate to take advantage of an opportunity, correct or mitigate some aspect that may cause problems and negative impacts in the future, it does not mean that a positive or beneficial change does not generate negative residual impacts, it means that to take advantage of an opportunity will require additional work and higher costs to manage it at the time, but the benefit will return in the long term.

IMPACTS IN TERMS OF TIME

Any change that implies additional work will always have an effect on time, which, according to its characteristics, the moment in which it is carried out and the resources it will demand, will have a certain magnitude of impact. Therefore, it is important to understand the influence that a change has on the time factor. Time is one of the main constraints of projects, so that delays in construction works have in turn a strong economic and even social impact on those involved and / or the target population of the project (Carvalho et al., 2021).

The following figure compiles the ranges in terms of percentage of excess time in which the impact on the project has been measured.

Figure 4. Ranges of increase in original project execution duration due to changes according to literature review



Source: Own elaboration

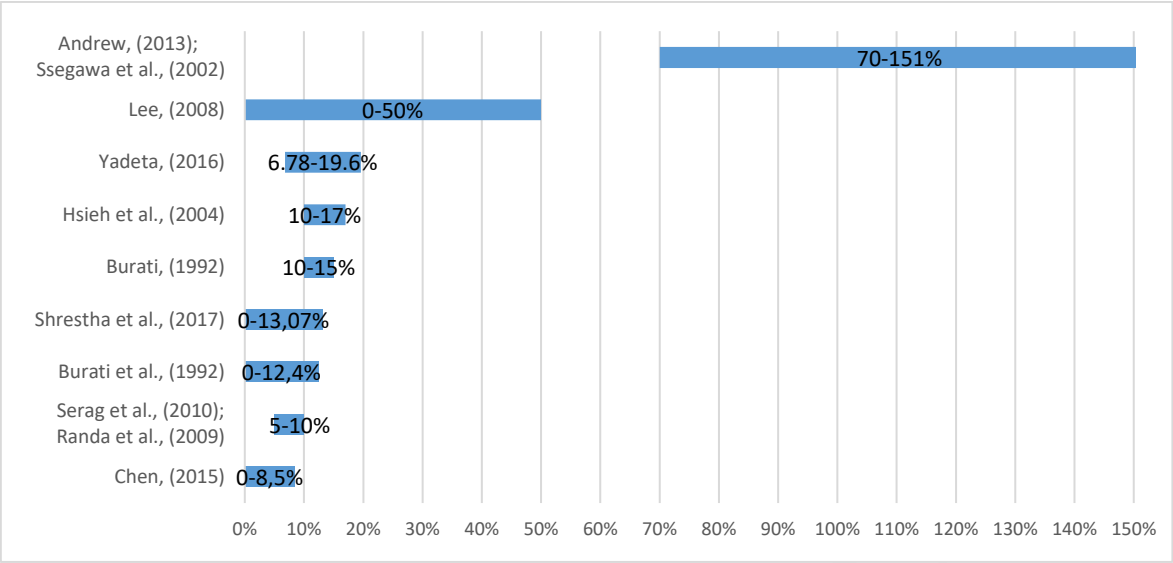
According to the above, it was possible to identify that there may be different perceptions and results regarding the impacts in terms of construction time overruns in projects due to changes, which in recent years has been validated and constituted as a constant in the causes that trigger delays in construction projects. It is highlighted that according to Rudeli et al., (2018) "80% of the causes of delay in construction projects are due to problems during execution, problems with labor, problems in design and administrative aspects". Reason why the execution stage requires a high level of management and work to perform an adequate follow-up and control of the scope, resources, risks, processes, etc.

IMPACTS IN TERMS OF COST

Changes in projects have a direct and indirect effect on cost (Yadeta, 2014) and contribute to cost overruns (Ndihokubwayo & Haupt, 2009). Because they usually materialize unexpectedly as a response to some problem, actions must be allocated that eventually result in higher costs to address and manage the changes, even other impacts also influence, such as impacts on time, since additions to the calendar and/or schedules mean delays in the delivery, commissioning and use of deliverables as initially planned, which can cause lack of revenue, lower and/or late return on investment, higher material costs due to inflation (Assaf & Al-Hejji, 2006), higher operational and administrative staff costs, lost opportunities for new projects due to decreased financial capabilities (Al-Khalil & Al-Ghafly, 1999), increased cost on contracts (Waty & Sulistio, 2020), depending on the circumstances recognize penalties and/or fines, etc. All delays usually cost money (Kaming et al., 1997), as a delay in the execution stage represents late occupancy of facilities and other factors (Ahamed, 2014).

Existing studies were used to determine the range of cost increases as a function of the total value of the project, as shown in the following figure:

Figure 5. Ranges of increase in the initial budget for project execution according to literature review



Source: Own elaboration

The actions and activities implemented to respond to a change in construction projects will always have a cost impact in ranges that may equal or exceed the profit margins that may be expected by those involved in the projects. The most common causes are changes in scope due to new additions, expansions, capacity increases after the feasibility study or during construction, design changes, cost increases due to changes in construction methods, among others. This is why changes are the main factor or most common cause of delays and cost overruns (Moselhi et al., 1991; Sun et al., 2006; Assaf & Al-Hejji, 2006; Motawa et al., 2007; Isaac & Navon, 2008; Olawale & Sun, 2010; Yadeta, 2014; Chen, 2015; Dickson et al., 2015; Motilla, 2016; Moayeri, 2017; Rudeli et al., 2018; Padala et al., 2020; Carvalho et al., 2021).

RESULTS IMPLEMENTATION INSTRUMENT

The first section of the survey made it possible to identify profiles of the respondents who participated, characterizing that of the 56 respondents, 87% have between 0 to 15 years of experience in the construction sector and 13% have more than 15 years. The most frequent modality in which they have developed construction projects is under the modality of new construction with 98.2%, the modality of expansion with 78.6%, the modality of adaptations with 64.3%, demolitions and modification with 51.8% and 50% respectively, being these the five modalities with the highest percentage.

On the other hand, the survey showed that the role that most frequently generated requests or change orders during the execution of construction projects is the constructor (RII 0. 739), followed by the manager and controller (RII 0.611), consultant (RII 0.582), owner/investor (RII 0.536) according to the perception of the respondents and importance index as illustrated in Table 3. Results and ranking of change request by role type.

Table 3. Results and classification of change requests by role type

	1	2	3	4	5	Total responses	RII	Ranking
	Never	Almost never	Sometimes	Almost always	Always			
Builder	1	5	15	24	11	56	0.739	#1
Manager	3	12	23	15	3	56	0.611	#2
Controller	3	13	22	14	4	56	0.611	#3
Consultant	4	14	22	15	1	56	0.582	#4

Owner / investor	4	17	28	7	0	56	0.536	#5

Source: Own elaboration based on SPSS software

Finishes and final details is the area with the highest frequency of changes according to the results obtained (RII 0.754), followed by the architectural proposal in second position as the area with the most changes (RII 0.718), in third place is the area of networks, including plumbing, electrical, data, fire and ventilation (RII 0.650), and in fourth position is the area of the structure (RII 0.582) as shown in Table 4.

Table 4. Results and ranking of the request for changes area

	1	**2**	**3**	**4**	**5**	**Total responses**	**RII**	**Ranking**
	Never	**Almost never**	**Sometimes**	**Almost always**	**Always**			
Finishes	0	5	15	24	12	56	0.754	#1
Architecture	1	5	20	20	10	56	0.718	#2
Networks (plumbing, electrical, data, fire protection, ventilation)	1	11	23	15	6	56	0.650	#3
Structure	1	19	24	8	4	56	0.582	#4

Source: Own elaboration based on SPSS software

CLASSIFICATION ACCORDING TO IMPACT ON TIME USING THE RII METHOD

The type of change during project execution most associated with high negative impacts on initial duration are changes in designs (RII 0.489), followed by changes due to client request (RII 0.421), changes due to contractual and/or administrative modifications (RII 0. 414), changes due to inconsistency in the construction-design interface (RII 0.396), changes in construction processes (RII 0.393) and changes due to inconsistency in the construction-design interface (RII 0.325) as illustrated in Table 5.

Table 5. Classification of types of changes according to negative impact on the initial duration of construction projects

	RII	**Ranking**
Design changes	0.489	#1
Changes by customer request	0.421	#2
Changes due to contractual and/or administrative modifications	0.414	#3
Changes due to inconsistency in the design-build interface	0.396	#4
Changes in construction processes	0.393	#5
Organizational change of the companies involved	0.325	#6

Source: Own elaboration

In terms of negative impact on the initial budget of most construction projects during execution, changes due to client request have the greatest influence (RII 0.461), followed by changes in designs (RII 0. 457), changes in construction processes (RII 0.443), changes due to inconsistency in the construction-design interface (RII

0.393), changes due to contractual and/or administrative modifications (RII 0.382) and organizational change of the companies involved (RII 0.325) as illustrated in Table 6.

Table 6. Classification of types of changes according to negative impact on the initial budget for construction projects

	RII	Ranking
Changes by customer request	0.461	#1
Design changes	0.457	#2
Changes in construction processes	0.443	#3
Changes due to inconsistency in the design-build interface	0.393	#4
Changes due to contractual and/or administrative modifications	0.382	#5
Organizational change of the companies involved	0.325	#6

Source: Own elaboration

CLASSIFICATION OF THE CAUSES OF CHANGE USING THE RII METHOD

In relation to the list of 25 causes of changes obtained from the theoretical characterization and classified into 6 groups, it was possible to identify by means of the rating on the frequency scale of each respondent and by calculating the importance index that they were congruent and that none was disregarded by the respondents. The following table presents the ranking of the 6 groups of changes:

Table 7. Classification of groups of causes of change

Group	RII (average)	Group level ranking
Design changes	0.707	#1
Changes due to construction-design interface	0.650	#2
Changes at the request of the customer and/or owner	0.636	#3
Changes in construction processes	0.566	#4
Changes due to contractual and/or administrative modifications	0.545	#5
Changes due to external events or conditions	0.478	#6

Source: Own elaboration based on SPSS software

It is evident both in the theory and in the results that the main causes of changes during execution, or those perceived as the most frequent, are those related to changes in designs and construction processes.

IV. DISCUSSION

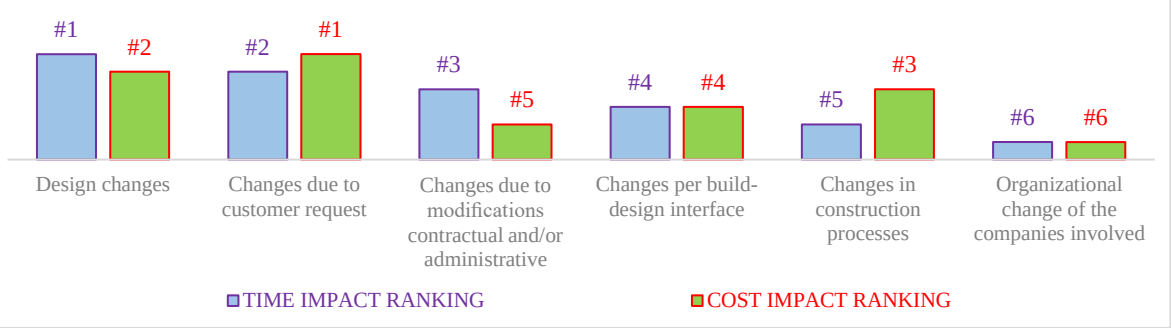
Based on the theoretical review, the types and causes of changes, the ranges of impacts, the perceptions of a group of experts, the contrast between the theory and the results of the survey, a series of strategies are presented as a reference guide that can contribute and support the identification of changes and the early identification of

possible impacts in terms of cost and time during the execution stage of construction projects, which is the stage on which this research focused, however, it is intended that it can also be taken into account and can complement previous stages of construction projects such as planning.

In contrast with the theory consulted and the results of the survey, differences are observed, since while in the literature it is concluded that the client and/or owner of the project is the main role that requests changes, in the survey results it was found that the role that generates or requests changes most frequently is the constructor and in last position the owner.

In the theory collected, it was identified that design changes tend to have the most negative impact on projects, which is consistent with the results analyzed through the collection instrument, since design changes are in the first position as those that have the most negative impact in terms of time, i.e., the type of change that causes the most delay to the project when it occurs. It also occupies the second position as the type of change that has the greatest impact in terms of cost. This is understandable, since in the execution stage a change in a design represents a major reprocessing and alteration of the schedule, which implies higher costs; below in Figure 6. Ranking of the relationship of the types of changes with the impacts on time and cost we can see the findings of theory vs. implementation and validation with the results of the instrument.

Figure 6. Ranking of the relationship of types of changes with time and cost impacts



Source: Own elaboration

According to the six groups of changes that were established from the theory and research, some actions and strategies are indicated according to some of the main causes of each group, in order to serve as a warning of possible events that may occur and consequently generate some change in the project. The actions and/or strategies do not list or assign responsible parties for each one; as mentioned, they are a reference guide that, according to the organizational structures, hierarchies and work teams, can be adopted and assigned as responsible parties to whoever or whoever is considered pertinent according to the criteria of the project leaders.

Table 8. Strategies during the construction stage to identify possible changes

Group	Main related causes	Check the general condition of the following factors:	Strategies

Design changes	❖ Design modifications proposed by the consultant, by the contractor, by influence of user requirements or needs, by opportunity for improvements or optimizations. ❖ Lack of integration and overlapping of designs. ❖ Lack of engineering design details and specifications. ❖ Errors, omissions, insufficient clarifications, contradictions or non-compliance with rules and regulations in the designs and/or engineering studies.	❖ It has details and a list of design specifications in the following areas: • Finishes • Architecture • Hydrosanitary networks • Electrical networks • Data networks • Fire networks • Ventilation networks • Structure ❖ There is an integration of designs. ❖ There is a record or a report of integration between the design and engineering departments. ❖ The designs have a report and concept of the designer, which formally guarantees compliance with current standards and regulations. ❖ A methodology was used in the planning stage to capture the influence of users' requirements, needs or tastes.	❖ Using the Work Breakdown Structure (WBS), identify the designs that relate to the physical deliverables, identify the date of preparation and approval of the corresponding design package and the date of commencement of works and/or activities of the corresponding deliverable. If there is a period of difference of more than one year, it is necessary to review which aspects require updating, taking into account the construction processes and technologies available at the time. KPI / Attribute • Date of approval of the designer's final version (A) • Start date of activities (B) (B) - (A) > 1 year ❖ Keep a record and control of designs, details and specifications, in order to identify missing information and request clarifications to designers and/or consultants. Validate along with the scopes of the design contracts entered into. ❖ Changes should be appropriately highlighted and updated in all relevant project documentation. ❖ Notify all parties involved in the project of how they would be affected and how the schedule and cost implications would be affected. Through meetings between all parties (manager, constructor, contractor, designer, client).
Changes due to construction-design interface	❖ Construction processes not taken into account in the design process. ❖ Inconsistency between designs, reports, studies and site conditions or location of existing service lines.	❖ Site visits were made by designers and consultants (Validate existence of visit minutes). ❖ There are recent and updated reports and/or plans of existing utility lines.	❖ Establish work teams in meetings to exchange knowledge and experiences by using boards and/or mind maps to validate the constructive feasibility according to the available resources and construction procedures. ❖ Implement the use of 3D modeling software and methodologies such as BIM, allowing collaborative work, modeling and integrating the different designs involved in the project to show how the work should be done and test the construction plan.

		❖ There is an integration of designs in which the reports and/or plans of existing utility lines have been taken into account. ❖ The designs have notes and recommendations for the work.	❖ Through the use of formats such as canvas boards, socialize the coordination that has been made between design and construction activities, allowing to contribute or identify key aspects to be taken into account among those involved in the work. ❖ Integrate the project planner in the field visits. ❖ Request support from existing utilities (electricity, gas, water, sewage, data, etc.) to confirm existing routes.
Changes at the request of the customer and/or owner	❖ Requests, modifications, new requirements by customer and/or owner. ❖ Design not in accordance with owner's requirement. ❖ Owner requests for additional work or change of scope. ❖ Owner requests for scope reduction or suspension of work. ❖ Quality improvement.	❖ There are high-level documents such as the project charter containing the objectives and requirements set by the client or owner. ❖ There are clear and defined written guidelines for the quality standards required by the client. ❖ The project client is aware of the resources and the degree of detail and planning for the project. ❖ The client was involved in the planning stage.	❖ Using agile tools such as product stacks, visual statements and user stories; compile a clear summary of the scope of work, what the customer requires and the high level stakeholders of your product or project. ❖ Ensure that a change request relates the implications to the approved work plan, time and cost. ❖ Simulate and analyze through sprint tools or methodologies, possible direct and indirect impacts, effects on other areas, work plans, available resources, chronograms or work schedules. ❖ In case of changes requested by the client, coordinate meetings with the parties involved to socialize the requirement, the reason and the new adjustment to the plan, how each party will approach the change, ensuring the understanding of all will allow to incorporate and better manage the change in the project.
Changes in construction processes	❖ Poor procurement and inventory processes, supplier and/or contractor delays and defaults, substitution of materials or procedures. ❖ Overlapping of design and construction phase, advance orders and simultaneity of activities, changes in schedule or construction schedule	❖ The organization has standardized constructability processes. ❖ There are work and supervision formats for civil works procedures. ❖ Planning and definition of work activities meetings are held to take into account the conditions of the	❖ Have a procurement process in place to guarantee the supply chain and evaluate the performance and compliance of suppliers and subcontractors. ❖ Socialize and record all information on contracting and purchasing procedures, and establish internal timelines for the procurement requisition and approval process. ❖ Implement and ensure direct contact channels with designers and consultants to guarantee prompt attention to clarification queries, possible problems and opportunities for improvement, etc.

	too limited, inadequate or unrealistic; changes, adjustments or errors in planning. ❖ Construction errors, omissions and reprocesses, lack of standardization of construction methods. ❖ Shortcomings in the direction, coordination, communication, approvals and decision making of work groups; and internal conflicts. ❖ Inadequate labor productivity, lack of experience and knowledge, lack of availability of specialized and qualified personnel. ❖ Safety, space and accessibility of work sites. ❖ Difficulties and increased complexity of work, unfeasible or unrealistic construction or activities. ❖ Inadequate interpretation of reports, designs, details and studies.	designs based on safety and access to the site. ❖ There is an approved and socialized procurement management plan. ❖ The construction schedule is very limited. ❖ The project has all plans and details approved. ❖ A Fast Tracking plan is being implemented. ❖ Complex or infeasible activities have been identified.	❖ If Fast Tracking is required to advance and/or overlap activities and shorten the duration, or actions to increase resources and/or change processes to improve performance and shorten the duration of the critical path (Crashing), the project participants should be convened and adjustments and simulations of the work program should be made beforehand, taking into account available resources, manpower capacity and procurement processes. ❖ Hold meetings to generate ideas and solve problems before and during the execution of activities that may present complexity.
Changes due to contractual and/or administrative	❖ Budget constraints or limitations, financial difficulties and/or shortcomings, inadequate estimation of quantities and costs, value engineering studies.	❖ Value engineering studies have been conducted to reduce future costs. ❖ There is a control and/or record of changes from	❖ Periodically check high-level requirements and design requirements against contracts before moving forward with contract formalization. ❖ Validate that designs and details are complete prior to soliciting quotes and/or initiating bidding processes during construction.

	❖ Lack of standards, construction manuals and procedures, execution controls, lessons learned bank. ❖ Shortcomings, errors, omissions, contradictions in contract documents and procedures. ❖ Modification or new project objectives, policies, internal organizational strategies.	previous stages (planning and design). ❖ Records of similar projects are available (lessons learned bank). ❖ At the bidding stage there were standardized processes or a consultant for defining the contractual scope.	❖ Establish periodic meetings between the project manager, budget and schedule controller, constructor and supervisor to alert them of possible variations to contracts, quantities, specifications, etc., in order to allow time to study alternatives and approve addenda or changes.
Changes due to external events or conditions	❖ Environmental problems or impacts, adverse or catastrophic weather and natural conditions. ❖ Economic and financial situation of the construction sector or all sectors at regional and/or global level. ❖ Opposition and complaints from the neighboring community, damage and interference from third parties, unsafe		❖ Analyze sector economic indicators and reports. ❖ Track economic performance reports. ❖ Have a risk register for the project, which integrates into the identification, allocation and management of potential changes to project deliverables. ❖ Conduct risk identification and management panels involving all relevant project parties to identify potential risks specifically for those complex project activities. ❖ Involve relevant subcontractors in risk analysis when a change request is generated.

	conditions (riots, conflicts, vandalism, etc.). ❖ Lack of availability of technologies, equipment, tools, materials, supplies and personnel. ❖ Changes or new requirements of government policies, regulations and building, environmental, urban planning codes, etc. ❖ Requirement, request, additional need from third parties with high influence on the project.		❖ Formalize risk registers through documents that are regularly updated and reviewed.

Source: Own elaboration

On-site activities usually have some complex aspects in their procedures, which is why, if the designs are not sufficiently clear or the particularities of the site have not been analyzed, problems may appear during the work that could have been identified in advance, which is recognized by several experts with experience in the sector.

Opportunities for improvement or optimization can influence changes proposed by the client, however according to Motilla, (2016) it is required that the change can be understood and assumed by all the people involved, although, contractually before a change of the owner it is usually made clear that the costs and times derived must be recognized, it is important that the change is understood so that it can be properly addressed and analyze possible risks or residual changes in the future. While the change can be anticipated and planned for, it still requires proper monitoring and management to avoid generating impacts outside of those estimated and accepted.

Construction adds many physical factors in the field that can determine the degree of complexity of the projects, if we also add aspects such as the above in relation to the degree of definition of the designs and the requirements of the parties involved; it should be understood that during construction situations may arise that require continuous monitoring and control to understand and monitor the components of a construction task as they are according to Loyola & Goldsack, (2010) actions, subjects, tools, materials, environmental conditions, restrictions. Some strategies are suggested in which these components must be taken into account in order to mitigate and manage changes in the construction processes.

In relation to changes due to contractual and/or administrative modifications, not many references were found in relation to mitigation strategies during the construction stage, although the main measures recommended are to have an adequate flow of information and communication between those involved in developing and managing the administrative processes in the project, and this is not only necessary to manage and prevent errors or contradictions in the contractual documents, but also to provide an adequate record, follow-up and formalization of changes in other areas such as those mentioned above.

It should be noted that, for this guide that focuses on changes that are usually caused by external events, a specific checklist is not presented, since, according to the theoretical bases explored, it is essential to have a list

of project risk identification from the planning stage, which is recommended to be related and integrated to this guide, since it will complement it, in addition to associating those risks identified in the project with the main causes presented in the guide.

The results obtained, the theoretical characterization and the proposed guide are also intended to be used to contribute to the different project management plans, since it is important that changes are taken into account in all processes and stages of planning, procurement, risks, scope and quality assurance, among others.

This reference guide seeks to show where efforts are directed when implementing the proposed strategies. Thus, identifying the 6 main groups of changes that affect construction projects, we can see for each one, a representation that brings together the most important causes, a check that allows to have a reference of the level of definition and identify some background of the project, followed by a series of strategies and recommended actions to prevent and mitigate the changes; and finally a range of possible impacts in time and cost, which may be generated at the end of the project, highlighting that these ranges are born of the proposed scales according to the theory found and the results of frequency in the collection instrument.

CONCLUSIONS

This research compiled at a theoretical level an extensive list of causes related to changes in construction projects (709 causes), which are classified, organized and synthesized according to the methodology described in 6 groups made up of 25 descriptions that summarize the main events and factors related to orders, requests or actions that imply an adjustment, an addition or elimination of some component, some task or work package or that affect the same and may have some consequence on the time, cost and/or scope baseline.

Undoubtedly, the problems generated during the execution of construction projects are the main cause of delays and cost overruns. The search and compilation allowed validating that part of these problems are mainly related to changes in designs, construction processes, new requirements and requests from the client, contractual, administrative and organizational modifications.

The collection instrument made it possible to classify the main changes identified in the theoretical review according to the level of importance using the relative importance index (RII) method based on the frequency of occurrence, cost and time impacts, identifying the most common changes based on their experience from the established population sample.

The three main groups of changes in terms of frequency of occurrence according to the evaluation obtained are design changes (RII = 0.707), changes due to construction-design interface (RII = 0.650) and changes due to client and/or owner request (RII = 0.636). This allows validating what was found in the theory resulting from research in other countries, in order to highlight the influence that these types of changes have at a general level in all construction projects and the relevance of identifying and continuing to deepen in the causes that generate them.

With the causes and their relationship with the impacts identified, it is possible to have a bank of experiences or events that serve as a reference for people who in their trade are involved or have the responsibility to manage changes in construction projects and can keep in mind situations that can lead to generate changes.

The set of strategies related to each group of changes, which were analyzed in this research, seek to address the problem and the difficulty that can still be observed in construction; in order to make a good identification of changes that allows announcing the need to take preventive actions and/or activate change management. Although these are not strategies that have not been addressed before in methodologies, standards or other similar ones, we sought to relate these strategies together with the data and results found in order to highlight the importance of the issue and, in turn, to show that it is still a constant that greatly influences the achievement of the expected objectives of the projects. At the same time, they allow to be used as a checklist during the execution stage and serve as a general reference in the initial planning of new projects thus generating value on

change management as an element beyond the diagnostic, as found in this research, proposing a real approach to the management of a binding change management that arises from the findings in existing literature and the experiences of stakeholders in the construction processes creating a practical awareness for the administration of the same as early warnings in its containment and management.

V. CRediT AUTHORSHIP CONTRIBUTION STATEMENT

Juan Felipe González Bermúdez: Conceptualización, Visualización, Escritura – Revisión y edición. **Fabian David Güiza Pinzón:** Conceptualización, Visualización, Escritura – Revisión y edición. **Jorge Andrés Sarmiento Rojas:** Conceptualización, Investigación, Escritura – Revisión y edición**. Oscar Javier Gutiérrez Junco:** Conceptualización, Investigación, Escritura – Revisión y edición**. Juan Sebastián González Sanabria:** Conceptualización, Metodología, Investigación, Escritura – Borrador Original.

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