PREDIMENSIONADO DE COSTES GLOBALES DEL CICLO DE VIDA EN LA EDIFICACIÓN PÚBLICA

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BUDGETING WHOLE-LIFE COST IN PUBLIC BUILDING

Abstract (Arial, 11', bold, centred)

The cost assessment of the public buildings was limited in the Spanish legislation to the study of the construction costs. Due to new legislative changes, with the appearance of the Directive 2014/24/UE about public procurement. Hereinafter public institutions must take into account in public procurements, economic indicators that include Life Cycle Cost (LCC) of the building.

The main objective, of the research, is to design a methodology that adapts the assessment of the costs of the building construction to a study that allows the calculation of the budgeting of Whole-life cycle cost (WLC) at the first stages of development of the design.

The methodology will be based on the structures of LCC, such as EN-15643-4, ISO 15686-5. And in the data of project of similar type, and Andalusian Construction Cost Database.

The methodology would let know a forecast of cost associated to building service life from first stages of project development and would an economic indicator of sustainability, useful for management of the public economic sources.

Key words: *Budgeting, Whole-life Cost, Public buildings, Sustainability*

Resumen

El estudio de los costes de la edificación de promoción pública se limitaba, en la legislación española, al estudio de los costes de la construcción. Debido a los cambios legislativos que se han producido en la Unión Europea por la aparición de la Directiva UE 2014-24 sobre contratación pública. A partir de ahora los organismos públicos deberán tener en cuenta en las licitaciones de obra pública, indicadores económicos que incluyan el coste del ciclo de vida (CCV) de la edificación.

El objetivo principal de la investigación es diseñar una metodología que adapte el estudio de costes de la construcción a un predimensionado que permita tener en cuenta el coste global del ciclo de vida en las etapas previas del diseño.

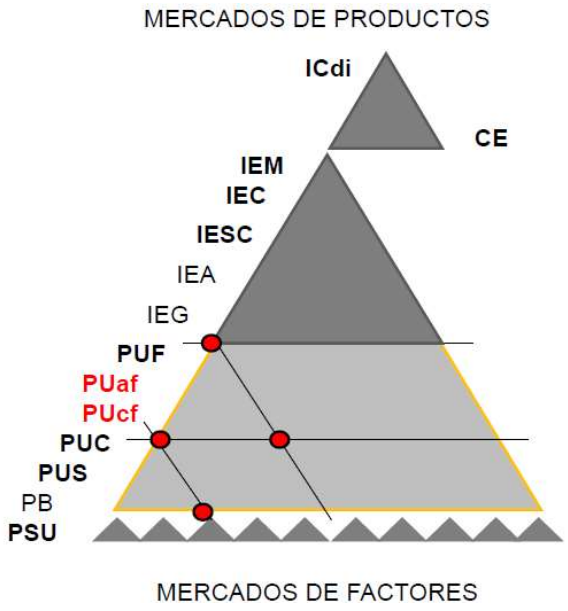
La metodología estará basada en las estructuras del cálculo del coste del ciclo de vida, tales como UNE- , y en los datos proporcionados por proyectos de tipologías similares y al Banco de Costes de la Construcción de Andalucía.

Dicha metodología permitiría conocer previsiones de costes asociados a la vida útil de la edificación desde las primeras etapas de desarrollo de la misma, y establecería un indicador de sostenibilidad económica útil para la gestión de los recursos económicos públicos.

Palabras clave: *Predimensionado, costes globales del ciclo de vida, edificios publicos, sostenibilidad.*

1. INTRODUCTION

The assessment of the economic aspects of the construction of new public buildings has usually focused on Spain in the study of the costs of building construction. Currently in the stage of previous studies of the development of the project are made the estimation of costs based on modules of costs per constructed area (€/m2), with the aim that the publics institutions have a forecast of construction costs. Subsequently, in the development phase of the implementation project, the study of costs is further studied using the cost structure proposed by the legislation of Public Sector procurements [1]. For this development the costs endogenous to the construction site (direct cost and indirect cost) and costs exogenous to the construction site (general expenses and industrial profit) are evaluated. In order to approach this costs assessment, the building is divided in units of work (constructive element realized by a same group of specialists) [2]. (Fig.1).



Leyenda	
ICdi	Importe por contrata después de impuestos.
CE	Costes exógenos
IEM	Importe de ejecución material
IEC	Importe de ejecución por capítulos
IESC	Importe de ejecución por subcapítulos
IEG	Importe de ejecución por grupos
IEA	Importe de ejecución por apartados
PUF	Precio unitario funcional
PUaf	Precio unitario de área funcional
PUcf	Precio unitario de célula funcional
PUC	Precio Unitario complejo
PUS	Precio Unitario Simple
PB	Precio Básico
PSU	Precio de suministro Unitario

Fig. 1: Cost hyerarchy. "Control de costes por anticipación", (Revuelta, P. et al.,2015)

Due to the legislative changes that have occurred in the European Union due to the appearance of the EU Directive 2014-24 on public procurement [3], obligatory transposition from the year 2016 by the member states. Public contracting authorities must take into account in public procurements, economic indicators that include the life cycle cost (LCC) of the building, to establish economically most advantageous tender(EMAT). Consequently, it will be necessary to take into account from the stage of previous studies, the expected costs of construction, maintenance, consumption and end of life, which are expected to support public administration.

Given this new paradigm, it is considered necessary methodologies to allow the budgeting of the LCC for the public works procurement, so as to be able to go from estimating the cost of construction to estimating the LCC, with reliable cost data from the previous studies of the building. Being long-term estimates, the evolution of the cost of money will be taken into account, in order to avoid economic inefficiencies in the use of public money in the present and future of the building. (fig.2)

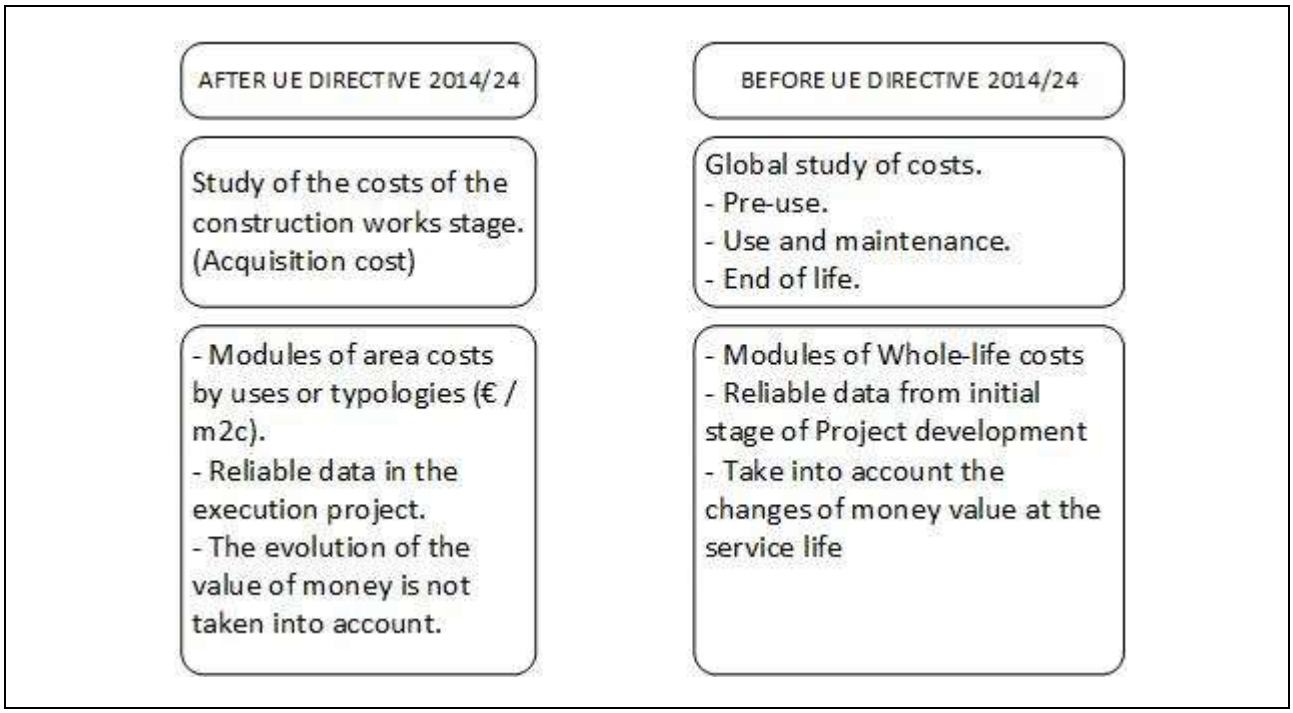


Fig. 2: New settings at costs budgeting.

In 2006, consultant Davis Langdon was commissioned by the European Commission to develop a common methodology at European level to calculate the cost of the life cycle in buildings to contribute to the sustainability of construction.

As a compilation of the results obtained from the application of this methodology in 2010, "Development of a promotional campaign for life cycle costing in construction" [4] is published in which the application of the methodology is studied from 5 points of view:

1) The revision of the structure of cost decomposition (Cost breakdown structure, CBS) in different countries of the European Union. Concluding that the work carried out in the "Code of measurement" [5], Joint Nordic Project and LCC-DATA "classification system for facility management information" [6] have been successful in the unification of criteria and the development of common CBS in different countries. Indicating also that the formal use of LCC and a cost structure is not applied in southern European countries.
2) The identification of the sources of information used to know the costs and yields of the key elements of the construction. Concluding that there is mainly a lack of reliable data about maintenance, use and energy costs because the bidding bodies do not usually collect information from the LCC of their assets (buildings) during the use stage. Recommending to the European Commission, the creation of a tool that facilitates bidding organizations to collect the information of their buildings and their comparison.
3) The application of the proposed common methodology and the evaluation of the lessons learned in its implementation. Where through 15 projects of several countries of the European Union, evaluates the application of the common methodology. Noting that, among other conclusions, that the net present value (NPV) method is the most used. That LCC analyses and environmental sustainability are not related. And that the cost data are based on the promoter's own data, there are few public databases of life cycle costs.
4) Evaluate the knowledge about LCC that the contracting authorities have. Recommending that it continues deepening in promotion of the proposed methodology.

5) To secure the active participation of a group of public sector clients and of construction practitioners in order to collect and share information and results from points 1,2 y3.

Otherwise, between 2009 and 2011 the SMART-SPP project (Innovation through Sustainable Buying) [7] was developed, financed by the Intelligent Energy Europe program, in which they create a guide and software for the acquisition evaluation of materials and equipment by the administration, taking into account the LCC and CO2 emissions. Mainly focused on materials and electrical consumption facilities (installation of LED lamps).

Also between 2009 and 2012, the SCI-Network (Sustainable construction and innovation through bidding) project was developed, a European project co-financed by the Lead Market Initiative program, in which a guide is created that tries to help public authorities in the bidding for works, following criteria of environmental and economic sustainability. [8]

This research has as main objective the development of a methodology that can combine the structure of costs currently used in the Spanish legislation with the study of Whole-life costs(WLC), to fulfil European procurement rules and even adding the analysis of non-construction related revenues and costs[9]. This methodology will take into account all costs and revenues related to building throughout its life cycle, and will be applied from the stage of previous studies and feasibility of project development, related to the cost budgeting [2]. The final objective will be to compare between building tenders and evaluate their future economic viability.

Currently the research is focused on the development of the methodology that allows to define the theoretical models and their adaptation to a specific constructive typology. This implies that the section of pre-dimensioning, which will be explained later, has not yet generated remarkable results.

2. METHODOLOGY

The research is developed in three main stages(fig.3):

- Establish the theoretical models for the budgeting of the WLC of the public building.
- Adaptation of the theoretical models to a construction typology.
- Perform budgeting WLC of the new building prototype of the construction typology.

At the first two stages, theoretical models and typology adaptation, it is contemplated:

- Establish the organization of the WLC,
- Calculation of WLC,
- Treatment of existing data to be able to pre-dimensioning WLC,

Obtaining a WLC Data Base (WLCDB) of a building typology.

In the last stage of the methodology, budgeting of the prototype, starting from the needs of the prototype given by the promoter. We use the WLCDB, to calculate the WLC.

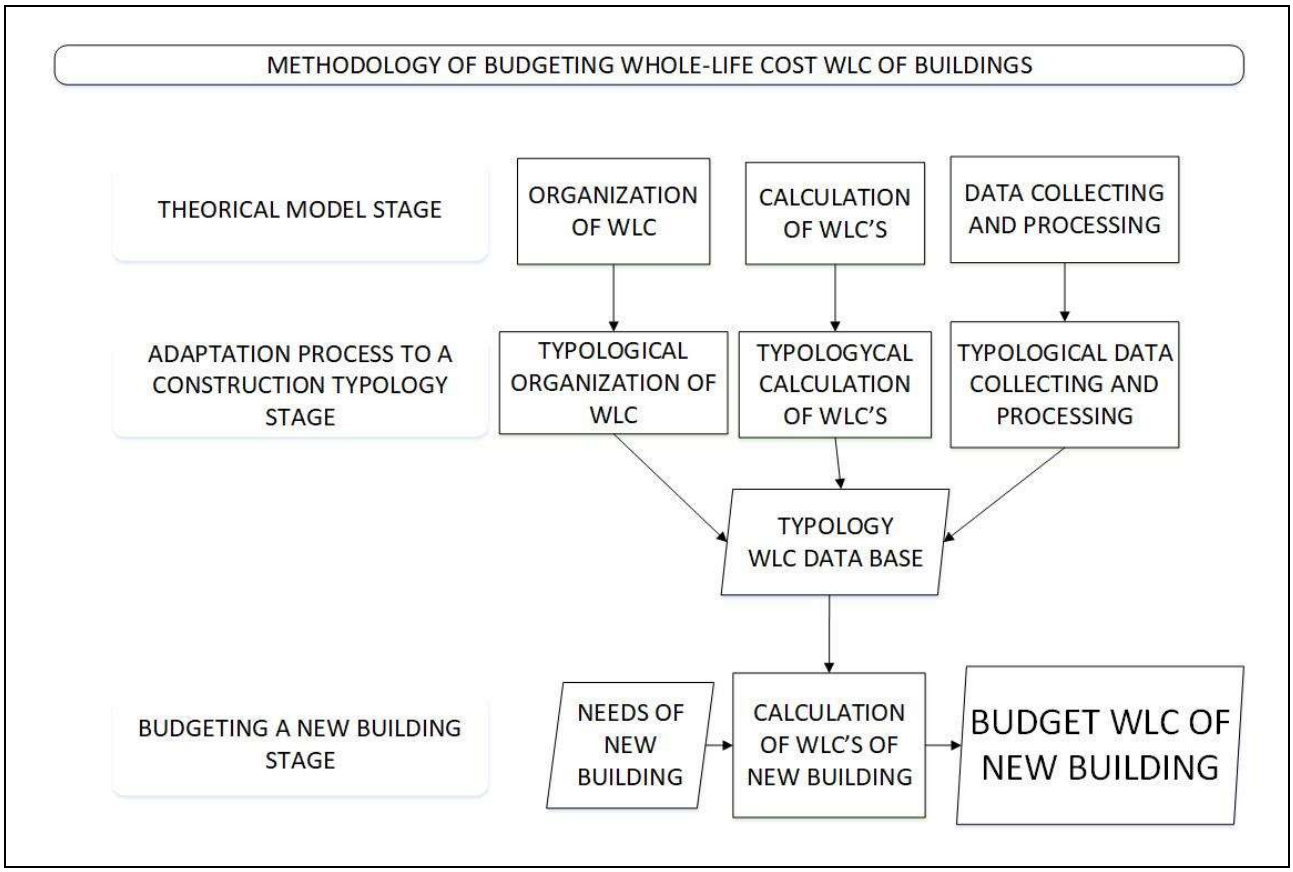


Fig. 3: Methodology scheme budgeting WLC.

At the stage of development of the theoretical models, the publications of international scope are reviewed and analysed, which are considered as reference in the organization and calculation of WLC:

- ASTM 917-13. Standard practice for measuring life cycle costs of building and building systems. [10]
- ISO 15868-5. Buildings and constructed assets. Service-life planning. Part 5. Life-cycle costing. [9].
- The methodology proposed by consultancy Company, Davis Langdon, in the research commissioned by the European Union in 2007 that tried to create a common European methodology for the calculation of the LCC. [11]
- EN 16627:2015. Sustainability of construction works - Assessment of economic performance of buildings - Calculation methods. [12]

This part of the research is also supported by publications made for the budgeting of construction works adapted to the Spanish legislation for the bidding of construction works, such as "*Presupuestación de obras*" [2] y "*Control de costes por anticipación*"[13]. With the objective that the cost structure is recognizable in the international scope and can be adapted to Spanish legislation.

In data collection and processing it should be borne in mind that data sources should be as reliable as possible and, if possible, based on previous works of the organization. Data from various sources should be homogenized to be in the same economic and monetary terms.

In the stage of adaptation to the typology, it is established as a hypothesis that the methodology will be aimed at promoters and managers of buildings that have similar types of buildings already built and need to cost pre-dimension of new buildings with similar characteristics to those already existing, since a fundamental part of the methodology is that the main source of data is the promoter itself.

Processes of application and adaptation of the theoretical models to the types of buildings that are intended to be budgeting are carried out. The costs should be structured taking into account the legislation of each country and the scope of the cost study that the investor wishes. Collecting cost data from previous projects is very important. In short, it is about knowing the buildings that are intended to be dimensioned and the cost data of these. As a result of this stage, we will obtain a WLCDB adapted to the typology was analysed, which will be the basis for the future costing of future projects.

In the stage of cost budgeting, starting from a scheme of the needs of the new building, we use WLCDB, to calculate the WLC of the building. These calculations should take into account monetary updates and discount rate apply.

For the realization of the pre-dimensioning of costs, we assume the following hypotheses:

- The client has to have a needs program, in useful surfaces, of the main rooms that will compose the future building, as well as to have an estimate of the interior distribution and volume of the building reflected in a draft planimetry.
- It is necessary the functional units WLCDB made in the previous stage.

The process of calculating the WLC budgeting consists of:

1) Divide the building into parts that represent the totality of the actions to be carried out, and perform its quantification. Without duplicities or gaps.
2) Extract from WLCDB, the cost of the parts.
3) Calculation of amounts of each parts at all life cycle.
4) Temporary transformation of amounts. In which you have to distribute over one or several annuities within the life cycle.
5) Monetary actualization. Annuities are adapted for the inflationary effects of the value of money.
6) Current value of the planned investment. To obtain a homogeneous value in current monetary terms, the current value of each annuity must be calculated. Affecting each annuity of a discount rate. (1).

   Present Value life cycle cost [5]

   $PVLCC = \sum_{t=o}^{N} \frac{C_t}{(1+i)^t}$ Ct: Costes del año t , i: tasa de descuento. (1)

   The discount rate to be used has to be determined according to the study promoter. You can take as a reference 3%, which indicates the Delegated Regulation of the European Commission 244/2012 [14].

7) The sum of the cost annuities is made in terms of current value. Obtaining the value of the budgeting WLC.

3. RESULTS

3.1. Theoretical model stage.

The basic element of the current budgeting for the estimation of the costs of a building in the execution project, the unit prices [2], is considered excessively complex for its use in the pre-dimensioning of costs, since it would require an excessive effort to realize a study of costs in the stage of development of the project in which we are (stage feasibility studies, preliminary project, basic project).

For all of that, it´s estimated he use of functional prices(fig.4), introduced by Ramirez de Arellano, A. [2,13], and defined as "t*he cost of the constructive element that constitute a constructive assembly with a complete function in the work",* to carry out the budgeting of costs. This level of cost analysis would be equivalent to that given by the ISO-15686-5 [4] annex E "*Built asses*".

10STM00020	**m2**	**Solado con baldosas de terrazo de 40 x 40 cm. Incluso rodapié de terrazo**		
Solado con baldosas de terrazo de 40 x 40 cm con marmolina de grano medio, recibidas con mortero M-4 (1:6), incluso nivelado con capa de arena de 2 cm de espesor medio, enlechado, pulido, limpieza del pavimento y p.p. de rodapié de terrazo de 40 x 7 cm; construido según NTE/RSR-6 y 26.				
Medida la superficie útil solada.				
CÓDIGO	**CONCEPTO**	**CANTIDAD**	**PRECIO**	**IMPORTE**
10STS00001	m2 Solado con baldosas de terrazo de 40 x 40 cm	1,000	14,37	14,37
10STR00001	m Rodapié de terrazo de 40 x 7 cm grano medio	0,800	3,11	2,49
		Costes Directos		**16,86**
		13 % Costes Indirectos		2,19
		TOTAL		**19,05**

The theoretical model of costs organization established by PhD's, Antonio Ramirez de Arellano Agudo, Pedro García Vázquez, Antonio Ferreira Sánchez y Elias Cózar Cózar, it is based on the division of building in its principal functions:

- Substructure,
- Superstructure,
- Services,
- Roof,
- Indoor finishes and,
- Outdoor finishes.

The remaining costs and revenues associated with the building are grouped under Non-construction costs.

In order to respond to the objective of analysing costs throughout their service life, it is estimated that the most appropriate structure is shown at standard EN-16627 [7], which divides the costs before the use of the building (land, professional fees, ...), the costs of building construction, the costs of the stage of building use (energy, water, maintenance, repair, replacement and rehabilitation), and the costs of end-of-life (demolition, recycling and disposal of waste). It also contemplates the optional study of costs and revenues beyond the limits of the system, which are considered to be not essential to research. (Table 1) (Figure 5). It would also allow a joint economic and environmental analysis (LCA).

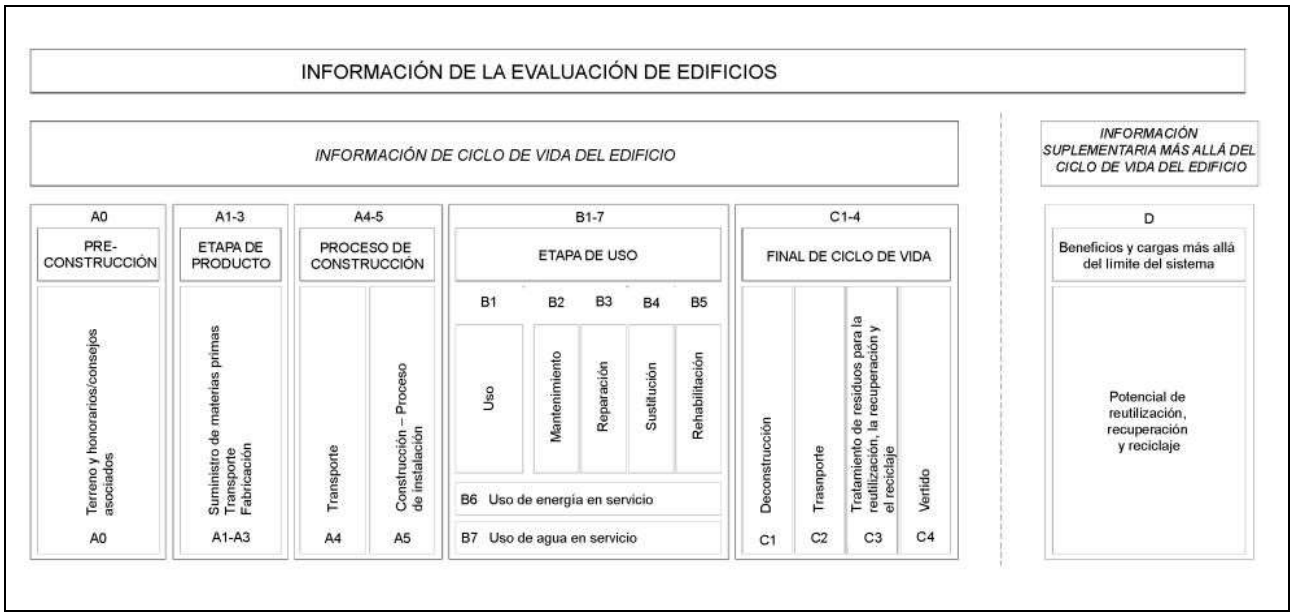


Fig. 5: Modular information for the different stages fo the building assessment UNE-EN 16627

Table 1: Scheme of WLC and cost examples.

	LIFE CYCLE STAGE	BEFORE USE		USE	END OF LIFE
Construction		Pre-Construction	Construction		
	Substructure		Superficial foundation	Maintenance, repairmen of foundation	Demolition of foundations
	Superstructure		Concrete structures , steel structure	Maintenance of structure	Demolition of structure
	Roof		Flat roof	Maintenance of roof	Demolition of roof
	Indoor finishes		rooms, office	Maintenance of rooms, toilets.	Demolition of rooms
	Outdoor finishes		Enclosure, Parking, gardens	Maintenance of gardens	Demolition of outdoor spaces
Non-construction		Land, Project fees	Works fees	Inspection fees, water, electricity, gas.	Demolition project fees

For the theoretical model for the creation and calculation of functional costs we will use the decomposed pricing theory described by Ramirez de Arellano [2], where we will identify all the basic elements (work units) that make up the functional cost unit. Therefore, a quantity and its direct cost of execution will be allocated within the functional cost unit, with which we obtain the amount of each basic element that corresponds to the functional element. With the sum of all the amounts we get the direct cost of the functional unit. The indirect costs will be added to obtain the material execution price.

The theoretical model for the collection and treatment of cost data has to take into account in order to be able to perform an analysis of LCC, the type of cost in which the data can appear, it been identified the following types

- Costs of construction and demolition of the building: the databases of costs are in terms of direct costs incurred in the execution of the work.
- Costs of use: these costs are in terms of total cost with VAT.
- Non-construction costs: these costs are in terms of total cost with VAT.

The differences between the types of costs make it necessary to standardize costs in terms of costs with VAT included.

3.2. - Adaptation of the theoretical models to a construction typology stage.

To obtain WLCDB the first necessary step is to establish a hierarchical classification of costs. For this, the classification developed by the researchers, Antonio Ramirez de Arellano Agudo, Pedro Garcia Vazquez, Antonio Ferreira Sanchez and Elias Cózar Cózar, is used. To this classification, levels 3 and 4 related to the building's CV have been added.

The classification levels are the following:

- Level 1: Type of client. It is classified by the main function that the client has. (eg Teaching, industrial, leisure, commercial, health, administrative, residential, ...)
- Level 2: Types of buildings. It is classified by the type of building that the client habitually promotes. (A client whose object is teaching may have kindergartens, primary schools, secondary schools, administrative buildings, ...).
- Level 3: Life cycle. The stages of the life cycle according to UNE-EN-16627 [7]: Before the use, Use and End of life cycle.
- Level 4: Sub-stage of the life cycle. Subdivision of the stages of the life cycle.
- Level 5: Construction parts. Division of construction in its main parts. (Foundation or substructure, Structure, Facilities or systems of facilities, Roof, Interior functional spaces and, Outdoor functional spaces.)
- Level 6: Types of parts. Subdivision of the previous level. (eg in level 5 of functional spaces can be divided into classrooms, libraries, meeting rooms, warehouses, auditorium, ...).

At level 6 it is where the functional prices will be placed.

The process of calculation of functional costs follows the calculation structure of the theoretical model described above applied to each functional unit of the building. It is necessary to establish previously the boundaries between each functional unit of the construction so that there are no duplications or gaps.

The process of collecting and processing cost data follows the theoretical model described above. And it consists of all the transformations that are necessary in the data that are arranged to homogenize the costs in the same economic terms, adapted to the demand and typology of the promoter.

As a result of the processes of adaptation of the theoretical models a functional costs data base is obtained, WLCDB.

3.3. Budgeting WLC of new building stage

In the current phase of research development, it does not obtain outstanding results in this section.

4. CONCLUSIONS

This methodology allows, through the functional costs WLCDB, to perform the budgeting of a new project. In addition, you get a complete cost analysis of your existing buildings throughout their life cycle.

The application of the theoretical methods to a concrete and repeated constructive typology, allows the creation of the WLCDB, with which the public promoter can know from a preliminary design stage the WLC of the building.

This calculation can be taken into account to compare different building designs, in the choice of construction systems, facilities or materials. Allowing the evaluation of the economic indicator that is part of the tender for the design and/or construction of public buildings and choosing the most economically advantageous tender with the criteria set by the Directive European of public procurement [3].

The structure of the analysis of the building proposed by EN-16627, allows a life cycle analysis (LCA) [15] and is compatible with the analysis of costs of LCC within the same framework, by analysing the environmental impacts of functional prices.

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