Vol 31 Nº1 2016 www.ricuc.cl

ENGLISH VERSION

Estimating building construction costs: analysis of the process-based budget model (POP Model)

La estimación de costes de obras de edificación: análisis del modelo de presupuestación por procesos (modelo POP)

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Fecha de Recepción: 10/10/2015
Fecha de Aceptación: 17/03/2016
PAG 17-25

Abstract

The recent economic crisis suffered by the Spanish construction sector has brought to light its excessive vulnerability to fluctuations in the real estate market. Overcoming this situation requires to innovate the sector in order to increase its efficiency. A large amount of researches in Spain focus on the improvement of the environmental efficiency of construction works, but only a few of them deal with its economic efficiency. The current study arises from the importance of the latter in order to achieve a comprehensive sustainability in construction. We introduce a process-based budget model, the POP model, whose most significant strength is the direct inclusion of all costs incurred at the building production site. In this way, process-based estimates expose with transparence and accuracy the real nature of the projected works, contributing to improve their economic management.

Keywords: *Cost estimate, production process, construction site, budget model, economic efficiency in construction*

Resumen
La reciente crisis económica experimentada por el sector de la construcción Español ha puesto de manifiesto su excesiva vulnerabilidad ante los vaivenes del mercado inmobiliario. La superación de esta situación pasa por la innovación del mismo en aras de incrementar su eficiencia. Numerosas investigaciones en España centran sus esfuerzos en la búsqueda de la mejora de la eficiencia ambiental de la edificación, si bien son aún escasas las que abordan la búsqueda de su eficiencia económica. De la consideración de la importancia de ésta como garante básico de su sostenibilidad, surge la presente investigación. En ella se presenta un modelo de presupuestación de obras basado en procesos productivos, el modelo POP, cuya principal fortaleza estriba en la imputación directa de todos los costes generados en el centro de producción. Así, la estimación de costes por procesos refleja con transparencia y rigor la realidad de las obras proyectadas, contribuyendo a mejorar su gestión económica.

Palabras clave: Estimación de costes, proceso productivo, obra de edificación, modelo de presupuestación, eficiencia económica en la edificación

1. Introduction

In Economics, technical efficiency is defined as the ratio between obtained results to costs incurred (Farell, 1957). Thus, a production unit is said to be technically efficient if it obtains optimal results from certain specific initial costs or if it is capable of minimizing those costs in order to achieve a result specified beforehand. If the production is distributed in the market according to its demand, thereby reaching a maximum benefit, the distribution efficiency is considered optimal. Therefore, economical efficiency is defined as the product of technical efficiency by distribution efficiency.

In Spain, the deep crisis impacting the construction sector since 2008 has evidenced its vulnerability to fluctuations in the real estate market, whose outcome is too little distribution efficiency and a deteriorated economic efficiency. Overcoming this situation requires the search of solutions that improve the sector's competitiveness and strength, emphasizing those dealing with environmental optimization and energy efficiency (Pacheco, 2009; Aranda and Zabalza, 2010; León et al., 2010; Ruiz and Romero, 2011; Travenzan and Harmsen, 2013; Villoria et al., 2013; Cuchí et al., 2014; Villoria, 2014). The corresponding research on sustainability and economic efficiency matters is still under development, although concerning a few specific issues (Montes et al., 2011; García-Erviti et al., 2015) if compared at international level (Badea et al., 2010; Appleby, 2012; Carson and Abbot, 2012; Slaughter, 2013; Ibrahim et al., 2014).

While focused on production costs, the present paper aims precisely at improving the economic efficiency of the construction sector in Spain, a country that has traditionally shown big deviations between the budgets of the works and their real costs (Bustos, 2014; Cordero, 2014). This lack of precision in the estimates is due to a lack of correspondence with the real productive model. The main detriment is suffered by constructors and promoters who have to bear the costs of the works without reliable preliminary data for making the necessary decisions. In order to resolve the problem, this research analyzes, improves and optimizes the so-called Process-based Budget Model (or POP model for Presupuestos de Obras por Proceso, in Spanish) (Montes, 2007). Supported by budgets based on productive processes, this model can simulate and adapt itself to the reality of each construction. Since it has already been successfully implemented in construction works of different typology (Torezano, 2011; Márquez, 2012; Mesa, 2012; Montes et al., 2012; Ponce, 2012; Vásquez, 2012; Villar, 2012; Montes et al., 2014), it is time to officially introduce it as a transparent,

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Vol 31 Nº1 2016 www.ricuc.cl
ENGLISH VERSION

efficient and consistent alternative to improve the economic efficiency in building construction.

The work's structure is the following: As an alternative to the model of construction work units, Section 2 presents the POP model as an integral, open and accessible model, capable of standardizing the procedures and languages in construction budgetary matters. Section 3 and 4 show the hierarchical structure of processes and costs, respectively. Section 5 details the procedure required to make a process-based budget, using an optimized version of the model; and finally, Section 6 presents a case study.

2. Budgeting models

Based on data provided in the expected cost estimate for the execution of the works, there are two types of budgeting models, the pre-dimensioned models and the detailed models. The first ones give a quick and approximate estimate of the works' costs in the preliminary stages of a building's life cycle, while the second ones estimate the costs of each process in detail. The POP model belongs to the latter.

In Spain, the most typical detailed model is the model of construction work units (Ramírez- de-Arellano, 1998). This work unit is defined as the "group of resources (materials, machinery or work force) that are necessary to build an indivisible unit, which is then incorporated to the construction site, and it also represents the smallest component of the construction budget". The corresponding cost structure generated at the building site distinguishes between Direct Execution Costs (CDE, in Spanish), which are integrated by applying the unit price to the quantity participating in the cost, and Indirect Execution Costs (CIE, in Spanish), which are incorporated by applying a relative value with respect to a reference value. Although this model has allowed an economic stability among different building actors, the crisis of the sector since 2008 has evidenced the need to rethink some of their fundamentals. For example, while the CIE include most of the costs generated by the implementation, operation and dismantling of the building site, it turns out that such relevant costs as those derived from the foreman's wage, cranes or temporary cabins or containers are diluted in the budget in the form of a percentage that does not properly represent how they were generated. They are not proportional costs depending on the volume of the works produced, but fixed costs. The lack of transparency in their estimation makes it difficult to modify them during the development of the works, which is especially problematic in rehabilitation works of existing buildings, where they can reach high percentages in relation to the CDE (Ramírez-de-Arellano, 2000). On the other hand, the processing of the CDE suffers from excessive homogenization derived from a generalized use of standardized cost-based pricing, which distorts what really happens in each construction work. Thus, it is considered, for example, that all square meters of a certain type of forging cost the same, when the truth is that the cost depends on the configuration of the voids in it, its environmental conditions, location, the means used for its execution and the efficiency of the work force, among others.

In contrast to the previous model, it is possible to stand for an integral approach of the resulting building product as a single product (Carvajal, 1992). This is precisely the vision offered by the POP model, which considers the construction work as a single product resulting from a complex production system made of several production processes that are orderly interrelated according to the specific needs of each intervention. In order to understand its basic characteristics, it is helpful to include this model in the frame of methodologies that are being internationally developed in relation to building costs budgeting. In the first place, the ABC methodology (Activity-based Costing) identifies, classifies and organizes every action involved in the building site that has an influence on costs (Woo, 2001; Yuan, 2011). In this way, the construction companies have more control, transparency and balance in their cost accounting, since costs are managed at every moment considering a hierarchical level in which the corresponding associated process has been classified. Furthermore, the PBC methodology (Process-based Methodology) analyses the costs associated to every action involved in the construction in order to transform certain inputs (preexisting building, resources, waste and byproducts) in outputs or results (Gyoh, 1999; Pulaski, 2005: Nguyen, 2010). This allows connecting the budgets to the works' planning. The POP model integrates these two methodologies in a natural way, thereby joining their advantages. The fact that both methodologies have not been extensively dealt with in Spain (Catalá and Yepes, 1999; Cavero et al, 2003) contributes with a novel factor to the model being addressed herein.

One of the main strengths is that it does not distinguish between direct and indirect costs; all costs are charged directly in the budget. Although it can be applied to all kinds of works, its advantages are especially evident in rehabilitation works, where the building site costs are more elevated than the production costs themselves; and because a greater number of changes occur on site derived from new elements being discovered during the execution. Construction companies share the same approach when it comes to estimate their costs. Moreover, since companies present a great dispersion of unconnected models, the POP model appears as an open and accessible alternative, capable of standardizing the procedures, favoring the information exchange among different actors and works, and optimizing the training of the sector's technical staff.

ENGLISH VERSION

3. Estimating costs by production processes

The POP model consists of a custom-made estimate of the costs of each construction works, depending on the way they are generated on the building site, that is, based on their generative production processes, called execution processes (PE, in Spanish), and the components into which they are disaggregated, that is, the basic processes (PB, in Spanish). The budget effectiveness depends on the correct frontier delimitation among these processes. Specifically, the PE represent all the tasks that take place at the building site, which transform the input components into results (Figure 1). They are measured in units of process (u). On the other hand, the PB are formed by the input and output components, except for the building product itself. A distinction between exogenous and endogenous components is made. The former have their origin or destination outside of the building site, such as resources coming from supply markets, byproducts for secondary markets and waste, whose value or price has to be estimated in order to be incorporated to the works. These processes are measured in units of the International Metric System.

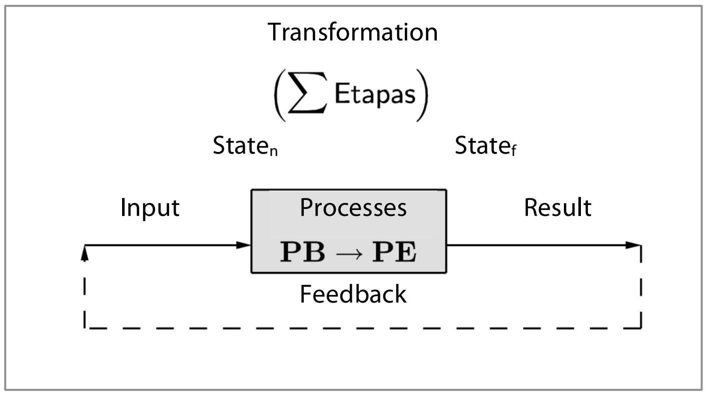

Figure 1. *Production system of the construction works*

Every process is collected, codified and classified, according to their nature, in a couple of process maps that enable a transparent information exchange among different actors of the sector. Thus, the PE and PB are codified based on the Execution Process Classification System (SCPE, in Spanish) or Basic Process Classification System (SCPB, in Spanish), respectively (Montes, 2016b; Montes, 2016a). Both systems distribute their corresponding processes in three levels: PE_1, PE_2 and PE_3 for the SCPE; PB_1, PB_2 and PB_3 for the SCPB. In both cases, the incorporation of every process is guaranteed through a shortlist of generic processes in each level: mixed, special and other processes. As an example, Table 1 presents the first level for both systems. A numerical codification was chosen in order to privilege the model's data processing and globalization. Specifically, each PE code is formed by adding two digits to the process code of its precedent level. For example, the following codes:

- *PE_1: 01 Building Sites*
- *PE_2: 0100 Complementary Constructions*
- *PE_3: 010030 Prefabricated Cabins*

All PB codes are analog, although they start with an asterisk to clearly distinguish them from the PE codes:

- *PB_1: *00 Human Resources*
- *PB_2: *0045 Technical Staff*
- *PB_3: *004510 Foremen*

In addition to the aforementioned standardized levels, process maps are disaggregated into a fourth additional level (PE_4 and PB_4), which has to be expressly defined by the budget estimator for every construction works.

- *Example PE_4: 0100300001 u Assembly of Temporary Cabins*
- *Example PB_4: *0045100001 month Foreman*

Table 1. *First level of the SCPE and SCPB*

SCPE (PE_1)		SCPB (PB_1)	
Code	**Concept**	**Code**	**Concept**
01	Building sites	*00	Human Resources
02	Preparatory actions	*10	Materials
03	Recoveries	*20	Equipment
04	Demolitions and disassembles	*30	Auxiliary resources
05	Sites conditioning	*40	Water & energy resources
06	Foundations	*50	Soil
08	Sanitations	*60	Information resources
10	Structures	*65	Wates & By-products
12	Enclosures	*70	Mixed processes
15	Roofing	*80	Especial processes
18	Interior walls	*90	Other
20	Air conditioning		
22	Electricity installations		
24	Plumbing installations		
26	Gas & liquids installations		
28	Fire protection installations		
30	Control & security installations		
32	Telecommunication installations		
34	Transport installations		
36	Solar installations		
38	Waste removal installations		
39	Other installations		
40	Carpentry		
45	Coatings		
48	Furnishing		
50	Exterior works		
55	Maintenance operations		
60	Final works		
65	Wates & By-products management		
70	Heterogeneous process		
80	Special process		
90	Miscellaneous		

4. POP model's cost structure

In the POP model, costs generated at the building sites are hierarchically classified in relation to their associated production processes (Figure 2). All of them are charged directly with their corresponding sign, where positive costs represent the expenses derived from the execution of the construction works, while negative ones represent the earnings of the constructor. The absence of indirect costs provides an accurate and transparent estimate according to reality, which facilitates the control of omissions and repetitions.

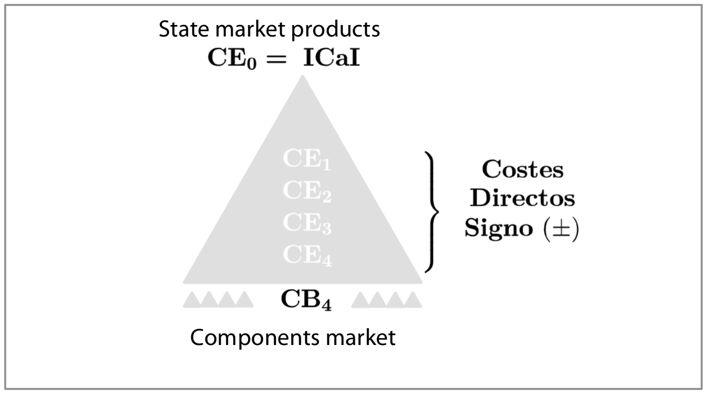

Figure 2. *Cost structure of the POP model*

Level 4 Basic Costs (CB_4) corresponding to the PB_4 are at the base of the structure. While representing the costs of the input or output components of the works, these costs are influenced by the characteristics of their markets of origin or destination, respectively, such as the prices and conditions of supply or waste removal. These costs are in turn incorporated to the costs corresponding to the lowest-level execution processes in which they take part: Level 4 Execution Costs (CE_4). Although for the exogenous components this incorporation is direct ($CB_4 \rightarrow CE_4$), when dealing with endogenous components, their basic costs are previously integrated to other CB_4 before its final incorporation to their corresponding CE_4 ($CB_4 \rightarrow CB_4 \rightarrow \ldots \rightarrow CE_4$). See Table 2 for an example.

The remaining execution costs are obtained from the successive inclusion of the costs of the level immediately after, $CE_4 \rightarrow CE_3 \rightarrow CE_2 \rightarrow CE_1 \rightarrow CE_0$, where the costs of level zero correspond to the total cost associated to the building production and are therefore equivalent to the Contract Price before Taxes (ICaI, in Spanish) of the building works, which is the objective of the budget.

Table 2. *Incorporation Sequence of CB_4 and CE_4*

Integration	**CB_4**	**CB_4**	**CB_4**	**CE_4**
$CB_4 \rightarrow CE_4$			*1020200001 *mu Drilled bricks*	1210000001 *u Enclosure execution*
$CB_4 \rightarrow CE_4$			*5020270500 *u Arabian tiles recovered to be sell*	0150500500 *u Selling of recovered Arabian tiles*
$CB_4 \rightarrow CE_4$			*5010050500 *m^3 Cement residue*	0150500001 *u Cement residues withdrawal*
$CB_4 \rightarrow CB_4 \rightarrow CB_4 \rightarrow CE_4$	*1016050001 *t Cement*	*7001100001 *u Mortar preparation M4 in situ*	*5020160001 *m^3 Mortar M4 prepared in situ*	1210000001 *u Enclosure execution*
$CB_4 \rightarrow CB_4 \rightarrow CB_4 \rightarrow CE_4$	*0005100001 *h Especial laborer*	*7004700001 *u Arabian tiles disassembling for reusing it in situ*	*5020270100 *u Recovered Arabian tiles to be re-used in situ*	1520200001 *u Roofing execution*
$CB_4 \rightarrow CB_4 \rightarrow CB_4 \rightarrow CE_4$	*5010050001 *m^3 Cement residue to be recycled in situ*	*7001500001 *u Recycling of cement residues in situ*	*5020160005 *m^3 Mortar recycled in situ*	1210000001 *u Enclosure execution*

5. Creation of the process-based budget

A process-based budget using the POP model starts with an integral analysis of the system. Some of the sources to be considered are project documentation, characteristics of the building site, prescriptions of the applying regulation, situation of the component markets, contractual provisions. The next step is to identify, define and codify all lowest-level execution processes PE_4 based on the planning, organization and scheduling of the works. Next, the lowest-level basic processes PB_4, which are necessary to implement each execution project, are analyzed and codified. In both cases, the corresponding codification allows defining which upper level processes enclosing this lower-level processes are. Afterwards, both process maps are merged, thereby configuring the process-based budget itself; the execution process map is incorporated to the first four levels of the map and the PE4 disaggregate into a fifth level of processes corresponding to the PB4. Thus, the process-based budget is broken down in five levels: $PE_1 \rightarrow PE_2 \rightarrow PE_3 \rightarrow PE_4 \rightarrow PB_4$. Additionally, the budget is complemented by records that specify all lower-level processes. These records merge the traditional content of decomposed prices and the terms and conditions into a single document. The records also specify parameters such as the theoretical consumption of components, the losses, and the quantity of components needed once the losses have been considered. As for the PB_4 records of endogenous components, they also include their breakdown in basic integral components.

After the division and structuring of the works into processes, the subsequent ascending economic processing is carried out through the successive implementation of three basic budgetary operations, which allow estimating the required total cost of the execution. In particular, once either an execution or basic productive process P_n of level n is specified, the following is defined:

- *The quantification operation (Equation 1) determines the quantity $Q(P_n)$ needed by the process P_n in the works and the corresponding unit cost $C(P_n)$.*

  $$Q(P_n),\ C(P_n) \quad \textbf{(1)}$$

- *The integration operation (Equation 2) allows obtaining the complex cost CC of the process P_n, that is, the total cost of all the units.*

  $$CC(P_n) = Q(P_n) \cdot C(P_n) \quad \textbf{(2)}$$

- *The aggregation ascending operation (Equation 3) allows obtaining the unit costs of every process P_{n-1} of level n−1 by adding the complex costs of the set $\{P_{n,1},\ldots,P_{n,m}\}$ of its component processes of level n.*

$$C(P_{n-1}) = \sum_{i=1}^{m} CC(P_{n,i}) \quad \textbf{(3)}$$

Thus, the process-based budget starts with the quantification of all basic processes PB_4. The calculation of their cost (Equation 4) comes from the corresponding quantification, integration and aggregation of the set of basic components $\{PB_{4,1},\ldots,PB_{4,m}\}$, and multiplication of the resulting value by a repercusion factor (F_R) obtained as the inverse of the measurement of the basic process being analyzed in the measurement unit of its resulting component. Each calculation is detailed in the corresponding process record.

$$CC(PB_4) = \sum_{i=1}^{m} CC(PB_{4,i}) \cdot F_R \quad \textbf{(4)}$$

The budget obtained is not just a static estimate of the costs expected from the execution of the designed works; it also enables a comparative analysis of their different planning, organization and scheduling alternatives, and the subsequent decision concerning the so-called optimal budget (Equation 5), that will allow getting the building product with the minimum total cost.

$$Budget_{optimal}\ (POP_{optimal}) \rightarrow Efficiency_{max} = Results\ /\ Cost_{mín} \quad \textbf{(5)}$$

Where:

- *$Budget_{Optimal}$ is the budget corresponding to the $POP_{optimal}$.*
- *$Efficiency_{max}$ is the economic efficiency level of the $Budget_{Optimal}$*
- *$Cost_{min}$ is the ICaI of the $Budget_{Optimal}$*

6. Case study

In the light of the methodology proposed by Yin (1986), a closer look at the POP model is achieved through its application to a case study. Illustrated in Table 3, the case study is focused on the cost estimates expected from the building site of a real construction of 203 social housing, located on a site of 7,862 m^2 in Sevilla (Spain). In order to estimate these costs, the first thing is to exhaustively analyze all the available information regarding the studied works (project documentation, awarding contract, among other sources), and the instruments that the construction company responsible for executing the works has. Following this analysis, planning of the actions needed to perform the assembly, maintenance and dismantling of the building site has to be done. This planning is crystallized in the identification and characterization of the execution processes of level 4 (PE_4) that are specific to the works; for example, the process 0100001005 u Temporary assembly of the building site enclosure with prefabricated galvanized mesh perimeter fence with prefabricated metal bars.

Vol 31 Nº1 2016 www.ricuc.cl

ENGLISH VERSION

Table 3. *Cost estimates of the case study building site*

PROCESS-BASED BUDGET					
IDENTIFICATION			ESTIMATE		
Code	**u**	**Process**	**Q**	**C**	**CC**
01	**u**	**BUILDING SITES**	1,00	1.276.699,00	1.276.699,00
0100	**u**	**COMPLEMENTARY CONSTRUCTIONS**	1,00	13.585,00	13.585,00
010000	**u**	**ENCLOSURE**	1,00	5.420,00	5.420,00
0100001005	u	TEMPORARY ASSEMBLY OF BUILDING SITE ENCLOSURE, GALVANIZED MESH PANEL, PREFABR. SUPPORT	1,00	5.420,00	5.420,00
		Assembly process of temporary building site enclosure, made with supports every 3 m of tubular galvanized metal bars of 50 mm inner diameter, rigid galvanized mesh panel and parts for the installation of bars, including maintenance and subsequent dismantling, as well as masonry assistance.			
		Initial condition: The zone is clear of weed and clean.			
		Stage 1: Material transport and unloading on site.			
		Stage 2: Material distribution along the entire perimeter of the building site.			
		Stage 3: Assembly of the galvanized mesh panel on supporting parts.			
		Stage 4: Tying two tubular metal bars with wire.			
		Stage 5: Periodical maintenance tasks during the works.			
		Stage 6: Dismantling of galvanized mesh panel on supporting parts.			
		Stage 7: Material loading in the truck.			
		Stage 8: Transport back to the warehouse.			
		Final condition: The zone returns to its initial condition once the works is finished.			
*0005101001	h	Workman job	80,00	17,00	1.360,00
*1025101001	u	Stone for introducing the metal bar of the mesh.	100,00	4,00	400,00
*1025501001	u	Electro-welded mesh 3.00 x 2.00 m	300,00	11,72	3.516,00
*2010101001	h	Transport of boom truck	6,00	24,00	144,00
010020	**u**	**CONDITIONING OF FACILITIES**	1,00	1.896,50	1.896,50
0100201005	u	TEMPORARY ADAPTATION OF OFFICE FACILITIES	1,00	743,70	743,70
0100201010	u	TEMPORARY ADAPTATION OF BATHROOM FACILITIES	1,00	420,30	420,30
0100201015	u	TEMPORARY ADAPTATION OF EATING AND DRESSING ROOMS	1,00	732,50	732,50
0100201020	u	TEMPORARY ADAPTATION OF FIRST AID FACILITIES	1,00	648,25	648,25
010030	**u**	**PREFABRICATED CABINS**	1,00	6.036,00	6.036,00
0100301005	u	TEMPORARY ASSEMBLY OF MODULAR CABINS FOR OFFICES	1,00	2.424,00	2.424,00
0100301020	u	TEMPORARY ASSEMBLY OF EATING AND DRESSING CABIN	1,00	611,00	611,00
0100301025	u	TEMPORARY ASSEMBLY OF BATHROOM CABIN	1,00	552,00	683,00
0100301030	u	TEMPORARY ASSEMBLY OF FIRST AID CABIN	1,00	516,00	647,00
0100301035	u	TEMPORARY ASSEMBLY OF WAREHOUSE CABIN	1,00	1.671,00	1.671,00
010040	**u**	**NEW CONSTRUCTIONS**	1,00	48,00	48,00
0100401005	u	TEMPORARY CONSTRUCTION OF GABLE ROOF FACILITIES BRICK ENCLOSURE	1,00	48,00	48,00
010050	**u**	**ACCESSES AND CONDITIONING OF EXTERIOR SPACES**	1,00	184,50	184,50
0100501005	u	LAND CONDITIONING IN ORDER TO INSTALL THE BUILDING SITE	1,00	184,50	184,50
0108	**u**	**SEWAGE SYSTEM**	1,00	307,50	307,50
0122	**u**	**ELECTRICAL INSTALLATIONS**	1,00	8.136,00	8.136,00
0124	**u**	**WATER SUPPLY INSTALLATIONS**	1,00	4.198,50	4.198,50
0128	**u**	**FIRE PROTECTION INSTALLATIONS**	1,00	1.916,00	1.916,00
0132	**u**	**TELECOMMUNICATIONS INSTALLATIONS**	1,00	4.975,00	4.975,00
0148	**u**	**FURNISHING AND SIGNPOSTING**	1,00	10.991,50	10.991,50
0150	**u**	**BASIC SERVICE AREAS**	1,00	1.232.589,50	1.232.589,50

In the next stage, the budget is structured according to the processes by drawing the corresponding process map, where the identified PE_4 are associated to their respective processes PE_3, PE_2 and PE_1 of the Execution Process Classification System, the latter being process 01 u Building Sites. On the opposite side, the PE_4 of the budget are disaggregated into its components, the so-called basic processes of level 4 (PB_4), such as *0005101001 h Construction worker or *1025501001 u Electro-welded mesh 3.00x2.00 m. Since there are too many specifications, Table 3 only details the breakdown of some of these processes: the fully detailed analysis of this case study can be looked up in the Master's Thesis of Juan Francisco Márquez Santana (2012).

Once the budget has been structured by processes, the economic processing is made through the operations of quantification, integration and aggregation of its different component processes, starting from the lowest disaggregation level, the PB_4, until ascending to the quantification and integration levels (Equation 6) of process 01 u Building Sites.

$$CC(01)= Q(01) \cdot C(01) = 1{,}00\ u \cdot 1.276.699{,}00\ €/u = 1.276.699{,}00\ € \quad \mathbf{(6)}$$

Where:

- CC(01) is the complex cost of process 01. In the present case study, this cost agrees with the total cost being estimated, which amounts to 1.276.699,00 €.
- Q(01) is the quantity with which process 01 participates in the works. In the present case study one unit of process is quantified.
- C(01) is the unit cost of process 01. This cost is calculated based on the quantification, integration and aggregation of the costs of their component processes, following the sequence of $PB_4 \rightarrow PE_4 \rightarrow PE_3 \rightarrow PE_2 \rightarrow PE_1$.

It should be noted that, in the case study's formal analysis of the process-based budget, the first three columns provide the qualitative information of the corresponding processes. Thus, the first column incorporates the codes associated to the SCPE and the SCPB, accordingly; the second column specifies the measurement unit and the third one, its denomination. On the other hand, the last three columns provide the quantitative information of each process: the quantity Q in its respective measurement unit, the unit cost C expressed in Euros/measurement unit and the complex cost CC in Euros, respectively.

Finally, after the detailed analysis of the present case study, it is possible to establish that the economic data related to the assembly, maintenance and dismantling of the building site have been collected in the budget in a totally transparent way; thereby, the actors of the construction sector who participate in their execution are able to know and control them properly. Furthermore, it is confirmed that, unlike the cost homogenization of the traditional models, the POP model enables the drafting of custom-made budgets for each construction work, for the sake of maximizing the accuracy and reliability of their estimates, so that the different actors may adopt the best decisions in relation to each building works, based on the information provided.

7. Conclusions and derivative R&D&I lines

The present paper has introduced the Process-based Budget, or POP model, as an alternative tool aimed at improving the offer of existing budgeting models. The POP model allows making integral and personalized cost estimates, adjusted to the way it is really built, where all the costs associated to the building site, except taxes, are directly charged. With transparency and accuracy, the model makes the economic management of the construction works easier throughout their entire development; it allows identifying, at all times, the origin of the information and it evidences the potential cost omissions or repetitions so that they can be corrected. Likewise, its versatility offers the possibility of using it in the different stages of the building works, although the model information will be more reliable inasmuch as it is closer to reality, just like in the drafting of budgets in the execution stage prepared by the building actor for the follow-up and control.

A future work may include the development of an integral model of construction works management based on production processes and the formulation of a transfer plan to the production network, which allows actors of the construction sector to rely on and implement the POP model, thereby contributing to actually increase the economic effectiveness of building construction throughout its life cycle.

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