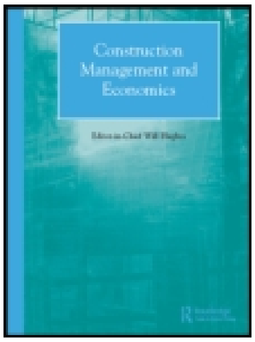

Construction Management and Economics

ISSN: 0144-6193 (Print) 1466-433X (Online) Journal homepage: https://www.tandfonline.com/loi/rcme20

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Construction Management and Economics (May 2010) **28**, 495–507

Routledge
Taylor & Francis Group

The building cost system in Andalusia: application to construction and demolition waste management

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Received 8 September 2009; accepted 27 February 2010

During the last 25 years, a building cost system (BCS) has been developed in Andalusia, Spain. The first step was to generate the Andalusia construction information classification system (ACICS). Not only is ACICS valid as an estimation of cost, but it also provides a common method to manage information during the design and construction of buildings. Another important innovation is that this BCS defines the cost structure which distinguishes between direct and indirect cost and thereby allows a clear definition of all costs for each project type. Its most extended usage is for estimating cost in building projects and it is mandatory in public developments in Andalusia. This is the first time that this system is presented internationally and compared to others. Furthermore, the latest additions to ACICS are explained, and these take into account the waste management of reused and recycled materials in the budget estimate through a new division in the classification: Waste Management. Finally, a new way to address the cost related to construction and demolition waste management is explained which increases precision and generates an estimate independent from the general budget.

Keywords: Cost control, cost estimation, waste, construction information classification system.

Introduction

All construction information classification systems (CICS) have the same goals and similar methodologies. The basic concept in all of these systems is to divide a complex problem into simpler parts that can then be aggregated to define a complete construction development. Many researchers have been working on the development of CICS such as Kang and Paulson (1997, 1998) for civil works, and Eldin (1991) and Jung and Woo (2004) who address cost and scheduling simultaneously. Other aspects, such as cost significant modelling and real-time unit price estimation, have been addressed by Yu (2006) and Munns and Al-Haimus (2000), respectively. There are several international CICS, of which the most frequently used include: Masterformat (2004), Uniformat (2008), the Civil Engineering Standard Method of Measurement (1991), CI/SfB (Jones, 1987), Uniclass (1996) and Omniclass (2006).

Masterformat (2004) is a specifications-writing standard for building design and construction projects in North America. It lists titles and section numbers for organizing data about construction requirements, products and activities. Each Masterformat number and title defines a section, arranged in levels depending on its breadth of coverage. Each title is made up of four levels, each of which delineates a gradually more detailed area of work. It has 49 main divisions. Masterformat is hierarchical although the main divisions are complex and consequently its application for cost estimating is difficult (Kang and Paulson, 1997, 1998). Furthermore, it does not follow the sequence of tasks necessary during the construction process, which renders this system less applicable for planning and control on the construction site.

Another American classification system, Uniformat (2008), organizes preliminary construction information into a standard order or sequence on the basis of functional elements. Functional elements, often referred to as systems or assemblies, are major components common to most buildings that usually perform a given function regardless of the design specification, construction method, or materials used. However, Uniformat makes cost estimation difficult because it

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Construction Management and Economics
ISSN 0144-6193 print/ISSN 1466-433X online © 2010 Taylor & Francis
http://www.informaworld.com
DOI: 10.1080/01446191003735500

does not go into enough detail for easy cost allocation (Kang and Paulson, 1997).

The CESMM, the Civil Engineering Standard Method of Measurement (CESMM, 1991), is the British CICS for civil works. It is a procedure to prepare the bill of quantities which has a work structure and defined measurement criteria. The CESMM main divisions are represented with letters that separate more or less the main types of processes that take place during a construction, such as demolition, earthworks and in-situ concrete.

Another widely used CICS is the European CI/SfB (Jones, 1987). CI/SfB stands for Construction Index/ Samarbetskommitten for Byggnadsfragor. This system is used worldwide for technical and trade literature in the construction industry. This is a standard, common framework or list of headings, used for setting up office libraries, collecting design information, preparing reports, cost plans, drawings, specifications, bills of quantities and other types of information for building. CI/SfB is enumerative decimal and is organized within a faceted classification. CI/SfB is superseded by an international framework developed by the ISO technical committee (ISO TC59/SC13 WG2, 1994) for an information classification system in the construction industry that is being applied in the Uniclass system (1996). The system is structured with a faceted classification system similar to that of CI/SfB rather than a hierarchical classification system such as contained in Masterformat (2004). However, when classifying items in detail, the hierarchical system is often partially used within a facet.

The ISO framework organizes construction information into eight facets, comprising facility, space, element, work section, construction products, construction aids, management and attributes. The scope of the ISO classification has expanded into life cycle information, including construction management and products.

Finally, the Omniclass (2006) is useful for many applications, from organizing library materials, product literature and project information, to providing a classification structure for electronic databases. It incorporates other systems: Masterformat for work results and Uniformat for elements.

The Andalusia system is hierarchically organized with 17 chapters (Carvajal-Salinas *et al.*, 1984). It uses alphanumeric codes, formed by a group of characters that contain letters and numbers. The structure is significant, which means that the codes identify and define some characteristics and qualities of the element referenced. The significant codes contain groups of partial codes whereby each partial code makes reference to one characteristic or quality that is highlighted.

ACICS is hierarchical, in the same way as Masterformat (2004) but its main structure follows the construction development, and needs different chapters to cover all construction site activities. The Uniformat (2008) and Omniclass (2006) element tables organize functional elements similar to ACICS work units thereby easing their potential compatibility. Uniclass (1996) is faceted instead of hierarchical as is ACICS, which could result in a more difficult adaptation since the two classifications overlap definitions between ISO facets and ACICS levels. The CESMM (1991) is the most similar method to ACICS since both of them include measurement criteria in the work unit description, are hierarchical and follow the work organization at the construction site.

ACICS can also be adapted to other work systems, such as Masterformat (2004), Uniformat (2008), Uniclass (1996), Omniclass (2006), etc., by using these other systems for the classification of upper hierarchic levels but ACICS for the lower levels. In such lower levels, ACICS proposes a simplification for cost allocation using a differentiated direct and indirect cost. The processes that are easily identified with a specific work unit are considered direct costs. On the other hand, materials, labour or machinery that are part of a variety of processes, for example, crane work hours, are considered an indirect cost and the allocation of their cost is simplified. The differentiation makes it possible to group together costs that are due to several activities into a simpler classification of indirect costs.

In Spain, as a result of the Spanish law on Public Sector Contracts (1986) more recently superseded by Spanish Law 30/2007, several construction cost databases have been developed, for example, COAATGU, IVE and ITEC. The ACICS differs from all of these databases in several aspects. The COAATGU (2009) has an internal structure that is not open and the interior aspects of the software tool that is used to calculate cost are not transparent either. The same happens with ITEC (2009), the classification system from Catalonia. In a different way, the Valencia database, IVE (2009), uses parametric cost calculations which imply that the cost is not directly applied to specific basic cost but obtained by equations that calculate the corresponding cost for a group of characteristics, normally using linear relationships between variables. All the previous systems are generally used by construction professionals. There have been efforts towards unifying all the Spanish systems by the Association of Construction Data Base Redactors by means of developing a standard exchange format, FIE-BDC (2007).

ACICS is a robust system due to its transparency in the structure and the clear level definition necessary to correctly allocate costs. It is also regularly upgraded through periodical professional discussions by the Technical Architect Associations of Andalusia published by Consejería de Vivienda y Ordenación del

Territorio de la Junta de Andalucía (2009). All the above makes it easier to adapt ACICS to the other international CICS.

Following ACICS, a waste management classification is presented that is based on the National Decree (Real Decreto 105/2008) which regulates the production and management of construction and demolition waste, and on the European Waste List 2000 (adopted by Decision 2000/532/EC, last amended by Council Decision 2001/573/EC.2000). The Alcores model (Local Authorities of the Los Alcores Community, 2003) and software are used to predict the amount of waste to be expected in dwelling construction (Solis-Guzman *et al.*, 2009). Finally, the waste quantities are translated into an independent budget within the construction project.

The questions addressed can be adapted to other CICS in respect of construction and demolition waste (C&D waste) management costs. In order to achieve such a goal, it is necessary to separate waste management activities from traditionally defined work units that already include waste management; these are referred to as direct costs. The new approach proposes an independent chapter, Waste Management, at ACICS top level, and the categorization of new related work units.

Relations and structure

ACICS, as mentioned in the previous section, is formed in a hierarchical structure. The levels that form the structure are no more important than the relations that connect them, since it is through these types of bonds that it is possible to cross the structure in any direction, ascending or descending, without committing errors or losing intermediate information generated in the processes. ACICS establishes a correspondence between each elemental code and the work unit that it represents (Ramirez-de-Arellano, 2006), similar to CESMM (1991) and Uniformat (2008). The work unit refers to a group of resources (material, labour and/or machinery) necessary to build an indivisible part of a building and also represents the smallest component of the construction budget. The fact that a code can be assigned to more than one work unit invalidates a classification. ACICS divides all possible work units into large groups of elements with common characteristics. The highest level is the construction site, L1 in Table 1. The next divisions are called chapters, L2 in Table 1, and represent a construction process: demolition, earthworks, foundation, sanitation, structure, partition, roof, installation, insulation, finish, carpentry, glass and polyester, coating, decoration, urbanization, safety, and waste management.

Table 1 Internal classification structure

Class levels	Definitions
L1. Construction site	All the construction elements that make up a construction site.
L2. Chapter	Sets of elements with a common characteristic. *e.g. 05. Structures.*
L3. Sub-chapter	Chapter division into smaller sets with a common characteristic. *e.g. 05H. Reinforced concrete.*
L4. Sections	Sub-chapter division into smaller sets with a common characteristic. *e.g. 05HH. Concrete.*
L5. Groups	Section division into smaller sets with a common characteristic. *e.g. 05HHJ. Reinforced concrete beam.*
L6. Work units	Group division into unitary elements. *e.g. 05HHJ00001 m3 Concrete HA-25 in …*

The subsequent divisions are the sub-chapters: level L3 in Table 1. For example, the chapter 'Installations' is divided into the following sub-chapters: air conditioning, electricity, water, communications, gas, electro-mechanics, fire protection and illumination. After this division, large groups still remain which need to be divided into sections: level 4. The sections represent batches to be carried out during the construction. For example, inside sub-chapter 'air-conditioning installations' are the following sections: cool air, heat and ventilation. Finally, the sections are divided into groups, level 5, and the groups into work units, level 6.

Within this structure, the representation process needs a detailed description of each work unit that refers to a set of resources (material, machinery or manual labour) necessary to construct an indivisible unit which is then incorporated into the construction site. This constitutes the smallest part in the classification and includes the following elements: a measurement unit, frequently used name, the elements that integrate this work unit, the corresponding construction methods, their reference norms and/or regulations, and measurement criteria.

As described before, the model has a pyramidal structure which, from the hierarchy vertex represented by L1 in Table 1, descends towards the inferior levels by dividing each family into sub-families of homogeneous characteristics. Inversely, the ascent from the inferior levels to the superior families is obtained by adding the amounts of the inferior-level sub-families.

Once the structure is established, an alphanumeric code is defined for the chapters, sub-chapters, sections, groups and work units. First, the chapters are defined by two numbers, for example, '02' represents the chapter Earthworks; the sub-chapters are defined by three characters: two numbers that define the chapter and one letter, generally the first letter of a characteristic common throughout the division. For example, '02P', where 'P' stands for the Spanish word *pozos*, means concrete pads. Any work that cannot be represented by one of the established sub-chapters since its characteristics are unusual or random, is included in the sub-chapter 'others'. These criteria keep the classification simple and become easy to remember after being used several times. The next level is formed by sections that are defined by four characters: two numbers and two letters. For example, in classification 02PM, the '02' is due to the chapter Earthworks, 'P' stands for concrete pads and 'M' refers to work mechanically done. There is also a section 'Others' for work that is not significant. This work happens sporadically or in such a small quantity that no specific classification is required. The following level is formed by groups that are defined by five characters: two numbers and three letters. Finally, the last level is made up of work units that are represented by 10 characters, for example 02PMM00001 is 1 m^3 of pad excavation, up to 4 m deep, in firm soil, by mechanical means. The work units are formed by constructive elements of material, machinery and/or manual labour.

Cost estimation model

The previously described classification system consists of a description of the construction work which can also be considered as a set of physical measurements (m^2, m^3, kg, etc.) that needs to be transformed into a set of economic groups expressed in monetary units in order to obtain the budget.

The cost estimation using Andalusia's BCS is also pyramidal with clearly defined levels, see Figure 1. The pyramid base is formed of the supplier costs that directly connect to market factors: material, manual labour, machinery, subcontracting, etc. The vertex of the structure contains the total cost contracted. It connects the economic information with the finished product market of residential buildings, offices, teaching institutions, etc. The structure is completed by intermediate levels between the two ends, depending on the degree of detail required. All cost levels are described in Table 2, where level n-5 is for the supply cost and goes up to level n for the total project cost contracted.

The structure division begins with the supply costs, obtained from market surveys, followed by the basic, auxiliary and unitary costs for the constructive elements. The constructive element is defined as the physical component associated with a process that enables it to be used on the construction site. The basic cost, level n-4 in Table 2, refers to a constructive

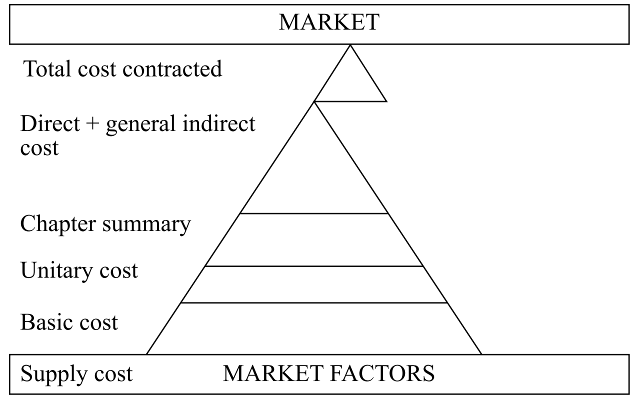

Figure 1 Pyramidal cost structure

Table 2 Structure of the building cost system

Basic cost levels		Optional levels	
n	Total cost contracted (TC)		
n-1	Production total cost (PTC) and general indirect cost (GIC)		
n-2	Chapter summary	n-2.1	Sub-chapter summary
		n-2.2	Section summary
		n-2.3	Group summary
n-3	Unitary cost (UC)	n-3.1	Functional unitary cost
		n-3.2	Complex unitary cost
		n-3.3	Simple unitary cost
n-4	Basic cost (BC)	n-4.1	Auxiliary cost
n-5	Supply cost (SC)		

element cost that represents a resource: manual labour, materials and/or machinery, which in turn takes part in the formation of an auxiliary element or in a work unit.

Within the basic cost, an optional level can be defined: that of the auxiliary cost. The auxiliary cost (level n-4.1) is a combination of basic costs that cannot be considered as a work unit by themselves. The unitary cost (level n-3) is formed as a combination of basic or auxiliary costs that represent a complete work unit and that are incurred by the same group of specialists.

The unitary costs can also be classified as simple (n-3.3), complex (n-3.2) or functional (n-3.1). The first, the simple unitary costs, are unitary costs formed by basic or auxiliary costs. The second class, the complex unitary cost, is formed by a set of basic, auxiliary and other unitary costs that constitute a constructive set and is incurred by one or several groups of specialists. The third class, the functional unitary cost, is formed by a set of basic, auxiliary and unitary costs that constitute a constructive set with a complete function within the building site.

Once the cost structure has been established, the subsequent step is to determine the total project cost. The assignment is direct when the allocation of the cost is made by means of the application of the cost (C_i) of the component i to the amount (Q_i) for those components which participate in the cost.

$$DC_i = C_i * Q_i \tag{1}$$

where DC_i stands for the direct cost of component i. The cost assignment will be indirect when the allocation of a cost is made by means of a relative-value application ($T_i\%$) with respect to a value (V_i) of reference.

$$IC_i = T_i\% / 100 * V_i \tag{2}$$

where IC_i stands for the indirect cost of component i. The direct costs are the costs that are integrated into the structure by means of a direct assignment. Consequently, the denomination 'direct' or 'indirect' does not depend on the type of cost, but on the form of assignment.

The unitary cost (UC_i) is formed by direct and indirect costs,

$$UC_i = DC_i + IC_i = DC_i + T_i\% / 100 * DC_i \tag{3}$$

The direct cost (DC_i) is incremented by the overhead which is calculated for each type of construction site. The costs that are due to specific or combined work units are considered direct. On the other hand, the costs that cannot be combined in a specific work unit are considered through an indirect approach. For example, the indirect cost percentage is higher for restorations of old buildings than for new constructions since, as can be seen in Table 3, the indirect costs are calculated from the specific project contract and include all the remaining costs that are generated on the construction site which are not included in the direct costs. For example, if the scaffolds and lifts are used by not only one specific work unit but by several work units, then the corresponding renting cost is considered indirect.

In the unitary cost, only those indirect costs incurred on the construction site are considered: other indirect costs related to the general activity of the construction company are not included in the unitary cost but applied to the completed building, at level n-1 of Table 2, and are called general indirect costs.

The total cost, TC_{at} in Figure 2, is formed by the production total cost (PTC), the general indirect cost (GIC), the industrial profit (IP) and the taxes (VAT). The PTC corresponds to the first general level of the cost structure that covers all production costs incurred due to the tasks necessary to carry out the projected work. The PTC is obtained from multiplying each work unit cost by the corresponding measured batch and adding them up. The current development at this stage can be obtained by applying different levels of aggregation from the classification system: groups, sections, sub-chapters and chapters, based on the criteria of the project manager, always starting from the amount of work carried out in each batch. 'Batch' refers to a delimited amount of the same work unit.

The second type of cost is the general indirect cost (GIC) which is imputed by an indirect route, by means of the application of a percentage that represents the concepts shown in Table 4. This group of exogenous costs represents the costs of the fixed structure of the construction company. These costs are distributed throughout the company projects, as a result of affecting all activities of the company.

The industrial profit (IP) incorporates the constructor's expected profit, e.g. the payment for its enterprise activity, within the structure. The calculation is made by means of the application of a percentage to the total cost of the PTC. The contract total cost before taxes is the result of adding together the production total cost, the general indirect costs, and the industrial profit.

Finally, the contract cost after taxes (TC_{at}), is obtained, located in the vertex of the structure: for this reason all the costs generated during the construction process are included. This amount is obtained by adding together the contract cost before taxes (TC_{bt}) and the sale tax (VAT). These are all costs that the promoter will have to pay to the constructor as a result of carrying out the projected construction, see Figure 2.

Direct cost approach to C&D waste cost and practical applications

The CICS described in the introduction have a division for construction waste, for example, Masterformat (2004), in order to generate a waste management independent budget, needs at least three different main divisions: Procurement and Controlling Requirements, General Requirements with subdivision Unit Prices and the last division, Existing Conditions with subdivision Demolition and Structure Moving. Furthermore, there is no specific subdivision for the construction material recycling. Omniclass (2006) also has a classification for waste management inside tables: Cleaning and Waste Management table inside Work Results. In a similar way Uniclass (1996) has

Table 3 Production cost classification

Code	Concept
C1	PRODUCTION COSTS (endogenous costs)
C11	PRODUCTION DIRECT COSTS
C111	Materials
C112	Machinery of direct production
C113	Direct manual labour
C12	PRODUCTION INDIRECT COSTS
C121	Indirect manual labour
C1211	Supervisors assigned permanently to the work
C1212	Foremen
C1213	Storekeepers
C1214	Guards
C1215	Attendance controllers
C1216	Others
C122	Auxiliary equipment
C1221	Auxiliary manual labour
C12211	Personnel for internal material transport from storage
C12212	Personnel for cleaning, watering and rubbish recollection
C12213	Collection and transportation of equipment and tools
C12214	Others
C1222	Auxiliary material
C12221	Mortar for fixing guides
C12222	Bricks and mortars for formation of provisional steps
C12223	Materials for laying out
C1223	Machinery, equipment and tools
C12231	Elevation (with assemblies, disassembling and machinists)
C12232	Concrete mixers
C12233	Cutting
C12234	Scaffolds
C12235	Tools
C12236	Other machines
C123	Accessory and complementary facilities
C1231	Work houses
C12311	Offices
C12312	Warehouses
C1232	Electrical, water connection and installation
C1233	Roads, previous underground installations detection and layouts
C1234	Others
C124	Personnel
C1241	Technicians assigned to the work
C1242	Administrative assigned to the work
C1243	Others
C125	Several
C1251	Office and warehouse expenses
C1252	Waste pick up
C1253	Others
C126	Health and safety
C1261	Preventive medicine and first aid
C1262	Specific training on heath and safety
C1263	Helmets and gloves of normal use
C1264	Safety personnel (meetings, committees, monitoring, etc.)
C1265	Offices and restrooms
C1266	Collective safety
C1267	Individual safety
C1268	Signalling
C1269	Others

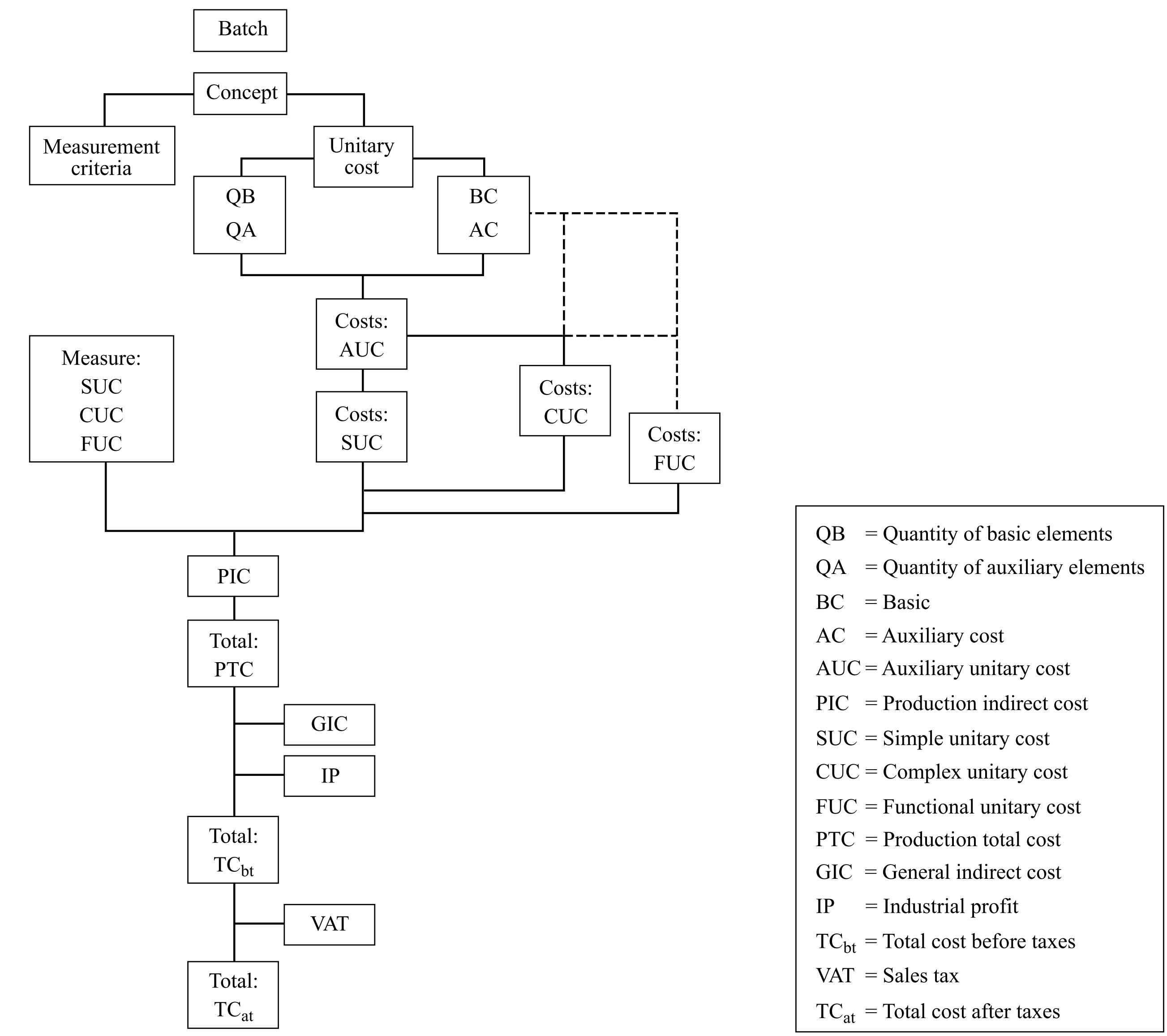

Figure 2 Budget model

table J, Work Sections for Buildings, that includes waste management issues. CESMM (1991) has a division Waste on Site, A9, A—Administration and management, A9 Sundry, A9t Articles, materials found on site not connected with the project and A9u Contingencies.

ACICS, since its first publication, has been adapted to the changing construction legislation and technology by incorporating new concepts and divisions. The first improvement took place in 1987 when a division related to safety was added due to the Spanish regulation Real Decreto 555/1986, which establishes that all building projects must have a separate safety budget. A second adaptation was implemented due to another regulation, the Technical Construction Code, which enforces control plans (Real Decreto 314/2006) and quality control work was included as work units. More recently, a division for waste management has been incorporated in accordance with the construction and demolition waste management regulation (Real Decreto 105/2008).

The C&D waste management costs can be considered, in the previous model, as either direct or indirect costs. During demolition, waste management is considered a direct cost inside the chapters: structure, walls, roofs and tiles. However, during the construction of a new building only the waste generated during chapter 02 Earthworks is considered a direct cost. For example, 14% of the total waste for a typical dwelling construction is considered indirect cost and

Table 4 General indirect cost classification

Code	Concept
C2	GENERAL INDIRECT COST (exogenous costs)
C21	CONTRACT RELATED
C211	Financial
C2111	Endorsement of the contract
C2112	Postponement of payments
C2113	Retentions
C2114	Delayed payment of price revisions
C2115	Others
C212	Rates and taxes of the administration
C2121	Work licence
C2122	Tax on construction
C2123	Public route occupation
C2124	Scaffold permit
C2125	Inspection and monitoring
C2126	Others
C213	Other expenses related to the contract
C2131	Advertising expenses in the press
C2132	Contract formalization expenses
C2133	Banners
C2134	Tests
C2135	Guarding and monitoring during the period of guarantee
C2136	Facility permit
C2137	Specific insurance
C2138	Maintenance and conservation during the guarantee period
C2139	Others

100% of the packaging waste (Solis-Guzman *et al.*, 2009). In Table 3 the following two waste costs are indirect, C12212: Personnel for cleaning, watering and for rubbish collection, and C1252: Waste pick up.

In order to overcome this unclear definition of waste cost, new characteristics for the work unit definition are proposed which can allow the Waste Management chapter to determine the whole waste cost as direct costs. This determination facilitates the waste management budget definition which can also be treated as a separate budget.

The Waste Management sub-chapters are: metals, asphalt, concrete-bricks-tiles, insulation material, wood-paper, soil and others. Furthermore, a new family of basic work units is created, see Table 5. The code is completed with five numeric characters to define specific units. The classification combines the National Decree (Real Decreto 105/2008) and the European Waste List 2000 (adopted by Decision 2000/532/EC, last amended by Council Decision 2001/573/EC.2000).

Table 5 Work unit classification

E.	WASTE (Overuse, losses, breakage, etc.)
EA.	Metals and alloys
EF.	Asphalt, tar and other tar products
EH.	Concrete, bricks, tiles, ceramic tiles, ceramic material, gypsum materials
EI.	Insulation materials
EM.	Wood, paper, cardboard, plastics, synthetics and glass
ER.	Metallic wreck
ET.	Soil
EW.	Others

The work units within those sub-chapters can be allocated the following conditions: waste put inside containers at the construction site, waste loaded on to trucks at the construction site, waste sent to the recycling centre without unloading and waste sent to the recycling centre with unloading included.

In order to explain the budgeting model, a simple example is proposed. First, supply costs are obtained from market conditions in order to use such information in the determination of the basic cost at the lowest level of the classification system. Two supplier costs are listed in Table 6. The term SC stands for the supplier prices of the described items, and T and h are the units used to measure the quantities: metric tons and hours, respectively.

This information is used to define the lowest level of the classification: the basic cost, which can be formed of the supplier cost together with another basic cost. In Table 7, the basic cost EA00001 is defined, whereby E stands for the family and A for the sub-family defined in the classification system. The quantity is measured

Table 6 Supplier cost (SC)

Code	Concept	Cost
PSU1	T steel waste loaded on to the truck inside the truck for recycling	72.00
PSU2	h ordinary construction worker	9.92

Table 7 Basic cost (BC)

EA00001	T Steel waste			
Weighted in a scale				
Code	Concept	Q	Cost	Amount
PSU1	T steel waste loaded on to the truck inside the truck for recycling	1.000	–72.00	–72.00
TP00001	h ordinary construction worker	1.212	9.92	12.02
			Direct cost	–59.98

in metric tons, T. The quantity refers to only useful unloaded tons, and disregards material lost. The basic cost is defined using a supplier cost and other basic costs.

The auxiliary costs are at the next level of the classification system. An additional letter is used, the letter A in front of the family and sub-family letters. In Table 8 the auxiliary cost AEW00001 is formed by one basic cost. Finally, the auxiliary and basic costs described are part of a unitary cost, 17AHA09001, Table 9. The overuse of material in cost estimation is taken into account at this level.

In order to clarify these proposals, a C&D waste management budget for a typical dwelling construction project is described in this section. Demolition, reuse, recycling and new construction all take place in the project. The proposed steps are: to identify the processes that generate waste, to quantify the expected waste and to transform such quantities into an independent waste management budget.

Many models have been established to determine the project waste quantities, such as OEKO Service Luxembourg (OSL) (SuperDrecksKescht fir Betriber, 2002) which proposes quantification of demolition and construction waste at the worksite, and is able to estimate types and volumes produced. ITEC (2000) has also analysed these types of waste and subsequently introduced a computer tool which allows, among other aspects, the quantification and classification of C&D waste per work package. A more recent model is SmartWaste (2008) which defines quantification and classification according to origin and type and also generates the waste management plans. The present work uses the model developed by the authors among others to estimate the type and quantity of waste generated by different construction types such as new buildings, demolition, renovations and alterations (Solis-Guzman *et al.*, 2009). The input parameters in the model are: work type, floor number; foundation type and total built area.

The best way to measure the quantities to be part of the waste management budget is to use the project at the design stage. This is achieved by transforming the project quantities into waste generation. The first step is to identify all budget unitary products that generate waste, see Table 10. The auxiliary products that are part of the previous unitary product list are listed in Table 11. The basic work units that are part of the unitary and auxiliary products are then determined. In Table 12, only groups A and C are listed instead of the whole project basic work units, as a brief example.

Once the project processes that generate waste have been identified the next step is to transform the project quantities into waste generation. In order to establish measurement criteria for the new work units, three transformation coefficients are necessary,

$$M = M_o \quad C_r \quad C_C \quad C_T \tag{3}$$

Table 8 Auxiliary cost (AC)

AEW00001 T Manual waste transportation within the construction site				
Manual waste transportation within the construction site up to a 50 m distance, including manual loading and unloading into containers.				
Weighted in a scale				
Code	Concept	Q	Cost	Amount
TP00001	h ordinary construction worker	1.212	9.92	12.02
			Direct cost	12.02

Table 9 Simple unitary cost (SUC)

17AHA 09001 T Steel waste pick up and transport up to 10 km away				
Waste transport in a truck up to 10 km away. Manually loaded and transported within the construction site. Mechanically loaded on to the truck.				
Weighted in a scale				
Code	Concept	Q	Cost	Amount
AEW00001	T manual waste transportation within the construction site	1	12.02	12.02
ME00001	h loader	0.020	21.64	0.43
MK00001	h truck	0.110	18,00	1.98
EA00001	T steel waste	1.000	−59.98	−59.98
		Direct cost		
		13% Indirect cost		
		TOTAL		

Table 10 Budget unitary products that generate waste

Code	U	Description	Quantity
01ALM11000	m^3	Wall demolition. Measuring wall openings not taken into account.	107.10
01QIP11000	m^2	Disassembly of Arabic roof tiles. Measuring real size.	68.60
01RCE11000	m^2	Mortar thick coating. Measuring all but wall openings.	455.25
01TLL02000	m^2	Land leaning and clearing. Measuring real size.	1654.78
01TVD01000	m^2	Garden clearing. Measuring real size.	432.00
02PMM00001	m^3	Pad excavation. Measuring natural state.	1500.00
02ZMM00001	m^3	Trench excavation. Measuring in natural state.	2250.00
02TMM02000	m^3	Waste transport to land field. Measuring in sponged state.	2008.36
04EAB20011	u	Main connection casket. Measuring real size.	26.00

Table 11 Auxiliary products that are part of the unitary products

Code	U	Description	Quantity
AC		Foundation and structure	
ACH		Concrete	
ACH22222	m^3	Concrete HA-25/P/40	1267.41
ACH33333	m^3	Concrete HA-25/P/20	1216.57
ACH44444	m^3	Concrete HM-20	3.30
AG		Mortars and binders	
AGL		Grout	
AGL11111	m^3	Cement CEM II grout	4.31
AGL22222	m^3	Limestone grout	1.13
AGM		Mortar	
AGM22222	m^3	Sand and cement mortar M-8	0.52
AGM44444	m^3	Sand and cement mortar M-4	134.37
AGM55555	m^3	Limestone sand and cement mortar M-4	110.01
AGM88888	m^3	Sand and cement mortar M-4 with plasticizers	153.72
AGY		Gypsum	
AGY11111	m^3	Black gypsum paste YG	241.61
AGY22222	m^3	White gypsum paste YF	60.40

Table 12 Basic products that generate waste in the categories: Aggregates and Foundation and structure

Code	U	Description	Quantity
A		Aggregates	
AA		Sands	
AA00200	m^3	Fine sand	86.15
AA00300	m^3	Coarse sand	1432.55
AG		Gravel	
AG00400	m^3	Gravel diam. 40/60 mm	1016.77
AG00700	m^3	Gravel diam. 18/20	997.58
AP		Stones	
AP00200	m^3	Limestone	579.56
C		Foundation and structure	
CA		Steels	
CA00200	t	Steel B400S	280.53
CA01200	kg	Steel frame A-42B, complex support	4495.87
CA01400	kg	Steel frame A-42B, beams	3086.50
CA01700	kg	Tie wire	1264.08

where M is the waste quantity that is obtained from the original material measurement, M_o; C_r is a coefficient that represents the percentage of the original constructive element that becomes waste; C_c is a coefficient to change from the constructive element units into waste element units; and C_T is a coefficient to transform the measurement criteria from the original constructive element into the waste element, see Table 13.

Within waste management, another special cost is incurred due to the fact that waste can be reused on the same construction site, or the waste can be sold for recycling or reuse, thereby generating an income. Therefore the first hypothesis for the C&D waste cost is that the material recuperated on the construction site belongs to the constructor and its recuperation offsets other costs. This means that negative costs are allowed in the structure in order to represent this type of income. In Table 14, the waste management budget has negative costs, such as 17AHA00001 Steel waste pick up, and 17HCT0001 Disassemble and pick up of Arabic ceramic tiles from roof which are both consequently sold in secondary markets and hence generate an income.

Conclusions

ACICS is a well-established construction information classification system. It has been in place for the last 25 years. Its structure has not remained static, however, and has been updated to comply

Table 13 Transformation of the project products in waste quantities

Measurement								
Identification		Dimensions				Results		
Code	Location	CR	M0	CC	CT	Auxiliary	Partial	Total
17.	Waste management							
17A.	Metals							
17AHA00001	T steel waste pick up, distance 10 km max., including loading on to trucks using mechanical means. The weight is measured in a scale.							
	=CA00200	1.00	280.53	0.01	1.00		2.81	
	=CA01200	1.00	4495.87			4495.87		
	=CA01400	1.00	3086.50			3086.50		
	=CA01700	1.00	1264.08			1264.08		
				0.01	0.001	8846.45	0.09	
	=CW00600	1.00	2101.33			2101.33		
	=GA00200	1.00	192.15			192.15		
	=PW00100	1.00	96.53			96.53		
				0.01	0.001	2390.01	0.02	
	=CA00200	1.00	4477.50			4477.50		
	=CA01200	1.00	409.04			409.04		
	=CA01400	1.00	163.62			163.62		
	=CA01700	1.00	24 726.47			24 726.47		
				0.001	0.035	29 776.63	1.04	
							Total	3.96

with new regulation and technology changes. The system is used for cost estimation by establishing families ordered according to a hierarchy in which each family of an inferior level belongs to a superior level. In order to carry out the internal calculations and to solve the rising cost levels, the internal structure is based on the following considerations: in the final cost all the costs generated throughout the construction process are represented, and no cost can be repeated.

ACICS is a robust system due to its transparency in the structure and the clear level definition, both necessary for correct cost allocation which makes it easier to adapt ACICS to the other international CICS, such as Masterformat (2004), Uniformat (2008), Uniclass (1996) and Omniclass (2006). These other systems can be used for the classification of upper hierarchical levels, and ACICS for the lower levels.

The present work successfully shows that it is possible to address C&D waste management using ACICS. A new way to address these costs is explained which increases precision and generates an estimate independent from the general budget. In order to achieve such a goal, it is necessary to separate waste management activities from traditionally defined work units that already include waste management.

ACICS enables new C&D waste management costs to be easily defined, by incorporating all costs as direct costs inside the chapter 'Waste Management' of the classification system while the prediction of the C&D waste quantities only depends on the original project definition.

Another important aspect identified of waste management cost is that the classification must follow a structure that allows waste separation depending on the final destination instead of its origin, for example: reuse, recycle or hazardous material treatment plant. In the case of reuse or recuperation of materials within the construction site itself, since it belongs to the constructor then its recuperation offsets other costs. This means that negative costs are allowed in the cost structure in order to represent this type of income.

In order to build on the findings, all waste-related activities must be separated to properly manage and allocate cost. The ASICS has developed an approach to C&D waste that can be incorporated into other international systems or specific enterprise classification methods. Future work will be related to adapting ACICS to obtain the C&D waste management plan for any construction site.

Table 14 Project waste management budget

Budget					
Identification		Dimensions		Cost	
Code	Concept	Measure	Cost	Partial	Total
17.	Waste Management				
17A.	Metals and alloys				
17AHA00001	t steel waste pick up	4.06	−34.26	−139.10	
				17A.	−139.10
17F.	Asphalt, tar, etc.				
17FAA00001	t asphalt waste pick up	0.10	31.48	3.15	
				17F.	3.15
17H.	Concrete, bricks, tiles, etc.				
17HAA00001	m^3 aggregate waste pick up	35.33	19.47	687.88	
17HAP00001	m^3 limestone sand waste pick up	5.80	19.47	112.93	
17HCT00001	u disassembly and pick up of Arabic ceramic tiles from roof	1750.00	−0.24	−420.00	
17HAP00001	m^3 ceramic waste pick up	43.43	22.65	983.69	
17HHC00001	m^3 cement waste pick up	0.24	21.66	5.20	
17HHH00001	m^3 concrete waste pick up	136.95	21.66	2966.34	
17HMM00001	m^3 mortar waste pick up	31.94	21.66	691.82	
17HMM00002	m^3 concrete vault waste pick up	38.96	22.16	863.35	
17HWM00001	m^3 ceramic, mortar and gypsum mixed waste pick up	139.23	21.66	3015.72	
17HYY00001	m^3 gypsum paste waste pick up	16.60	21.66	359.56	9266.49
				17H.	
17M.	Wood, paper, cardboard, etc.				
17MMM00001	t wood waste pick up	35.96	29.32	1054.35	
17MMM00002	kg cardboard and paper waste pick up	673.74	−0.01	−6.74	
17MMP00001	t plastic and synthetic waste pick up	1.03	38.42	39.57	
17MVV00001	t glass waste pick up	0.11	33.48	3.68	
				17M.	1090.86
17R.	Mixed waste				
17RRR00002	m^3 mixed waste pick up	46.86	4.04	189.31	
17RRR00002	m^3 rubble pick up	4485.00	6.74	30 228.90	
				17R.	30 418.21
17T.	Soil				
17TTT00001	m^3 earth transport on site	25.02	9.92	248.20	
17TTT00002	m^3 earth transport off site	4712.52	4.04	19 038.58	
				17T.	19 286.78
		Execution Direct Costs			59 926.39

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