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Integration of Durability Data of Construction Elements Within a BIM-Based Environment

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Abstract. *In the unavoidable way to achieve more sustainable buildings, it is essential to provide the architects with data on the environmental impact and the durability of the different components of the building, and make it available in the format they are using in the design phase. In this regard, the use of the building information modelling (BIM) tools has arisen as a new trend in the construction industry to improve the sustainable assessments of buildings in the design phase. In order to improve an existing tool developed by the Valencian Institute of Building in cooperation with the Valencian Regional Government, on providing the characteristics of the most common construction elements within a BIM-based environment, a database of durability and environmental impact data of construction elements and materials has been developed for integration within the tool. The reference service lives database has been created from a multicriteria study consisting in the analysis of sixty service life data bases published in recent decades. The work developed allows the architects working in Spain to have the durability required data of the construction elements from the design phase, for the integration and information exchange within a BIM-based environment to be able to use the existing BIM-based LCA/LCC.*

Keywords: *BIM-Based Software, Durability, Life Expectancy, Cost, Maintenance.*

1 Context

As it is considered to be a basic industry, the construction sector in Spain is one of the major sources of economic growth and development. So far, the most extended strategy among the construction companies applied to improve the efficiency and become more competitive has been to decrease the buildings construction costs without taking into account the life cycle of buildings. Trying to lower the initial construction costs had a negative impact on the quality of its processes and materials.

In this context, voices are being raised in the academic field that demand a change in the production model of the construction sector proposing solutions taking into account the whole life cycle of the building and the impact it has on the environment. The economic assessment of estate projects beyond the construction phase becomes an essential tool for cost optimization, allowing realistic comparison between different investment options (García-Erviti, Armengot-Paradinas, and Ramírez-Pacheco, 2015).

The science of life cycle cost analysis is a fundamental tool to make changes in the Spanish construction sector. That is the reason why it is necessary to provide the stakeholders of the sector with the necessary tools to modify the decisions in the design stage based on the global cost. As an agent of the construction sector, The Valencian Institute of Building seeks to help technicians to apply the life cycle cost methodologies during the design phase by providing them with tools and data.

The Valencian Institute of Building (IVE), as a public interest incorporated foundation in the construction sector subjected to private law, constituted in 1986, promoted by the Second Vice Presidency of the Valencian Government and Regional Ministry of Housing and Bioclimatic Architecture and directed by a board committee, brings together a collective of professionals involved in the building and urban process. Its main interests, among others, lie in improving the processes linked to the edification and urban space, encouraging research and enhancing life quality, sustainability, safety, accessibility and durability standards through the smart development in the built environment.

2 Objective

During the last decades there has been rising concerns about the service life in terms of stability, safe functioning and appearance of the constructions already built and the ones to be built. The problem is not only to make the buildings and products last longer, which can be advantageous from the point of view of the scarcity of resources (MIT CSHub Cambridge, s.f.), but to know the reference service life of the systems mostly used (and therefore their global cost) to take knowledge based decisions.

The final purpose of the research is not to find out how to increase the durability of the products and systems, but to compile the maximum quantity of durability data available in order to have the ability to compare different constructive solutions. For this purpose, a reference service life database has been developed, not from tests, but from an analysis of different existing worldwide databases.

The developed database is due to be included in a BIM-based computer software so that architects and construction professionals can use it to predict how much their buildings will last and how much they will have cost at the end of their service life.

3 Methodology: Multiple-Criteria Decision-Making

Obtaining reliable data regarding the durability of building materials and systems was one of the difficulties in achieving the final goal. Instead of selecting a specific database, it was decided to rely on a multiple-criteria decision analysis applied to existing databases.

Multiple-criteria decision-making (MCDM) or multiple-criteria decision analysis (MCDA) studies, as part of the operational research linked to applying advanced analytical methods to provide a wide range of problem-solving techniques through applied mathematics methods, are a scientific method of obtaining information to aid in decision making by providing a comparative judgement between complex data. It is based in relating different indicators and giving each one of them certain degree of importance. (Mardani, 2011)

Even though it's a comprehensible and rational method which helps finding solutions in complex situations, it is difficult defining the comparison criteria, researching available data and, maybe the most important of all, the time factor.

Stage 1. Scope of application

To correctly evaluate the different sources, a taxonomy of the components of the constructive elements was developed, so the comparison can be as accurate as possible when compared to other sources under the same conditions.

Stage 2. Available databases

The next step was a thorough research to locate the most majority of available databases worldwide.

There were identified sixty service life databases published in the recent decades, from Spain, Germany, Portugal, UK, US, Canada, Australia, Italy, Sweden, Switzerland and Israel.

Stage 3. Indicators

Four indicators were defined to evaluate the weight each database should have when pondering the data: data affinity, which refers to the climate zone of the country were the study was made; data obsolescence depending on the publishing year; reliability of the source, depending on the authors and investigation center where the study was made and the level of expertise of the data base related to the different constructive elements. For each indicator 2 or 3 levels were created in order to rank the databases depending on the level achieved in each indicator, as seen in the tables below.

Table 1. Data Afinity.

Climate zone (country)	Score
Mediterranean climate zone (Spain, Portugal, Italy)	3
Temperate climate zone (Germany, UK, Sweden, Switzerland)	2
Cold and sunny climate zone (UK, Canada, Australia)	1

Table 2. Data Obsolescence.

Year	Score
2012 to present	3
2000-2005	2
Before 2000 or unknown	1

Table 3. Data Reliability.

Reliability	Score
High	3
Medium	2
Low	1

Table 4. Level of expertise.

Level of expertise	Score
High	2
Low	1

Stage 4. Multiple-criteria weigh

The analyzed databases were scored for each of the indicators mentioned above. As seen in the tables above, the maximum score that could be obtained was set in 11 points. Each database was scored a total number of points after evaluating the four indicators.

Stage 5. Multiple-criteria decision-making

After scoring the databases, to obtain a service life data for each construction element, a weighted average was applied to each durability data of every constructive element obtained from the different data bases. The weighted average was based on the weigh that each database obtained. Aberrant data was not taken into account.

For instance, considering a constructive element such as a wooden beam of which 3 different durability data were gathered, a weighted average was applied having more weight in the average the data gathered from sources closer to Spain, more reliable, more specialized and more recent.

Multiple-criteria decision-making results

The reference service life of the constructive materials database was a result of the multiple-criteria decision-making.

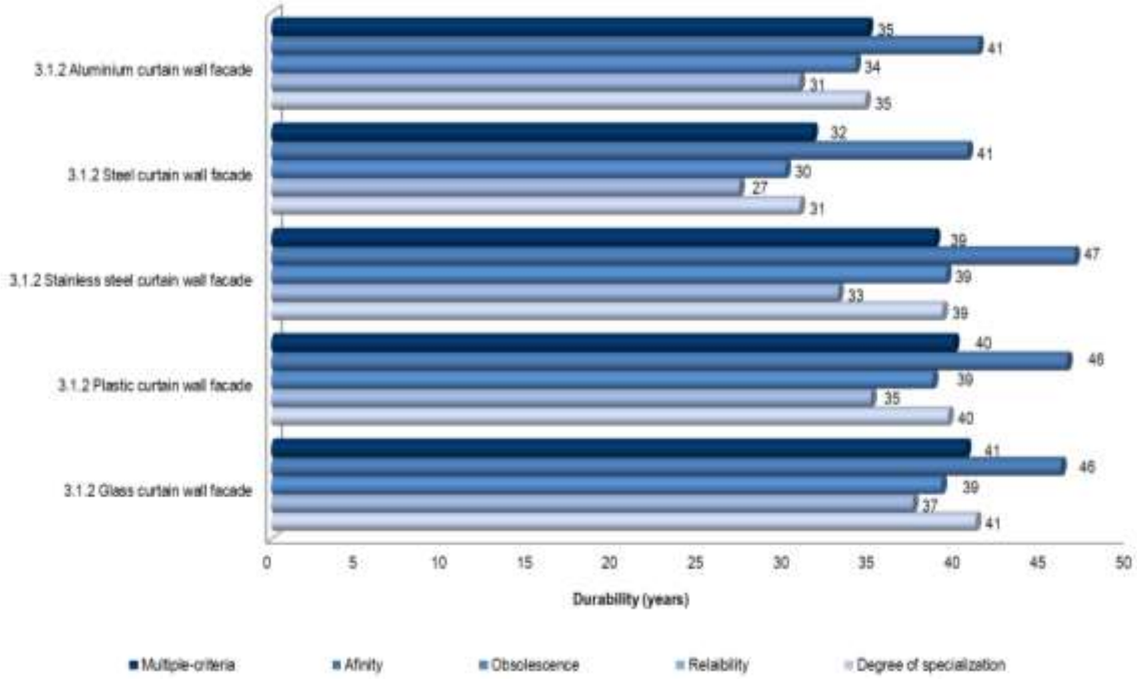
The service life data to be used with the objective of including it into a BIM-based environment tool was the one resulted from the process explained above. However, with research purposes, the results were also organized and sorted into a table including more complex information as the minimum and maximum service life or an average service life having considered only one of the four indicators or the critical value. The Image 1 below shows the results of the analyzed and processed data of the constructive elements of a brick wall façade. The data used for the BIM-based tool was the Multiple-criteria average service life column.

Image 1. Example. Durability data results.

Construction material: TAXONOMY			Construction material	Group	Data dispersion		Minimum service life (years)	Maximum service life (years)	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
03 Facade	3.1 Wall	3.1.1 Brick: cooked clay	Fabrica ladrillo ceramic	Brick clay pieces	23	High	40	150	79	90	77	[illegible]	[illegible]	[illegible]	[illegible]
03 Facade	3.2 Exterior cladding	3.2.3 Plastered	Cement mortar plastering	Plastering	15	Medium	5	66	32	40	32	[illegible]	[illegible]	[illegible]	[illegible]
03 Facade	3.5 Others	3.5.2 Thermal insulation in 2-layer	Non-hidrofilic mineral w	Thermal insulation in two-layered facade	14	Medium	25	90	46	55	46	[illegible]	[illegible]	[illegible]	[illegible]
03 Facade	4.2 Interior cladding	4.2.2 Plastered and trimmed	Plastered plaster	Plaster	14	Medium	5	62	38	48	38	[illegible]	[illegible]	[illegible]	[illegible]

The database created allowed the extraction of a variety of relations between the analyzed elements. The Graphic 1 below shows an example of comparison between the durability of different types of curtain wall façade depending on the indicator taken into account. The first bar refers to the multiple-criteria, that is all the indicators, and the rest of them have into account just one indicator.

Graphic 1. Curtain wall façade durability comparison results.



4 Durability Into BIM-Based Computer Software

The Valencian Institute of Building in cooperation with the Valencian Regional Government, has been gathering information and created a database about the most common construction materials characteristics and put it together in the Catalogue of Construction Materials.

Complementary information such as materials durability, maintenance and costs are being added to the already existing Catalogue of Construction Materials in order to improve it and update it to nowadays needs.

It is well known that Building Information Modelling (BIM) as a method of developing architecture projects is as its peak and the big majority of architects and construction professionals are already using BIM-based computer software to efficiently plan, design, construct and manage buildings and infrastructure. The construction materials' information gathered and applied when planning buildings will allow knowing the service life of buildings and its cost from the design phase.

The current catalogue was released to the public as a software program tool in 2010 and it's being updated at the moment with the purpose of turning it into a web application. The catalogue provides tools for designing custom constructive solutions, calculate their properties and check them according to the Spanish law. The image 2 below is part of the Catalogue of Construction Materials being developed and it shows different façade types and its properties.

Table 5. Example. Façade types and properties. Catalogue of Construction Materials under development.

Tipos Subtipos Soluciones de Catálogo

Modificar Parámetros Ver sólo habilitadas

✓		Código	Sección	E (mm)	M kg/m²	Caso cámara aire	DB-SI	DB-HS		DB-HR		U
							R/E/I	G.I.(h)	G.I.(nh)	R_A dBA	$R_{A,tr}$ dBA	
✓		FC01a03M3205		265	361		EI120	1	2	52	47	
✓		FC01a04M3205		285	383		EI180	1	2	52	47	
✓		FC01b01M3205		195	172		EI120	1	2	43	38	

The Valencian Institute of Building has been working on integrating construction materials data, characteristics, durability data from the latest databases and information from other IVE tools in a BIM-based environment. Therefore, users will be able to know constructive information and characteristics from the design phase.

This web application will let users define and choose a bundle of constructive solutions for their project, downloading them in IFC and RFA formats with the properties of each solution, such as durability. It is currently in development and it is not released yet to the public, although it is expected to be available by the beginning of 2020.

Assessing the building over its life cycle (planning, construction, use and demolition phase) provides an insight into the real quality of the building (Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMUB), 2016). The application of the durability data into BIM software will allow professionals to previously assess buildings' life cycle.

The final input lies in the integration of the present research results and information gathered from other IVE tools into BIM software in order to be applied to projects from the design phase. A web application will let users define and choose a bundle of constructive solutions for projects, download them in IFC and RFA formats with the properties of each constructive element, such as durability. It is expected to be released to the public by the beginning of 2020.

5 Conclusions

The previous and numerous worldwide studies carried out in the field of predicting the construction materials service life and the latest research here displayed allowed us to carry out data extraction, process it and apply it to our nearby environment (Spain).

In these moments in which the construction sector needs to change the model that has been applied in the last decades, the progress achieved with the present research allows to take steps in order to improving quality and sustainability, encouraging a better understanding of the construction systems we use, as well as its components and materials. We cannot improve the functioning of the construction systems if we do not know their behavior.

The present study provides with data that architects and technicians need in order to be able to consider the reference service life of the buildings from the design phase, allowing the advance in multiple aspects that result in the improvement of the construction sector efficiency, such as maintenance plans, better forecast of life cycle costs, buildings and construction systems design, information given to clients accuracy... etc.

Nevertheless, in order to successfully carry out this process, it is necessary to raise awareness in the construction sector and to be supported by public policies. The Valencian Institute of Building works in parallel in this line together with the regional government for the improvement of quality and sustainability in the construction sector with a holistic and comprehensive vision of the entire construction process.

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