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Integration of Cost and Work Breakdown Structures in the Management of Construction Projects

Alberto Cerezo-Narváez *, Andrés Pastor-Fernández, Manuel Otero-Mateo and Pablo Ballesteros-Pérez

School of Engineering, University of Cadiz, 11519 Puerto Real, Spain; andres.pastor@uca.es (A.P.-F.); manuel.otero@uca.es (M.O.-M.); pablo.ballesteros@uca.es (P.B.-P.)

* Correspondence: alberto.cerezo@uca.es; Tel.: +34-9564-83211

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Abstract: Scope management allows project managers to react when a project underperforms regarding schedule, budget, and/or quality at the execution stage. Scope management can also minimize project changes and budget omissions, as well as improve the accuracy of project cost estimates and risk responses. For scope management to be effective, though, it needs to rely on a robust work breakdown structure (WBS). A robust WBS hierarchically and faithfully reflects all project tasks and work packages so that projects are easier to manage. If done properly, the WBS also allows meeting the project objectives while delivering the project on time, on budget, and with the required quality. This paper analyzes whether the integration of a cost breakdown structure (CBS) can lead to the generation of more robust WBSs in construction projects. Over the last years, some international organizations have standardized and harmonized different cost classification systems (e.g., ISO 12006-2, ISO 81346-12, OmniClass, CoClass, UniClass). These cost databases have also been introduced into building information modeling (BIM) frameworks. We hypothesize that in BIM environments, if these CBSs are used to generate the project WBS, several advantages are gained such as sharper project definition. This enhanced project definition reduces project contradictions at both planning and execution stages, anticipates potential schedule and budget deviations, improves resource allocation, and overall it allows a better response to potential project risks. The hypothesis that the use of CBSs can generate more robust WBSs is tested by the response analysis of a questionnaire survey distributed among construction practitioners and project managers. By means of structural equation modeling (SEM), the correlation (agreement) and perception differences between two 250-respondent subsamples (technical project staff vs. project management staff) are also discussed. Results of this research support the use of CBSs by construction professionals as a basis to generate WBSs for enhanced project management (PM).

Keywords: scope management; work breakdown structure (WBS); cost breakdown structure (CBS); construction industry; cost classification system; building information modeling (BIM)

1. Introduction

According to the PricewaterhouseCoopers's "When will you think differently about programme delivery?" report [1], only 2.5% of companies successfully complete 100% of their projects. Similarly, the Project Management Institute (PMI) in its "Pulse of the Profession 2016" report [2], highlights that less than 50% of organizations achieve their objectives when there is not a PM culture in the organization. When there is, more than 70% of companies achieve their objectives instead. It seems project management (PM) is important then.

The adoption of PM methods brings multiple benefits to companies [3]. This is why there is a growing number of professional bodies, PM frameworks, and certified project managers [4]. However, in the context of construction, KPMG's "Climbing the curve" report [5] reveals the construction sector's low productivity in which less than a third of projects are completed within less than a 10% delay and a quarter within less than a 10% overrun.

Construction projects performance is influenced by many aspects (e.g., constraints, specific tasks, project changes) [6]. The project stakeholders need to state the functional requirements at a very early stage [7]. This allows identifying the elements that must be considered in the project definition (scope). The interrelationships among these elements and their relative importance allow the formulation of a first project network structure model. In this regard, scope management constantly assesses and updates this project network structure to carry out the project [8,9]. This implies the definition of all work a project involves, and also how to break it down into more manageable pieces. Generally, this progressive task decomposition is referred as work breakdown structure (WBS). Eventually, people and responsibilities will also be attributed to the different work packages. This links the WBS to the project and company's organigram.

Additionally, but somehow in parallel, companies draft the project budget. They normally resort to another structure where items are classified in chapters, subchapters, and units. This structure is generally referred to as cost breakdown structure (CBS). CBSs may keep some parallelisms (or not) with the WBS. This, as items in the CBS may be grouped according to multiple criteria such as items location, similar construction methodologies, materials, equipment, or resources involved.

Still, thanks to these processes, more accurate schedules and budgets can be generated and projects can be controlled (facilitating a comparison of what is actually carried out with what was intended to be executed). Conversely, ill-defined scopes are one of the most frequent causes of project failure [10]. This normally arises as poor project definition, contradictory requirements, important tasks omission, very inaccurate estimates, and inappropriate (unrealistic or overly optimistic) contingencies [11].

In summary, scope management takes care of what must be done in a project, why it should be done, and how it can be done [12]. All these play a key role in project performance. In scope management then, a hierarchical decomposition of all project tasks under the form of the WBS is paramount. However, the CBS is equally important, as it allows to manage the project cost dimension. Hence, both the WBS and the CBS are valuable PM tools as they establish the basis for planning, scheduling, budgeting, resource allocation, responsibility assignment, and information management [13]. In the construction industry, the development of the WBS and CBS allows the implementation of other project monitoring and control techniques that can also handle potential risks [14].

The main objective of this research is to confirm whether a significant alignment between the WBS and the CBS offers additional advantages when managing construction projects. It also investigates how this alignment can positively benefit and facilitate the adoption of BIM and other management tools. To do so, we will confirm the existence of a direct and significant causal relationship between the overlap (integration) between WBS and CBS with a higher degree of project objectives fulfilment. This piece of research is a continuation of the authors' research on the influence of the scope management in construction projects success [15].

This paper is structured as follows: Section 2 analyzes the PM standards and frameworks regarding WBS. Then, it compiles current coding systems of construction prices classification (CBS). Section 2 ends with the integration of WBS and CBS as BIM tools. Section 3 consists of the Methodology. The beginning of Section 3 describes which criteria were selected as synonym of project success, as well as how the theoretical model is built. The second part of Section 3 then describes the survey that was distributed among project technicians and project managers of the construction industry. The statistical analysis is also presented at the end of this section. Section 4 presents the Results of a structural equation model (SEM). This model describes the relationships between the project success criteria and the survey respondents' questions on WBS and CBS. Section 5 presents the Discussions. Finally, Section 6 includes the Conclusions, research limitations, and further research continuations.

2. Literature Review

Delivering projects on time, within budget and with required quality is one of the most difficult and challenging goals for project managers [16,17]. In the construction industry, an incomplete scope definition in the early stages of the project life cycle may be a source for future problems [18]. On the contrary, if a project is well defined, all necessary information is provided to identify the work that must be carried out [19]. During planning, stakeholders' needs and expectations become requirements. They shape the scope and inform about the major project deliverables, assumptions, and constraints [20–22]. The scope definition also allows to handle future project alterations [23,24]. In short, scope management ensures that only activities that contribute to meeting the project objectives are performed, from planning to closure [25–28].

2.1. Work Breakdown Structure (WBS)

Structuring the project scope at the outset is a good way of mapping the project elements and keeping internal consistency with the project objectives. All project work is broken down into activities and deliverables to which resources are allocated, scheduled, budgeted, and later, controlled [8]. This process is formalized under the creation of the work breakdown structure (WBS), as summarized in Figure 1.

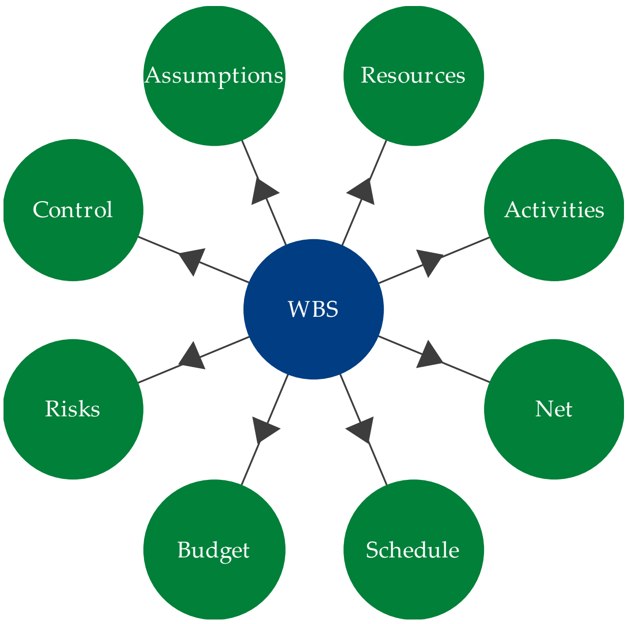

Figure 1. Relationship of the work breakdown structure (WBS) with the project.

The WBS has been extensively discussed and recognized as a powerful tool. Through the WBS, a project is hierarchically organized and systematically decomposed into smaller and manageable units for better performance control [29]. In this regard, the WBS aims at breaking down, classifying, and sub-grouping all project elements. Hence, in a WBS, each descending level represents increasingly detailed definition of all project components [30].

2.1.1. WBS in the International PM Standards

In order to achieve the project objectives, the ISO 21500 standard [31] suggests that the WBS must state all project deliverables and break them down into smaller packages. All WBS elements must include identification codes aligned with the configuration management plan. This way, the PM team can control the progress and assign responsible people to each of them.

For the International Project Association (IPMA), the project scope must stipulate what is outside and what is inside (what must be done/achieved) [8]. A good definition of the scope and deliverables ensures that discrepancies are eventually avoided and helps with the project planning. However, projects can be broken down according to different points of view (work distribution, project organization, information, documentation structure, etc.) [32]. The (hierarchical) project structures are key mechanisms for keeping the order and ensuring that nothing important is neglected [33]. The work packages (WPs) are assigned to a resource provider, the work is scheduled, the costs are estimated, and eventually the work is commissioned, controlled and completed.

For the PMI [9], the WBS subdivides all project work into components, including its deliverables. The WBS also includes a dictionary, which helps to better organize all necessary work into more-easily-identifiable portions. The decomposition has to be oriented to the deliverables required [34]. In this context, there are at least two main issues when developing a WBS: The level of detail and the decomposition criteria [35]. However, there is no universal rule for establishing the level of detail to be reached. Still, project managers know well that project decomposition requires subdividing the work of all deliverables and components into their most fundamental elements, up to the level at which they represent verifiable products, services, or results [9]. This is because the work contained in the WPs has to be eventually scheduled, resourced, budgeted, risk-assessed, measured, and monitored later. The WBS decomposition can also include information on contracts, quality requirements, and technical references of each element to facilitate the project control. However, the WBS does not sequence the work, nor states their interdependencies.

For the Project Management Association of Japan (PMAJ) [36], the focus of the WBS lies on the relationships between processes and work through cooperation and compensation. The documentation required for the elaboration of the WBS is prepared by focusing on the tasks and processes required to achieve the objectives. The objectives, in turn, are stated as the summary of characteristics of the qualitative results expected and the quantitative objectives to be reached.

To complete the review of the most common international PM standards, it is necessary to underline the approach of AXELOS (a joint venture created by the Cabinet Office on behalf of Her Majesty's Government and Capita PLC) in its PRINCE2 2017 standard [37]. In it, the product breakdown structure (PBS) is at the project core, not the WBS. The PBS refers to the products to be produced during a plan, but containing just that: Products. The WBS on the other hand, involves the entire work that needs to be completed during a plan, containing just activities. Project managers need to plan the whole project then by breaking down the products or outputs of the project first. Only then, they can break down the activities needed to produce those products.

To sum up, the decomposition of the project scope into a WBS (or PBS) includes the processes to define the work and deliverables required by the project (ISO 21500: 2012 [31]). Additionally, by doing so, it also defines the project boundaries (IPMA ICB 4 [8]). This way, it ensures the inclusion of all work required to complete the project satisfactorily (PMI PMBOK 6 [9]) and the work dedicated to delivering the project's purpose successfully (AXELOS PRINCE2 2017 [37]). It can be noted then that the WBS covers the processes for analyzing the tasks and resources needed to achieve the project objectives. As a result, it guarantees both the correct project execution and the availability of all resources necessary (PMAJ P2M 3 [36]). Hence, the main PM-related areas directly affected (and that are directly benefited) by the project WBS according to the international standards listed in Table 1 below.

Table 1. Management areas dependent on the WBS.

Standard	Value	Design	Change	Quality	Time	Resource	Supply	Cost	Risk	Delivery
ISO			X	X	X	X	X	X		
IPMA		X	X	X	X	X	X	X	X	
PMI			X	X	X	X	X	X	X	
PMAJ	X		X	X	X			X		X
AXELOS	X		X	X	X			X	X	

2.1.2. WBS in the Construction Industry

Tracking is necessary at all project execution stages [17]. However, the approval and implementation of changes at the planning stage of the project usually have a lower cost impact [38]. Later, during the execution stage, the measurement of work in progress is one of the most pressing problems for project managers [39]. In fact, accurate and up-to-date measurement of work in progress is essential for other PM functions such as schedule and cost control, financial reporting, change requests, and legal claims [40]. It is in this context that the WBS can be used by contractors as an evaluation tool (especially in large projects) [41,42]. The specific choice when drafting this kind of WBS depends mainly on three issues [43]:

1. The decomposition criteria, grouping activities into construction units assigned to the different contractors, and/or subcontractors involved in the execution of the project.
2. The degree of work complexity and level of detail that identifies the sequence and other relations between the activities in a logical flow of execution.
3. The criticality of the tasks, being defined in terms of units of work, according to their importance to avoid activity preemption.

Hence, there must be some logical pattern (decomposition criteria) in the way the activity tasks are subdivided [44]. For any significant project there usually is more than one correct way of breaking down the project work (according to the physical parts of the project, organizational patterns or work, allocation by managers and supervisors, etc.) [45]. The use of adequate WBS templates may help clients, contractors and consultants, particularly at the planning stage. More precisely, it can offer guidance to avoid important omissions at the conceptual and detail design and construction stages [46]. Despite this, decomposition criteria will still vary across organizations and projects as they involve some subjectivity [47]. In order to define consistent decomposition criteria, the considerations indicated in Table 2 must be observed [43].

Table 2. Decomposition criteria to construction unit level.

Criterion:	Comment
Global Vision:	Integrate to simplify, prevent omissions, and allow global analysis of the deliverable
Strategy:	Segregate to facilitate cross-referencing and save resources
Homogeneity:	Share measurement units and measurement approaches
Appraisal:	Be executed by a single trade to be paid once completed
Equity:	Make the investment profitable avoiding construction units that are executed separately
Analysis:	Meet aggregation criteria for cost analysis
Normalization:	Facilitate searches and comparisons

Regarding the level of detail of the decomposition, there is no uniform criterion either. Still, depending on the industry, organizational culture, and type of contract, a series of guidelines can be provided. For example, for effective project planning and control, the WBS must reflect an appropriate level of detail, reflecting the extent of decomposition and the sizing of the WPs [16]. This level of decomposition must be balanced with the administrative burden costs of managing them [48]. Some organizations also have general guidelines to make it easy to identify this optimum level of detail (emerging as one of main purposes of their PM offices). These are typically expressed in terms of effort or elapsed time, but do not usually consider the activities' specific aims [49]. Some researchers have also proposed alternative approaches, such as breaking down the project into 40-h work elements [50] (a person's work week), with no need to break it down further. Others have established that it is pointless to decompose the project elements once they represent less than 4% of the total project in time or cost [51].

As a general rule in construction projects, seven criteria can be considered to stop further subdivision of project tasks [52]:

1. Organizational unit's fixed responsibility.
2. Clear deliverable.
3. Exact scope of work.
4. Reliable schedule estimation.
5. Specific risk resolution.
6. Reliable cost estimation.
7. Specific organizational guideline.

Hence, the WBS defines the work content, but to classify all this information, it needs a coding system. Only in this way it is possible to use the WBS for archiving and retrieving project information. Hence, choosing an adequate classification system (more or less aggregated) is the first step when preparing the WBS [53]. Table 3 summarizes the evolution of some exemplary proposals of WBS that compile both decomposition criteria and progressive levels of detail in the construction industry.

Table 3. Examples of decomposition criteria and level of detail for a WBS in the construction context.

Chang and Tsai 2003 [54]		**Jung and Woo 2004 [48]**		**Ibrahim et al. 2009 [45]**		**Rianty et al. 2018 [55]**		**Ramadhan et al. 2019 [56]**	
1	Type	1	Facility	1	Location	1	Name	1	Name
2	Life Cycle	2	Space						
		3	Element	2	Element				
						2	Section	2	Section
		4	Section	3	Section	3	Area		
		5	Aid	4	Aid	4	Sub-section	3	Sub-section
3	Product	6	Product	5	Product				
4	Function	7	Attribute	6	Work Unit	5	Work Unit	4	Work Unit
5	Task	8	Management			6	Activity	5	Activity
6	Resource					7	Resource	6	Resource

Management by deliverables and deadlines is based on detailed and strict planning and control of project outcomes [57]. In this vein, identifying and prioritizing interactions and interdependencies among activities is essential [58]. This of course, requires that all project requirements and specifications have been stated and categorized beforehand. However, current techniques for scheduling and budgeting only take technical constraints into account when handling activities. That is, they commonly neglect activity location, continuity and productivity, among other constraints [59]. Consequently, misjudgments about the critical activities on construction projects can be caused by constraints that are not explicitly dealt with. This lack of information can also result in disruptive work sequences and ineffective resource usage.

2.2. CBS

A construction project involves of a series of processes, from design to planning, construction, maintenance, and disposal [60]. The cost breakdown structure (CBS) identifies all relevant cost categories in all project life cycle phases [61]. Hence, the CBS constitutes a functional breakdown of project costs. The CBS classifies all kind of costs (e.g., equipment, preparation, wages, welfares, maintenance, energy consumption, depreciation, taxes, fees, etc.) [62].

The hierarchical structure descends from the project to the task as shown in Figure 2. The project relates to the construction type, whereas the phase does it to its life cycle stage. Additionally, categories and elements are referred to the type of cost according to the project life cycle. Finally, the cost of a task (as a combination of its sub-activities) is the total cost of all resources needed to complete such a task, including direct and indirect costs. It must be noted, though, that international standards for life cycle costs (LCC), such as the ISO 15643-4:2012 and ISO 15686-5:2017 [63], suggest slightly different cost categories and cost breakdown structures.

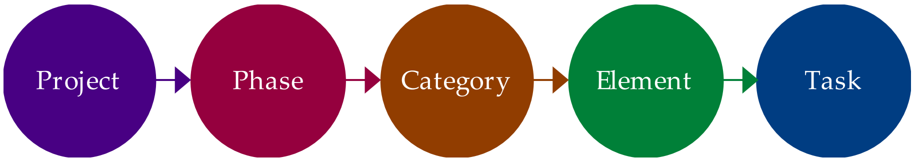

Figure 2. Hierarchical structure of the cost.

This study is focused on the management at the planning (including design) and construction stages of projects. During planning, the project schedule cannot be finished until resources have been allocated to WPs and their activities. Resources include funds, salaries, equipment, machinery, and materials required to achieve the project deliverables. In addition to the cost of resources, project expenditure encompasses other costs such as overheads, expenses, and facilities. If the overall cost estimates are accurate and reliable, fewer variations and remedial actions will be expected.

When the construction phase begins, the contractor carries the work out according to the planned schedule and cost. In this stage, the estimates have been expressed as a budget. This budget acts as the baseline for the stakeholders' later control tasks [64]. During the construction stage, significant differences between planned and actual costs will probably occur [65]. Many causes can be attributed: Poor design [66], price rises, scope changes [67], incomplete estimates and inadequate planning [68], additional or replacement works [69], optimism bias [70], etc.

Hence, at the planning and construction stages, the CBS enables costs to be collected, analyzed, and reported for any cost-generating item. These costs are also consolidated in a similar manner to the WBS. The codes of both systems may even be similar. However, the lower level of the CBS is generally known as the cost account (CA). The CA is the counterpart of the WP in the WBS. The CA is a natural and logical management center in which the costs of the work to be performed are integrated. Generally, it also comprises the costs relative to the organizational structure supporting its development, and the individual accountability and responsibility to undertake it. All this involves management functions such as planning, control, work definition, cost definition, estimating, change control, expenditure, information analysis and reporting [71], etc.

In this context, the use of ontology technology helps automate the process of searching for the most appropriate items coding [72,73]. By identifying the cost-driving features of the construction tasks, manual coding can be minimized. Examples of cost estimates conducted by the use of semi-automatic design models based on open Industry Foundation Classes (IFC) standards have also been developed recently [74].

2.2.1. Costs Based on Activities

The activity-based costing system (ABC) is a method that allows the allocation and distribution of indirect costs according to the activities carried out (direct costs). This, with the intention of being faithful to the added value chain and to determine adequately the cost sub-inputs [75]. A schematic of ABC is shown in Figure 3. Hence, the final result of the project can be broken down into WPs. These, in turn, can be divided into activities, which are the ones that generate costs. Once activities are defined, indirect costs can be allocated to activities through their cost-drivers [76].

Figure 3. Activity-based costing in the construction industry.

A variant to the ABC system is the time-driven activity-based costing (TDABC) system [77]. TDABC arises as a simpler, yet more precise and applicable model, that uses time as a cost driver. Once activities are defined, their durations must be estimated (thanks to their resource usage) and we can derive their cost-driver rates [76].

In the context of Spain where this research has been developed, there is no standard form for contract in construction projects. Most contracts between clients (public and private) and contractors are based on quantity survey models. In quantity survey contracts, contractors assume all future variation of unit prices, but not variations in the bill of quantities due to the design defects or events that could not be planned. Other international contracts, such as FIDIC [78], are also used in Spain, but only when international financing is involved. The quantity survey contract then reduces contractors' uncertainty and allows them to become more competitive by adjusting their mark-ups [79]. Additionally, from the clients' point of view, it is very important that all activities are included and that they are well defined, both in terms of scope and quality [80].

Furthermore, in Spanish projects and public tenders, unit prices are taken from a series of construction price databases [81–83]. Most Spanish regions have their own price databases (e.g., Andalusia [84], Catalonia [85], Extremadura [86], Madrid [87], etc.). These prices are generally binding when used in a project. In the private sector, there are also companies that have their own construction price databases (e.g., Arquimedes by CYPE [88], Premeti by PREOC [89], Menfis by PROSOFT [90], etc.). The vast majority of all these public and private price databases are broken down in five progressive levels, as shown in Figure 4.

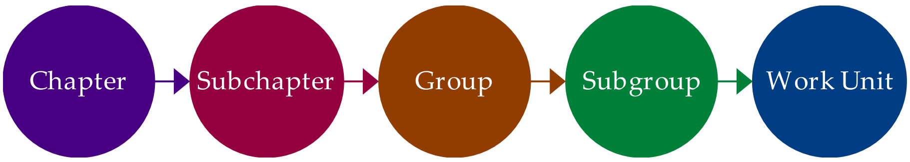

Figure 4. Hierarchical structure of Spanish construction price databases.

2.2.2. Coding Systems in the Construction Industry

A coding system is a methodology based on relationships and affinities that promotes organization and standardization. Coding systems allow terms homogenization, but also the adoption of common methods and concepts. They must have these three properties [91]:

- Consistency (single classification principle).
- Mutual exclusivity of categories.
- Exhaustiveness.

Identifying the criteria to be applied in the decomposition of WBS is the first challenge [13]. The International Organisation for Standardisation (ISO) identified eight possible classification criteria of construction information [92]: Space, element, work section, construction product, construction aid, attributes, and management. However, other authors have suggested to separate construction and engineering works [93]. Namely, the latter proposed a construction information classification system on the one hand (based on facility, space, element, operation, and resource criteria), and an engineering information classification system on the other hand (this based on construction type, life cycle, product or service, function, tasks, and man-hour attributes criteria) [54].

Hence, it soon became apparent that these deeply rooted national approaches would make the adoption of an international standard difficult. In this situation, a compromised agreement was necessary. A framework for classification tables was suggested that would at least make communication easy between the classification tables that different national organizations were using. This could spur them on to establish tables using the same criteria. This is why in the second half of the 20th century, construction organizations from different countries began to develop other classification and coding systems [93]. A good example was the European classification standard Code of Measurement for Cost Planning (CMCP) [94]. This standard is observed in Europe. The CMCP was developed by the European Council of Construction Economists (CEEC), which encompasses the following countries: Belgium, the Czech Republic, Denmark, Estonia, Finland, France, Germany, Hungary, Ireland, the Netherlands, Poland, Portugal, Spain, Switzerland, and United Kingdom (UK).

The European system is based on the classification and coding of the German standard DIN 276-1 [95] and, to a lesser extent, on the standards from other countries (BSAB from Sweden [96], UniClass from the UK, Australia and New Zealand [97], TALO from Finland, Estonia and Russia [98], and DBK from Denmark [99], etc.). The CMCP, and its successor ICMS [100], arise from harmonizing working methods and exchange of information among construction projects. This is achieved by sharing a standard set of measurement rules and essential guidance on cost management. According to the CEEC [101], the creation of a WBS for construction projects consists of these six stages:

1. Identify the final result (or deliverable) to achieve the objectives.
2. Review the scope to ensure consistency between requirements and the WBS elements.
3. Define the chapters (first level of decomposition) in a way that facilitates the understanding by dividing them into clearly differentiated blocks.
4. Continue to break down each chapter to an appropriate level of detail.
5. Break down the chapters to the final level of detail (construction unit), where both the cost and the schedule are reliable, allowing efficient project monitoring and control.
6. Review and refine the WBS until main stakeholders agree on the planning and execution.

There have been other coding system initiatives. In United States (USA) and Canada, the Construction Specifications Institute (CSI) [102] created standards such as Masterformat [103] and Uniformat [104]. Masterformat keeps a material-based organization and Uniformat keeps a systems-based organization. As a result of the combination of these two systems, the Omniclass standard emerged [105]. With them, the CSI facilitates information management and sharing in the construction industry. This is also eventually aimed at improving construction projets performance.

Similarly, as a result of all these disjoint initiatives, the international standards ISO 12006-2 [106] and ISO 81346-12:2018 [107], were created. According to the IOS, the construction industry's lack of consistency (regarding standardization) was probably hindering the progress of the industry towards higher quality, efficiency, and productivity. Building on the ISO standards, though, most countries with construction classification systems have either proposed new standards (e.g., OmniClass in USA and Canada [105], CoClass in Sweden [108], CCS in Denmark [109], and ICMS in Europe [100]). Some countries have also updated existing ones (e.g., UniClass in the UK [97], and TALO in Finland [98]). The approach of these coding systems is compared in Table 4.

Table 5 on the other hand, shows major coding system proposals aimed at standardizing project cost structures. With the advent of BIM, information needs to be processed automatically. Naming all objects and their properties in an unique and unambiguous way is a must, and the use of reference libraries for object-oriented information in another. All this has led to the development of a new standard: The ISO 12006-3 [110]. This standard is currently under review.

Table 4. Comparison of international coding systems.

ISO 12006-2	ISO 81346-12	OmniClass	CoClass	CCS	UniClass
Information		Information		Documents	Forms
Products	Components	Products Materials	Components	Components	Products
Agents		Disciplines Roles		Documents	Agents
Aids		Tools		Equipment	Tools Equipment
Management		Services		Documents	PM
Processes		Phases		Documents	Phases
Complexes			Complexes		Complexes
Entities		By Functions By Forms	Entities	Entities	Entities Activities
Built Spaces	Spaces	By Functions By Forms	Spaces	Built Spaces User Spaces	Spaces Locations
Elements	By Functions By Technics	Elements	By Functions By Technics	By Functions By Technics	Functions Systems
Work Results		Work Results	Production		
Properties		Properties	Properties Landscape	Classes	Properties CAD

Table 5. Evolution of the main coding systems in the construction industry.

Code	Edition		Ref	Scope	Organization
	First	Last			
Masterformat	1963	2018	[103]	USA [1]	Construction Specifications Institute
Uniformat	1973	2010	[104]		
OmniClass	2006	2019	[105]		
DIN 276-1	1993	2008	[95]	Germany	Deutsches Institut für Normung
BSAB	1996	2005	[96]	Sweden	Swedish Building Centre
CoClass	2015	2018	[108]		
UniClass	1997	2019	[97]	UK [2]	Construction Project Information Committee
TALO	2000	2017	[98]	Finland [3]	Building Information Foundation
DBK	2006	2010	[99]	Denmark	Building Information Technology, Productivity, and Stands (Dansk Bygge Klassifikation)
CCS	2012	2017	[109]		
CMCP	2008	2014	[94]	Europe	European Committee of Construction Economists(International coalition)
ICMS	2017	2019	[100]		
ISO 12006-2	2001	2015	[106]	World	International Organisation for Standardisation
ISO 81346-12	2018	2018	[107]		

[1] and Canada, [2] and Australia and New Zealand, [3] and Estonia and Russia.

2.3. Integration of WBS and CBS

Defining the construction project scope and establishing the WBS are the first steps to estimate activity costs. Finding applicable unit cost items from construction price databases are the next [111]. Thanks to the use of a unique coding system, cost items related to a project, organization, work package, resources, materials, etc., can be easily integrated [71].

Duration and cost are considered the two major targets of construction projects [81]. This is why a significant effort is required at the planning and control stage [112]. The interdependency between schedule and budget is obvious. Time and cost performance are closely related as they share similar control processes such as common data, resources, and bills of quantities [113]. Project efficiency can then be raised by establishing a breakdown structure based on integration of CBS and WBS [114]. This would also allow developing and systematizing future management standards as well [115].

As presented earlier, the use of a coding system is essential to integrate the project structure. This way, schedule and budget can be more easily planned [116]. In addition, this integration enables a better definition of the attributes of all project entities, and it also ensures consistency [117]. A need for a tighter control has also been claimed for thirty years (e.g., [35,118,119]). The integration of the CBS and WBS, for example, could allow building a matrix that mapped activities progress and location of each project element (WP- and CA-based). In fact, most existing integration models aim to manage projects by measuring the progress rate during the execution stage. This, to check if they are progressing according to planned schedules and costs [120]. This could also be promoted thanks to the integration of CBS databases and WBS-based entities.

2.4. BIM in the Construction Industry

The implementation of BIM allows managing the construction project information (and its documentation) from the design phase to its maintenance and operation [121]. BIM has demonstrated its potential in several environments, such as facility management (FM) [122], lean management (LM) [123], and more recently in the railway industry [124]. The first reason is that BIM systems contain enriched information. This facilitates the exchange and interoperability of information making it capable of supporting multiple types of analysis, including PM analyses (e.g., scope, quality, schedule, cost, and risk) [111]. Thanks to the growing popularity of BIM, data automation (at least regarding acquisition and processing) is guaranteeing a more reliable, accurate, and precise scope definition and cost estimation. These aspects enable wider collaboration and more active participation of project stakeholders in all stages [11].

In this context, where there is more available and reliable, but confidential, information, the whole construction process must be standardized. This can be done introducing a WBS in the BIM model [125]. The WBS has proven to be an excellent tool for the prevention and control of cost overruns, delays, and risk triggering [126], especially in combination with PM software [127]. Indeed, many BIM-based tools have been developed for construction scheduling and cost estimating [111], although most of them focus on product and element level [128].

BIM-based WBSs have occasionally been introduced in construction (for example prototyping a linkage between the CBS and the WBS [125]). However, these have mostly focused on the product (the infrastructure or building) neglecting the management dimension. The integration of the CBS and the WBS must take into account this double dimension (the result and the necessary work to materialize it) [114]. However, the process classification system and the cost classification system must be assembled into BIM models. This means dimensional activities must be aligned to cost statements according to the combination of both WBS and CBS classification systems simultaneously. Fortunately, the object-oriented approach of modeling building information facilitates the standardization of different WBS databases [16].

BIM offers the best automatic approach to generate accurate and direct quantity measurements from virtual models [129]. Management information such as progress, cost, safety, and quality is integrated via 3D models providing useful information for project managers [130]. Additionally, BIM adds many other engineering information database capabilities, such as storing architectural designs with geometric and technical information.

However, a critical issue in current 3D BIM models is the discrepancy between the element breakdown structure (EBS) and the WBS of the project schedule. Integrating construction records into BIM remains a challenge due to their heterogeneous and unstructured data formats [131]. In fact, at the construction stage, a large number of construction reports are generated (e.g., schedule and cost reports, construction methods, site photos, shop drawings, change orders, etc.), but these are not properly integrated in the current as-built project documentation.

3. Methodology

The investigation of critical success factors in the construction industry has been a source of ideas for the organizations to address their challenges [132]. The analysis of critical success factors has also been a source to improve the efficiency of the companies' work processes [133]. This research will allow companies to increase their competitiveness [134] by facilitating that the stakeholders' expectations are more easily meet [135]. As described earlier, the first step of the planning stage of a construction project consists of managing the scope [136], establishing objectives, setting boundaries, specifying deliverables, and ensuring the understanding of staff roles [137]. This way, organizations that undertake construction projects list the necessary specifications, requirements, restrictions, and exclusions [138]. Eventually, they disaggregate the work to achieve the project objectives [139], monitor the process [140], and validate the deliverables [141].

This research analyzes the existence of a causal relationship between the use of work breakdown structures (WBS) based on cost classification and coding systems (CBS) with the achievement of project objectives, as summarized in Figure 5. Based on the analysis of critical factors (related to the work structure) and project success, a structural equation model (SEM) is proposed.

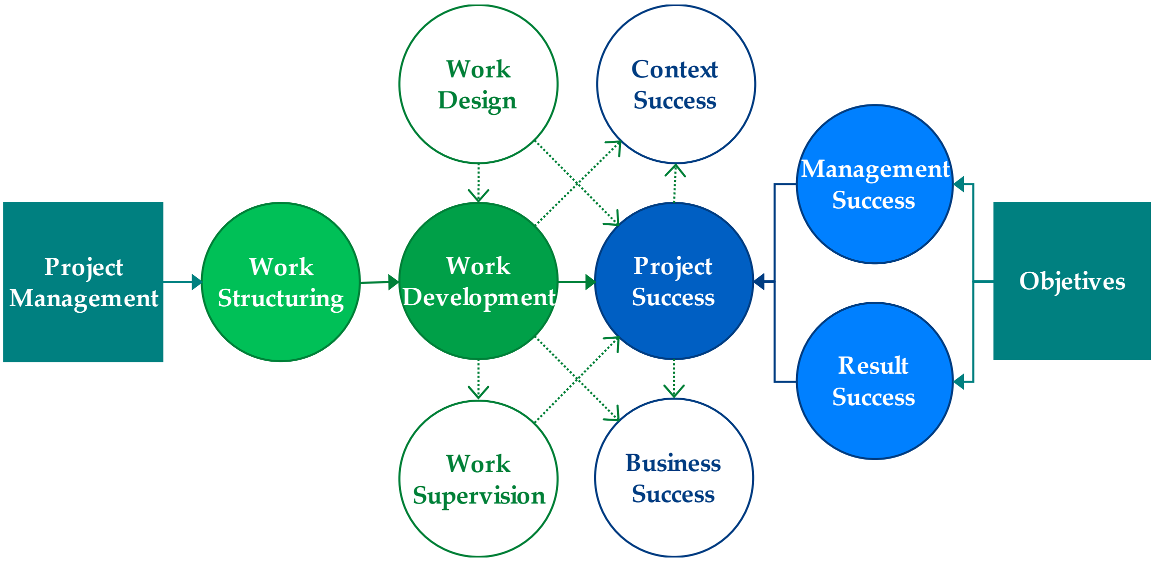

Figure 5. Theoretical model.

The primary research method chosen for the study was the analysis of a questionnaire survey. This survey was distributed among technical personnel and management staff working in the construction industry. The questionnaire explored their respondents' perceptions on the importance of a series of factors on work development (the work to be done for making and managing the scope of the project) and project success (the result to be done for accomplishing the objectives of the project). In this research, subjectivity and possible biases in data extraction were minimized by maximizing the diffusion of the questionnaire [142].

It can be noted that the responses were processed separately for each subgroup of professional (technical personnel and management staff). To identify potential perception differences between both groups, a five-point Likert scale ranging from 1 (completely marginal = irrelevant) to 5 (completely crucial = critical) was employed. This way, the extent to which the participants considered the importance/impact of each factor on project success can be determined. Similarly, other authors have also previously contrasted two or more respondent population samples in the context of the construction industry (e.g., field workers vs. experts [143], contractors vs. consultant project managers [144], industry professionals vs. experienced professionals [145], by trades [146] or buyers vs. supply managers [147], etc.).

The questionnaire itself was divided into three parts. In order to ensure the credibility of this study, the respondents were carefully selected, restricting the population universe thanks to the first part. This first part consisted of a pair of questions. The first question classified the industrial sector in which the respondents currently work. In the same vein, the second question filtered their experience in BIM environments. This way, respondents from outside the construction industry and without any experience in the design, development, and/or management of BIM projects could be ruled out from this piece of research.

The second and third parts develop the main purpose of the research. The second part of the questionnaire included the demographics in order to classify the respondents (age, company size in which they provide their services, and average cost and duration of the projects in which they usually work). A second section of this part of the demographics set of questions allowed us to discriminate whether the respondents were technicians or managers.

In order to differentiate and discriminate the sample of technicians from the sample of managers, the questionnaire namely asked a series of questions. First, if the respondents had received official PM training (as undergraduate or graduate). Next, if they were familiar with some common PM frameworks (such as ISO 21500:2012 [31], IPMA ICB 4 [8], or PMI PMBOK 6 [9]). Then, if they were certified PM professionals (by IPMA or PMI, for instance). Last, their experience in the construction sector. These control questions are summarized in Table 6. In order to classify the respondents, five bins were generated for each question.

Table 6. Population demographic questions for sample classification.

Bin Variable	1	2	3	4	5
Age (in years)	<25	25–30	31–45	46–60	>60
Company size (Staff size)	Freelance 0	Micro 1–9	Small 10–49	Medium 50–249	Large >250
Avg. project duration size (in months)	<4	4–12	13–24	25–48	>48
Avg. project budget size (in €)	<100 k	100 k–500 k	500 k–1 M	1 M–2 M	>2 M
PM training (Highest level only)	–	Degree	Postgrad	Master	PhD
Knowledge (ISO 21500/PMI PMBOK/IPMA ICB)	Poor	Fair	Average	Good	Excellent
Experience in the construction industry (in years)	<1	1–5	6–10	11–20	>20
PM certification (Highest recognition only)	–	CAPM IPMA-D	PMP IPMA-C	PGMP IPMA-B	PFMP IPMA-A

The third part of the questionnaire contained twelve questions: Six related to project scope management (design and development) and six to success (project and organization). Table 7 summarizes the questions, which were assessed with 5-point Likert scales.

The questionnaire was distributed through the public lists of Spanish official colleges of technicians and engineers with legal attributions in the construction industry:

- CSCAE (Higher Council of the Colleges of Architects of Spain).
- CGATE (Spanish General Council of Technical Architecture).
- CCIP (College of Civil Engineering, Channels and Ports of Spain).
- CITOP (College of Technical Engineers in Public Works of Spain).
- CGCOII (Higher Council of Colleges of Industrial Engineers of Spain).
- COGITI (Spanish General Council of Technical Industrial Engineering).

However, also among PM professional associations:

- AEIPRO (Spanish Project Management and Engineering Association).
- PMA (Project Managers Association of Andalusia).
- PMI (Chapters of Andalusia, Balearic Islands, Barcelona, Madrid and Valencia).

Additionally, in several specific interest groups through the social network LinkedIn:

- AECMA (Spanish Association of Construction Management).
- AEGC (Spanish Construction Management Association).
- B&M (Building and Management).
- AEPDP (Spanish Association of Project Management Practitioners).
- CCPM (Construction Certified Project Managers PMP).
- CMAS (Construction Management Association of Spain).
- DIP (Integrated Project Management).
- DP (Building and Infrastructure Project Managers and Professionals).
- IAC (Engineering, Architecture and Construction).
- ISO 21500 (Project Management).
- Search&Drive (Architecture and Engineering Professionals).
- TL (Architecture, Construction and Engineering Technicians).

Table 7. Third part of the questionnaire questions on critical project success factors.

	Scope Design:
Q01	Agreement on requirements
Q02	Scope definition
Q03	Deliverables definition (regarding specifications and acceptance criteria)
	Scope Development:
Q04	Work breakdown
Q05	Work organization (prevention of tasks omission)
Q06	Identification of activities
	Project Success:
Q07	Performance of project constraints (time, cost, quality, risks, resources)
Q08	Stakeholders' satisfaction (clients, users, shareholders)
Q09	Project outcomes usability (products and/or services)
	Organization Success:
Q10	Compliance with strategic objectives (alignment)
Q11	Market positioning (creation, expansion, and consolidation)
Q12	Profit generation (business)

The survey remained open until the confidence interval and statistical errors for both samples were narrow enough to draw valid conclusions (see the sample analysis in the next section). From the 640 responses received, only respondents working in the construction industry and with experience in BIM environments were selected. Most of them were either working in building and/or civil works as their main occupation. Five hundred individuals eventually met this condition. Coincidentally, 250 respondents were found to belong to each subgroup of professionals: Technicians and managers. Their company role profiles are summarized in Table 8a,b.

Table 8. Technical (a) and managerial (b) roles of the respondents.

(a) Technical Roles	**Number**	**Average**	**(b) Managerial Roles**	**Number**	**Average**
Architects	112	44.8%	Portfolio Managers	48	19.2%
Civil Engineers	45	18.0%	Program Managers	59	23.6%
Industrial Engineers	39	15.6%	Project Managers	82	32.8%
Quantity Surveyors	54	21.6%	PM Team	61	24.4%
	250			250	

4. Results

Figure 6 summarizes the demographic traits of both 250-respondent groups: Construction Industry Technicians (CIT) and Construction Industry Managers (CIM). Namely, Figure 6 shows eight histograms corresponding to the eight variables and five bins described earlier in Table 6. These are the demographic samples highlights:

- The age and experience in the construction industry of both groups is quite similar.
- Technician practitioners (CIT sample) mostly work in smaller companies, whereas construction managers (CIM sample), while still work more for small companies, also work in companies with other sizes.
- The project duration and cost size tends to be higher in the projects where construction managers participate.
- The knowledge and training of PM methodologies (e.g., ISO 21500, PMI PMBOK, IPMA ICB, etc.) is almost null in the case of technicians, and fairly high in the case of construction managers.
- PM certification is much more common among construction managers too (probably an expected outcome).

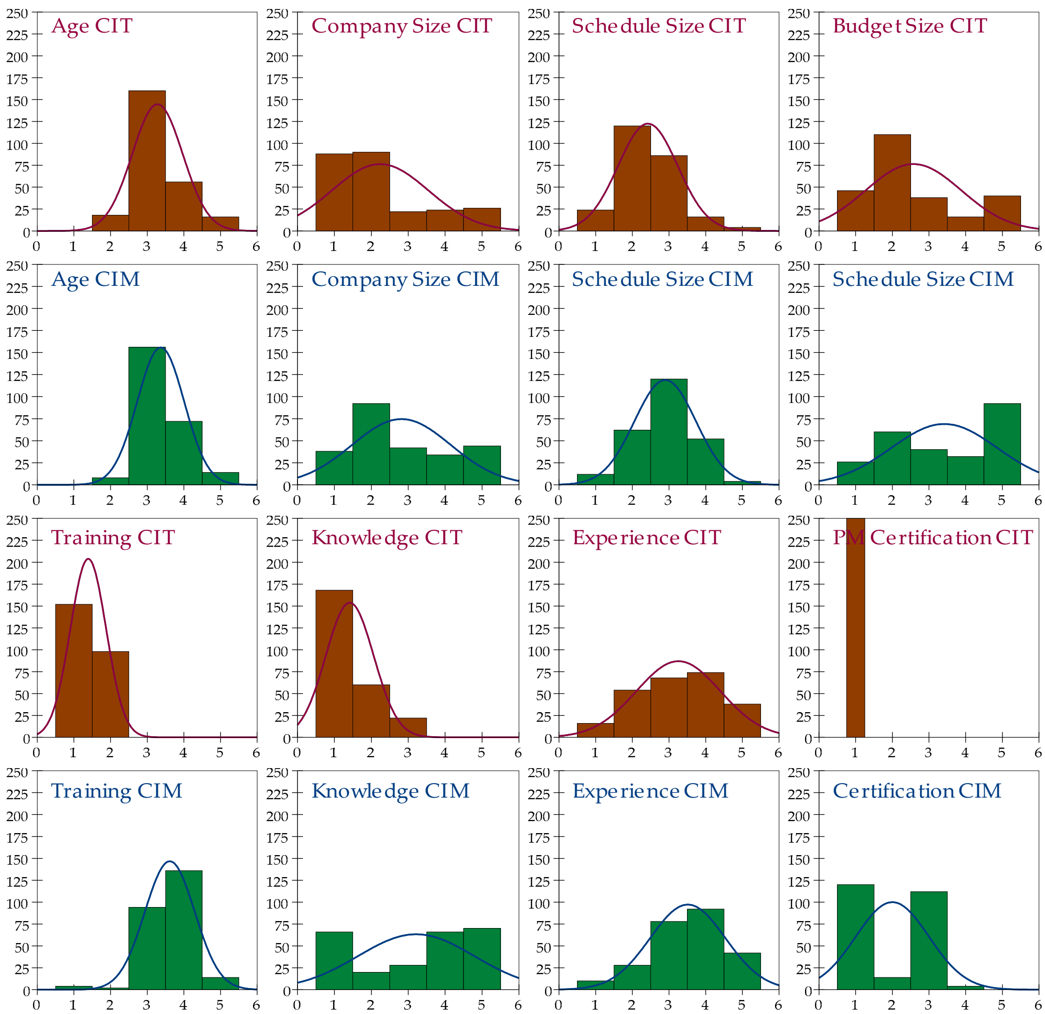

Figure 6. Results of the control questions.

With both samples described, the results of the third part of the survey (the last 12 questions about the critical success factors) could be filtered, analyzed, and contrasted. We kept a separate analysis of this part of the questionnaire by sample group to observe whether each group had a significantly different perception regarding the importance of each critical success factor.

First, we checked the reliability and accuracy of the measuring instrument. With a normal confidence interval (95.45%) and a standard deviation of 50% of the scale ((5 − 1)/2) at worst, a sample of 246 respondents was needed not to exceed a 5% error. Since the survey automatically closed when each sample received 250 (valid) respondents, it was guaranteed that the error did not exceed 5%. The actual survey error results are shown in Table 9 for both population samples.

Table 9. Reliability and accuracy of the measuring instrument.

Item	Statistical Properties	CIT	CIM
n	Sample	250	250
μ	Mean	76.95%	77.50%
σ^2	Heterogeneity	22.91%	22.36%
1-α	Confidence interval	95.45%	95.45%
E	Statistical error	02.97%	02.93%

Ensuring the responses error was small enough, the next two tables summarize a descriptive summary of the perceived (average μ and standard deviation σ) importance of each of the 12 items regarding project scope planning (Table 10) and project success (Table 11). It can be observed that the perception differences between both professional groups (CIT and CIM samples) are marginal, both on average, but also by item.

Table 10. Answers to questions related to scope design and development (1–5 scale).

Item	Question	CIT Sample		CIM Sample	
		μ	σ	μ	σ
F1	**Scope Design:**	**3.95**	**1.03**	**3.97**	**1.03**
Q01	Agreement on requirements	4.47	0.71	4.36	0.71
Q02	Scope definition	3.93	0.88	3.90	0.88
Q03	Deliverables definition (specifications and acceptance criteria)	3.46	1.18	3.65	1.18
F2	**Scope Development:**	**4.05**	**0.89**	**4.11**	**0.89**
Q04	Work breakdown	4.00	0.88	4.11	0.88
Q05	Work organization (prevention of tasks omission)	4.14	0.89	4.20	0.89
Q06	Identification of activities	4.00	0.90	4.03	0.90
		4.00	**0.96**	**4.04**	**0.96**

Table 11. Answers to questions related to project and organization success (1–5 scale).

Item	Question	CIT Sample		CIM Sample	
		μ	σ	μ	σ
C1	**Project Success:**	**4.35**	**0.84**	**4.33**	**0.83**
Q07	Performance of project constr. (time, cost, quality, risks, resources)	4.23	0.87	4.16	0.84
Q08	Stakeholders' satisfaction (clients, users, shareholders)	4.24	0.89	4.24	0.84
Q09	Project outcomes usability (products and/or services)	4.60	0.70	4.58	0.75
C2	**Organization Success:**	**3.96**	**1.00**	**3.99**	**1.01**
Q10	Compliance with strategic objectives (alignment)	3.91	0.98	3.93	0.94
Q11	Market positioning (creation, expansion, and consolidation)	4.04	0.98	4.02	1.01
Q12	Profit generation (business)	3.92	1.04	4.02	1.07
		4.16	**0.94**	**4.16**	**0.94**

4.1. Hypotheses

In this section, we confirm several hypotheses regarding the existence (or not) of a relationship between the four constructs analyzed: Scope design (F1), scope development (F2), project success (C1), and organization success (C2). The six hypotheses (numbered as H1 to H6) are listed in Table 12 and depicted in Figure 7. These hypotheses were tested with a structural equation model (SEM) described later.

Table 12. Hypotheses.

Hypotheses	Positive Influence		
H1	(F1) Scope Design	→	(F2) Scope Development
H2		→	(C1) Project Success
H3		→	(C2) Organization Success
H4	(F2) Scope Development	→	(C1) Project Success
H5		→	(C2) Organization Success
H6	(C1) Project Success	→	(C2) Organization Success

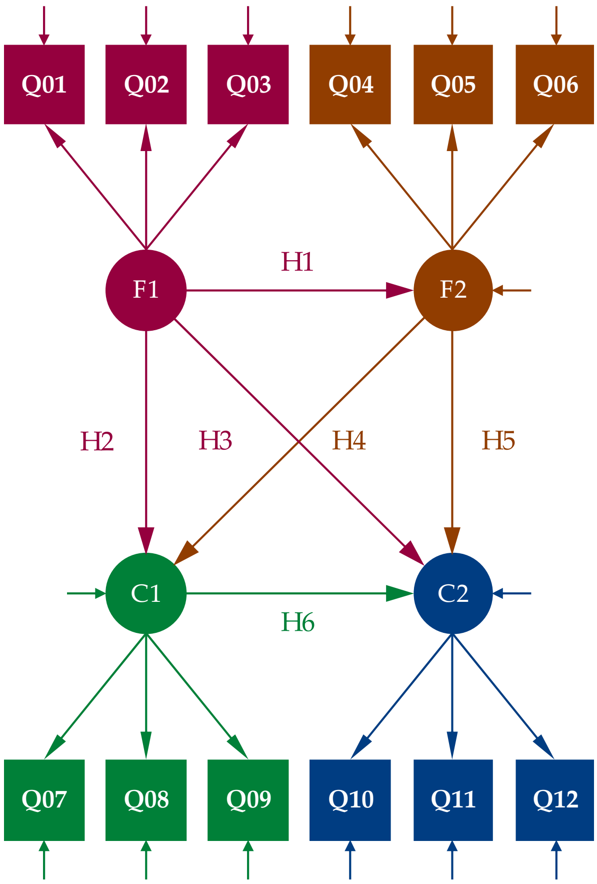

Figure 7. Structural components.

4.2. Confirmatory Factor Analysis (CFA)

The first step after building the SEM involved the CFA. Through factor analysis, the observed variables (in this case, the 12 questions) were grouped by trios. This allows reducing the model dimensions to just four. Tables 13 and 14 present the principal component (extracted from each trio of observed variables). It can be noted that this CFA follows Kline's principle [148] by clustering variables by groups of three.

Table 13. Principal components analysis of the factors related to work design (F1) and work development (F2).

Items	Principal Components			
	F1		F2	
	CIT	CIM	CIT	CIM
Q01	0.798 [a]	0.853 [a]		
Q02	0.824	0.832		
Q03	0.532	0.744		
Q04			0.766 [a]	0.856 [a]
Q05			0.742	0.829
Q06			0.762	0.819

Note: Results represent analyses that included company size as a control variable. All factors without superscript 'a' are significant at $p < 0.001$; factors with superscript 'a' are set to 1.00 before estimation.

Table 14. Principal components analysis of the criteria related to project success (C1) and organization success (C2).

Items	Principal Components			
	C1		C2	
	CIT	CIM	CIT	CIM
Q07	0.820 [a]	0.812 [a]		
Q08	0.831	0.822		
Q09	0.709	0.763		
Q10			0.807 [a]	0.806 [a]
Q11			0.872	0.872
Q12			0.866	0.829

Note: Results represent analyses that included company size as a control variable. All factors without superscript 'a' are significant at $p < 0.001$; factors with superscript 'a' are set to 1.00 before estimation.

4.2.1. Principal Components

The CFA reveals that the first six questions (Q01–Q06) related to scope management at the planning stage, and the last six questions (Q07–Q12) related to future project success, can be reduced to just a pair of principal components, respectively [15]:

- (F1) Scope design (which involves the project managers and key stakeholders agreeing on the requirements, defining the scope and deliverables characteristics, specifications and acceptance criteria).
- (F2) Scope development (which involves the project managers and their management team, breaking down the work to be done, avoiding tasks omission, and identifying the project activities).
- (C1) Project success (which includes the constraints performance, the stakeholders' satisfaction, and the outcomes usability).
- (C2) Organization success (which includes the strategic objectives compliance, market positioning, and the business profit generation).

4.2.2. Validity

Based on the results above, the CFA model could be deemed as valid, because, as summarized in Table 15:

- The total variance explained by the principal components, was greater than 50%.
- The measure of sampling adequacy, by the Kaiser–Meyer–Olkin test [149,150], was greater than to 0.5.

- The model applicability, by the Bartlett's sphericity test [151], discarded a lack of correlation between items, as it presented a high Chi-square and a significance lower than 5%.

Table 15. Validity of the model confirmatory factor analysis (CFA) results.

Questions	Variance Explained		KMO Test		Bartlett Test	
	CIT	CIM	CIT	CIM	CIT	CIM
Q01–Q06	82.51%	87.37%	0.771	0.868	283.81 (15,*)	557.51 (15,*)
Q07–Q12	87.64%	87.12%	0.766	0.793	448.07 (15,*)	464.29 (15,*)

Note: * 15 degrees of freedom with a significance (p-value) below 0.001.

4.3. Structural Equation Model (SEM)

SEMs are widely used to explore and test causal relationships among latent variables by the combination of factor analysis, multiple correlation, regression and path analysis [152]. Compared to other multivariate analysis methods, such as multidimensional scaling, multiple regression and neural networks, SEM has the ability to [148,153]:

- Define a model explaining a complete set of (significant) relationships.
- Uncover unobserved (indirect) relationships between variables.
- Estimate multiple and interrelated dependence relationships.
- Consider measurement errors in the estimations.
- Test the model where a structure can be imposed and assessed as to fit of the data.

However, before showing the effects, both direct and indirect, that confirm the hypotheses proposed in Table 12, it is necessary to check the model's:

- Reliability:

  By the Cronbach's alpha and composite reliability.
- Validity:

  By the standardized regression weights and squared multiple correlations, as well as the average extracted variance.
- Goodness of fit:

  By absolute, incremental, and parsimonious fit measures.

4.3.1. Reliability

Cronbach's alpha (Cα) value is used to test the consistency of the hypothesized constructs based on the data [154]. Cα is inflated by a large number of variables, and there is no exact interpretation as to what constitutes an acceptable limit. However, a rule of thumb applies to most situations with the following ranges [155,156]:

- Cα > 0.9 as excellent.
- 0.9 > Cα > 0.8 as good.
- 0.8 > Cα > 0.7 as acceptable.
- 0.7 > Cα > 0.6 as questionable.
- 0.6 > Cα > 0.5 as poor.
- 0.5 > Cα as unacceptable.

Due to almost all Cα coefficients (including the six constructs and the overall model) were above 0.7, the measurement of this study can be considered at least as acceptable, in terms of consistency of the measurement scale. However, although Cα coefficient is the most widely used estimator of the reliability of tests and scales, the composite reliability (CR) is also proposed as an alternative [157]. The CR represents the ratio of the true score variance of a construct divided by its observed score variance. Values of CR above 0.9 are considered very good and above 0.7 as acceptable. As shown in Table 16, the items measured in the six constructs (and the overall model) were sufficiently consistent and reliable.

Table 16. Reliability tests of the questionnaire responses.

Variables	All (12)		F1		F2		C1		C2	
	CIT	CIM	CIT	CIM	CIT	CIM	CIT	CIM	CIT	CIM
Cα	0.831	0.890	0.599	0.717	0.627	0.782	0.696	0.716	0.805	0.783
CR	0.864	0.910	0.768	0.852	0.801	0.873	0.831	0.841	0.885	0.874

4.3.2. Validity

In addition, it is important to verify whether the measurement validity was acceptable. Statistically significant standardized regression weights (SRWs) of 0.5 or higher indicate good validity, suggesting adequate convergence [156]. In the case of the squared multiple correlations (SMCs), also called reliability coefficients, a significant value of 0.5 or higher indicates good validity too [158], as long as at least half of its variance is predicted. Tables 17 and 18 present the SRW and the SMC values for each observed variable, both for the sample of technicians (CIT) and managers (CIM).

Table 17. Standardized regression weights (SRWs) and squared multiple correlations (SMCs) of the factors related to the work design (F1) and work development (F2).

Items	SRWs				SMCs	
	F1		F2			
	CIT	CIM	CIT	CIM	CIT	CIM
Q01	0.626	0.769			0.492	0.591
Q02	0.642	0.708			0.512	0.602
Q03	0.423	0.634			0.279	0.501
Q04			0.613	0.762	0.476	0.581
Q05			0.607	0.718	0.469	0.515
Q06			0.575	0.737	0.431	0.544

Table 18. SRWs and SMCs of the criteria related to project success (C1) and organization success (C2).

Items	SRWs				SMCs	
	C1		C2			
	CIT	CIM	CIT	CIM	CIT	CIM
Q07	0.726	0.711			0.527	0.603
Q08	0.738	0.796			0.544	0.586
Q09	0.525	0.722			0.275	0.506
Q10			0.684	0.631	0.468	0.622
Q11			0.781	0.697	0.611	0.734
Q12			0.826	0.709	0.582	0.604

Furthermore, we resorted to Fornell and Larcker's measure of average variance extracted (AVE) to approve the validity of the constructs [159]. The AVE determines the amount of variance apprehended by a construct through its factors relative to the amount of variance as a result of the measurement error. Significant values of AVE above 0.7 are considered very good and 0.5 are deemed as acceptable. Therefore, there is acceptable validity in the measurement of this study as shown in Table 19.

Table 19. Validity test of the questionnaire responses.

Variable	F1		F2		C1		C2	
	CIT	CIM	CIT	CIM	CIT	CIM	CIT	CIM
AVE	0.533	0.658	0.573	0.697	0.622	0.639	0.721	0.699

4.3.3. Goodness of Fit

Measuring the goodness of fit is another important part when building SEMs and a large number criteria have been developed for this purpose [160]. However, three model fit measures are generally used to judge the fitness of the measurement components [161]:

- Absolute fit measures (AFMs).
- Incremental fit measures (IFMs).
- Parsimonious fit measures (PFMs).

In this study, all three types of goodness indicate that the overall measurement model is acceptable, as shown in Table 20.

Table 20. Goodness of fit model results.

Type	Measure	Criteria	Reference	Index		Status
				CIT	CIM	
AFM	χ^2/DF	<5.00	[162]	1.915	1.915	Ok
	p-value	<0.05	[163]	0.00003	0.00015	Ok
	RMSEA	<0.08	[164]	0.064	0.061	Ok
	SRMR	<0.08	[165]	0.053	0.045	Ok
	GFI	>0.90	[166]	0.939	0.943	Ok
IFM	CFI	>0.90	[167]	0.942	0.964	Ok
	NFI	>0.90	[168]	0.893	0.928	Ok
	NNFI	>0.80	[169]	0.920	0.950	Ok
PFM	PNFI	>0.50	[170]	0.906	0.916	Ok
	PGFI	>0.50	[170]	0.901	0.907	Ok

Note: χ^2/DF: Chi square vs. degrees of freedom ratio. *p*-value: Significance level; RMSEA: Root Mean Square Error of Approximation; SRMR: Standardized Root Mean Square Residual; GFI: Goodness-of-Fit Index; CFI: Comparative Fit Index; NFI: Normed Fit Index; NNFI: Non-Normed Fit Index (also known as Tucker–Lewis Index (TLI)); PNFI: Parsimony Normed Fit Index; PGFI: Parsimony Goodness-of-Fit Index.

4.3.4. Indirect Effects

Indirect effects (also called mediation) were also analyzed. In terms of the SEM model, if some variables act as mediators between two variables, then they have both a direct effect on each other, as well as an indirect effect through mediating factors. Sobel test [171] determines the significance of mediation effects. In this model, all the paths summarized in Table 21 were found to be significant.

Table 21. Indirect effects measurements.

Project Criteria (C1)			Business Criteria (C2)		
Paths	Indirect Effects		Paths	Indirect Effects	
	CIT	CIM		CIT	CIM
F1-F2-C1	0.294	0.390	F1-F2-C1-C2	0.256	0.312
			F1-C1-C2	0.165	0.181
			F2-C1-C2	0.161	0.197

4.3.5. Direct Effects

Once the model's reliability, validity, goodness, and indirect effects were checked, the direct relationships between variables (factors and criteria) were analyzed. Results are shown in Table 22.

Table 22. Direct effects measurements.

Scope Development (F2)			Project Success (C1)			Organization Success (C2)		
Paths	Direct Effects		Paths	Direct Effects		Paths	Direct Effects	
	CIT	CIM		CIT	CIM		CIT	CIM
F1-F2	0.924	0.906	F1-C1	0.822	0.985	F1-C2	0.533	0.755
			F2-C1	0.702	0.889	F2-C2	0.511	0.752
						C1-C2	0.941	0.917

The complete model can be presented now in Figure 8.

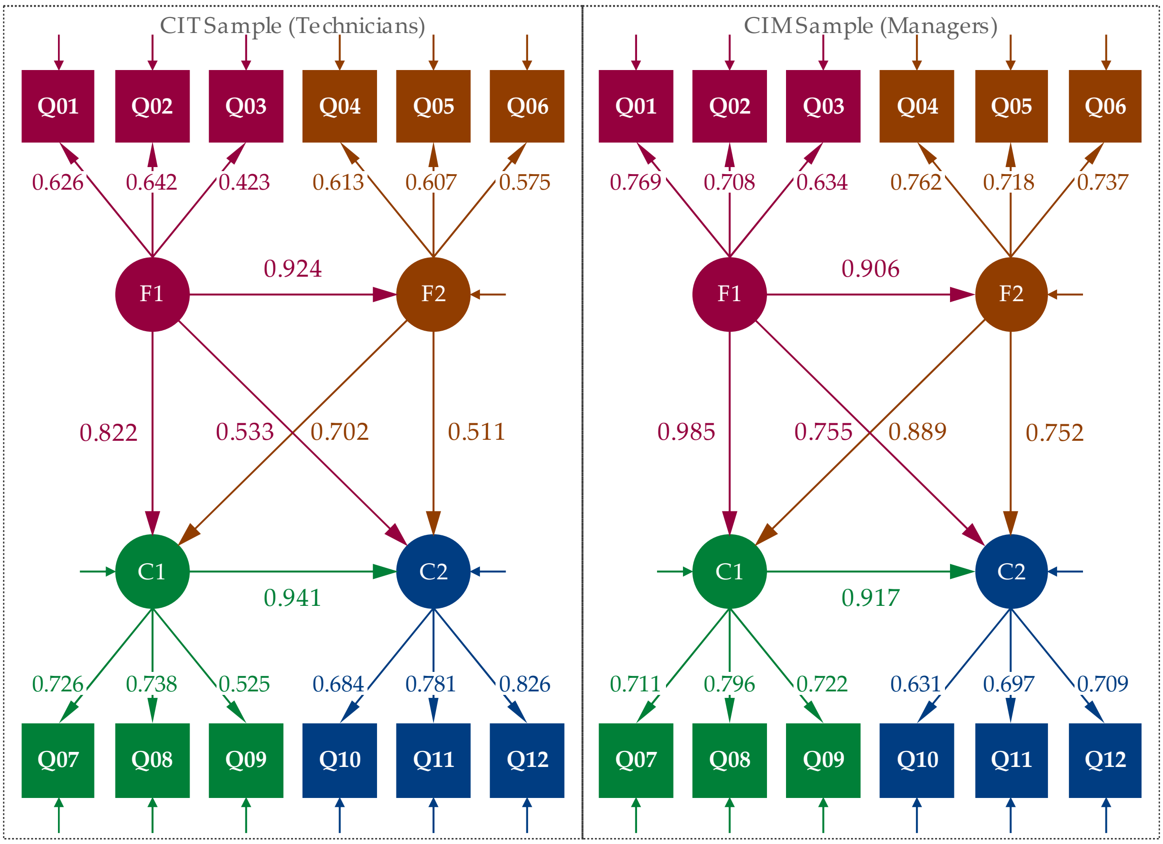

Figure 8. Final structural equation model (SEM) model (Note: Measurement errors are not shown for the sake of simplicity and to avoid information cluttering).

According to the results shown in Table 22 and Figure 8, there is a strong relation between the design of the project scope and its development with the success of the project. These links are stronger among managers. The success of the permanent organization (its business and the context of the project) is also dependent on the management of the project scope. Although the value given by technicians and managers to the factors and criteria (as can be seen in Tables 10 and 11) is very similar, their consistency increases when technical roles are being replaced by managerial ones. Relations among factors and criteria are significant for both samples.

5. Discussion

In this study, the importance of project scope management has been endorsed, as it was in previous studies (e.g., [15,25,172]). However, we have emphasized that scope management is not just relevant to project planning. On the contrary, poor scope management may have very negative implications in later stages of project execution, mostly regarding project performance.

Hence, a clear definition of the project scope is key to successful project scope management. In the construction industry, some tools such as PDRI (project definition rating) [173,174], DECRIS (detail engineering completion rating index system) [175], and FEL (front-end loading) [176] have been implemented to better define the project scope. A clearer definition of the project scope can also be achieved by actively involving stakeholders [137]. Another is obviously by building a consistent and realistic WBS [26].

A good WBS is a hierarchical decomposition, oriented to the project deliverables and the work that has to be actually done to achieve the project objectives [30]. If stated properly, it constitutes the core of project management (PM) [29,177]. This, because the WBS allows implementing other PM functions such as planning, scheduling, budgeting, resource allocation, and risk management, as well as quality assurance and control.

Other authors, however, put the schedule at the centre of the whole project planning and definition stages [178,179]. In BIM contexts, the WBS has already been implemented for monitoring and reacting to changes in the work schedule [180]. For example, measures to handle design conflicts (configuration management) related to construction components have been already introduced in BIM platforms [181]. Unfortunately, this approach tends to manage time and cost independently, and in it, the WBS is generally not integrated with the CBS [13]. Hence, in those cases, the WBS is used for project time control whereas the CBS is used for budget control.

However, if the focus remains on the WBS, project risks can be more efficiently managed, as many authors have also noted [10,55,56,182]. Risk information can be relatively easily managed in BIM environments [183]. For example, risks with their associated project activities in the dynamic process can be considered with a series of linkage rules [184]. These risks that generally derive in non-compliance of project deadlines, budgets and quality requirements, usually arise from incomplete designs, inadequate specifications, and construction procedures, as well as scope changes [185].

However, when the WBS is integrated with the CBS, schedule and cost can be jointly managed [48,120]. This allows project performance to be more easily measured too [144]. The latter also allows the implementation of project control techniques such as earned value management (EVM) [117]. EVM for example assumes that work packages (WP, from the WBS) and cost accounts (CA, from the CBS) are significantly overlapped.

Still, the integration of WBS and CBS is not new in the construction industry, even before the advent of BIM [14]. Unfortunately, the absence of accurate and real-time as-built information has generally made it difficult to integrate and manage those events that produce project variability and uncertainty [186]. Conflicts arise more often, though, when the schedule depends on a WBS, and the budget on a (separate) CBS. Furthermore, there still seems to be no common agreement on which are the best criteria for decomposing the WBS and CBS, nor which is the best methodology to apply [49,52]. In the construction industry, there have been proposals that have attempted to provide a reference framework. However, although there is a global interest in standardizing processes, through coding systems for instance, the result is still far from satisfactory. Indeed, even after the publication of the ISO 12006-2 and 81346-12 standards (among others), many countries have kept issuing their own new standards.

The growing popularity of BIM, though, has made it possible to continue standardizing the integration of information at the project level. Nevertheless, without agreement on how to structure and break the work down all the time, resource and cost information, many conflicts, compatibility issues, and cost discrepancies will keep arising [53,131]. Still, while some authors continue researching how to manage project costs in BIM environments [11,73], only a few of them have started to focus the problem on the potential benefits of time and cost integration with the project scope (e.g., [47,111,113]). It is worth highlighting, though, that other digital technologies may help in preventing project delays and cost overruns [187]. Two examples might be geographic information systems (GIS) and integrated project delivery (IPD) frameworks.

Still, with the exception of Korea [125], no representative initiatives have been undertaken to standardize work coding systems in most countries, including Spain [188]. While most construction projects in Korea are generally contracted at a fixed price [14], in Spain most contracts are based on quantity survey models [189]. It is very important then that all activities are included and that they are well defined. However, a significant number of Spanish construction price databases, both public and private, have been published. Their aims are significantly overlapped with the definition of WBSs. This is because price databases require classifying different types of work and coding them. In fact, the utilization of these databases has become mandatory for most public works in Spain.

In short, thanks to the predictive nature (facilitating the works execution and control from the planning stage) and global nature (connecting to deadlines, resources, costs and risks management), a more structured work management is essential in construction projects. That is why it is essential to contemplate it into the digital management of projects.

6. Conclusions

Project scope management is key for project success. A sound project definition and structure generate fewer changes when project deficiencies are found. Similarly, with the integration of WBS and CBS fewer contradictions will arise and more realistic estimations will be possible at the execution stage. Conversely, poor project definition and structure at the planning stages will surely have performance repercussions at the execution stage. These changes can proceed, for instance, from the task omission, cost overruns, project delays, and/or quality losses.

Most construction projects are not created as a whole, but as a collection of parts [45]. In this context, WBS are used for breaking projects down into a number of small pieces that can each be more easily handled by a project manager, on site or in a screen. An early use of the WBS at the project definition stage is critical for the achievement of the project objectives. Likewise, the use of the WBS, as a fundamental tool for the management of a project, is also confirmed with the development of the standard ISO 21511:2018 work breakdown structure (WBS) [190]. Its integration with the CBS also allows both clients and contractors to develop the schedule based on the construction units level (the units of quantity survey contracts).

This research has confirmed the importance and advantages of developing WBSs based on CBS in construction projects. By means of a questionnaire distributed among 500 Spanish construction professionals and a structural equation model, direct, significant, and causal relationships between the integration of WBS and CBS have been identified with the achievement of project goals. We have also found that as the competences and training in project management increase, there also is a higher awareness for any factor that facilitates managing the work to be done and implementing the tools that can measure its progress. This individuals' competence and training can be improved through specialist courses, mentoring, professional certification, study of PM methodologies, and gaining experience by participating in complex projects. In summary, according to the results obtained in the survey it can be stated that:

- The WBS involves structuring the project scope in a hierarchical manner. It is oriented to the deliverables, and avoids both duplication and omission of tasks.
- As the project work is defined more clearly, project roles and responsibilities can be assigned to subcontractors and organizational units more easily. This, in turn, also allows to define more representative project schedules and budgets.

This research also has some limitations. The survey took place in Spain, a country whose construction sector has no standardized system of coding and construction works classification.

Furthermore, in the Spanish construction market, open quantity survey contracts are dominant. This might have partially biased the respondents' perceptions regarding the relationship of project scope, time, and cost management with project success. Moreover, the use of the BIM methodologies is not widespread in Spain. This means, major project stakeholders in this country may not fully grasp (yet) the advantages of standardization and integration of work-related and cost-related structures.

To conclude, future research will pursue to quantitatively measure the influence of integrating the WBSs and CBSs with the projects' actual quality, time, and cost performance. It will also be worth asking whether this integration will improve a company's knowledge and change management capabilities.

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