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ENVIRONMENTAL PERFORMANCE AND TECHNOLOGICAL DESIGN
AN EVALUATION MODEL WITH BIM INTERFACE

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ABSTRACT
In the European building panorama, studies, aimed at the development of systems and components, follow one another, classifiable as sustainable in relation to a series of performances and characteristics. The approach to construction has led, not only to cognitive theories and research on new materials, but also to the development of 'high naturalness' building products. Nevertheless, even today there is no scientific methodology that can conform these environmental performances to the specific use of these products. The paper presents the ongoing research at the CITTAM of the University of Naples 'Federico II' for the development of a product evaluation methodology that guarantees sustainability certification and, in fact, contributes to the digitalization of the executive project.

KEYWORDS
BIM, evaluation, performance, environmental sustainability, database

The work presented in these pages is the result of research carried out at the CITTAM, the Interdepartmental Research Center for the study of Traditional Techniques of the Mediterranean Area of the 'Federico II' University of Naples, which has among its objectives the conservation of Mediterranean area traditions and Sustainable Development. Among the research lines developed by CITTAM particular attention is paid to research on 'bioregional' materials so that their use, in combination with traditional techniques, allows to improve the performance of the built in terms of: 1) 'cost-effectiveness' of the construction, because materials present on site are often supplied at lower prices thanks to a logistical and positional advantage compared to others; 2) 'ecosustainability', because in addition to reducing environmental transport costs, the impacts related to decommissioning are also minimized by not introducing waste material foreign to the ecosystem; 3) 'social sustainability', because it favors the local economy and also traditional production techniques and systems.

Already during the first phases of study, it was necessary to identify in an objective way how to discriminate 'regional' materials from those that are not, and also to measure their eco-sustainability and biocompatibility (Francese, 2007), or their propensity to be tolerated by the environment and the life forms with which they come into contact. To do this, it was agreed to start from the vast technical literature available on the subject; in an initial phase of the research activities, the environmental sustainability assessment systems currently used in construction were analyzed (Francese, 2007; ITACA, 2015; Buoninconti, 2016; Green Building Council Italy, 2016; CasaClima, 2019; BREEAM, 2019) to compare the structure of the respective 'multi-criteria matrices'; this allowed to identify the main mechanisms used in the different methods, and to identify the most common indicators. A second research step consisted in the study of the software that analyzes the life cycle of the products (OpenLCA, 2019; SimaPro, 2019; DGNB, 2019), and the relative reference regulations (UNI EN ISO 14040:2006); attention to the protection of environmental resources makes it unavoidable to estimate the impact of any transformation activity on the environment through the Life Cycle Assessment (BREEAM, 2019; DGNB, 2019); in this process, the estimation of the performance of a material in its working time and, in particular in relation to durability and recyclability, are significant factors in the environmental sustainability report.

On the theoretical basis defined in the preliminary investigation phase of the research, the study focused on defining the parameters of Regionality and Sustainability (De Joanna, 2016; Kapoor, 2017; Environdec, 2019) of construction materials and products, focusing on attention to 'Type III environmental labels' and related legislation (UNI EN ISO 14025:2010). Among these, the Environmental Product Declaration (EPD), in which the impacts on the environment in the different life stages are explained of the material, has proved particularly useful for defining the indicators of the developed method. The elaborated system therefore relates all this information and, to make the results easier to interpret, classifies the materials using a six-level scale, from a minimum of 0 to a maximum of 5 stars, which allows designers to have a catalog of bioregional materials to be used in their projects.

The digital catalog can constitute a database that can be used by selecting materials through different filters related to their global assessment, but also as a function of the 'score' totalized by each indicator. This allows the user to choose the products to use according to the particular needs that the project must satisfy. The digital format and the structure of the database are finalized to the implementation in a BIM software (Building Information Modeling). In these programs (Read, 2012; Argiolas et alii, 2016) it is in fact possible to define a 'family' of materials and products characterized by different 'attributes': by inserting among them the evaluations that the individual materials have obtained through the proposed method, it is possible to quickly obtain an estimate of the Bioregionality of the project solutions and compare different conceivable layouts.

Performance evaluation – For the realization of an evaluation system, necessary to establish the performance level of the analyzed materials, a 'multi-criteria' matrix has been elaborated: as we know, in these methods a sufficient number of indicators is established able to describe the analyzed phenomena; these are assigned a score, according to the 'threshold-parameters', which allows to compare the indicators, and therefore the different phenomena taken into consideration[1]. The choice of indicators must be made on the basis of the 'needs' that the construction must satisfy; for this reason, the 'demand-performance' approach developed in the technical standard in the 1980s (UNI 8289:1981) was adopted as a theoretical reference, as amended in the first decade of 2000 (UNI 11277:2008); it was then processed according to Table 1. As usually happens in the 'multicriteria' evaluation systems (Francese, 2007; UNI/PdR 13.1:2015), also in this case the evaluator assigns the 'weights', both to the Requirement Classes and to the Needs, thanks to which the final result is obtained through a simple weighted average, using the relation:

$$EP_m = \sum_k w_c w_{cn} S_{(cn),k}$$

The letters 'w' represent the weights, while 'S' is the score that is associated with each indicator. Table 1 shows the weights 'w_1' and 'w_2' which were used for the classes of need, and from 'w_{11}' to 'w_{24}' those of the individual needs; these are expressed as a percentage (the sum of homologous weights always returns 100%), and can be modified according to need, making the system flexible. The score is assigned to each indicator using a six-level scale (see Table 2), for which the 'EP_m – environmental performance of the material' index is also variable from a minimum of 0 to a maximum of 5. This 'synthetic index', representative of each material analyzed, allows to choose the best solution from the environmental point of view in the design phase; in the case of equivalent indexes, the designer can choose the most suitable material for use by consulting the database where the 'scores' assigned to the individual indicators are stored, and thus verifying the score attributed to the needs which he considers a priority for the functionality of the construction. The indicators have been determined by declining every need in one or more requirements (UNI 11277:2008; UNI 8290-2:1983), and finally identifying the 'parameters', which can be expressions of 'variables' or, if it were not possible, of 'attributes' (UNI 10838:1999). Table 3 shows the articulation developed in the method: as required by the standard, the use of variables was preferred to that of the attributes.[2]

In the evaluation phase, the required variables must first be determined; these can be found in the technical literature, or alternatively are disclosed by the manufacturer. In particular, many environmental impact variables can be taken directly from the Envi-

Class of requirement	*Definition*	*Description*	*Need*	*Weight*
Well-being (w_1 = 45%)	Set of conditions relating to states of the 'building system' adequate to the life, health and performance of user activity	Ability of the 'environmental sub-system' or of its parts to develop states able to favor the performance of actions by users and to prevent risks to their health	Thermal comfort	w_{11} = 25%
			Visual comfort	w_{12} = 20%
			Auditory comfort	w_{13} = 20%
			Healthiness of the air	w_{14} = 20%
			Hygienic environment	w_{15} = 15%
Environment protection (w_2 = 55%)	Set of conditions relating to the maintenance and improvement of the state of the 'supra-systems' of which the 'building system' is a part	Ability of the building system to reduce resource consumption and waste production, and to promote the protection of natural and socio-cultural systems	Resource utilization	w_{21} = 30%
			Waste production	w_{22} = 30%
			Landscape protection	w_{23} = 20%
			Socio-cultural protection	w_{24} = 20%

Tab. 1 - Structure of the classes of needs considered in the valuation method.

Performance	Absolut. negative	Insufficient	Almost sufficient	Sufficient	Good	Excellent
Score	0	1	2	3	4	5

Tab. 2 - Scale of the scores used for the indicators.

Needs	*Requirements*	*Indicators for the material*	*Parameters (attribute or variable)*	
Thermal comfort	Solar factor control	Light absorption	Absorption index (adim.)	Var.
	Interstitial condensation control Control of surface condensation	Steam permeability	Vapor resistance factor (adim.)	Var.
	Control of thermal inertia	Thermal admittance	Thermal conductivity (adim.) Volume mass (kg/m^3) Thermal capacity c (J/K)	Var. Var. Var.
	Control of heat losses	Thermal transmittance	Thermal conductivity (adim.)	Var.
	Impermeability to gaseous fluids	Steam permeability	Vapor resistance factor (adim.)	Var.
	Thermal insulation	Thermal transmittance	Thermal conductivity (W/mK.)	Var.
Visual Comfort	Light absorption Luminous flux control	Light absorption	Absorption index (adim.)	Var.
		Light transmission	Transmission rate (adim.)	Var.
Auditory comfort	Sound absorption Soundproofing	Sound absorption Density	Absorption coefficient (adim) Volume mass (kg / m3)	Var. Var.
Healthiness of the air	Absence from the emission of unpleasant odors	Dynamic olfactometry	Metric odor unit ($O.U._E/m^3$)	Var.
	Absence from the emission of harmful substances	Potenz. of global warming Potenz. ozone reduction	GWP (kg CO_2 eq/ ton) ODP (kg CFC_{11} eq/ ton)	Var. Var.
	Impermeability to gaseous fluids	Steam permeability	Vapor resistance factor (adim.)	Var.
Hygienic environment	Non-hygroscopicity	Porosity Absorption Saturation	Open porosity φ (adim) Absorption coefficient A (adim) Saturation coefficient S (adim.)	Var. Var. Var.
	Asepsis	Porosity	Porosity n (adim) Index of voids e (adim)	Var. Var.
	Absence from the emiss. of harmful substances	Potential tropospheric O_3 formation	POCP (kg C_2H_4 eq/ ton)	Var.
	Impermeability to liquid fluids	Capillarity Freezing	Capillarity coefficient (kg / m2 min1 / 2) Risk of freezing	Var. Att.
Resource utilization	Control of intrinsic energy content	Energy embodied	PERT (MJ/ton) PENRT (MJ/ton)	Var. Var.
	Reduction of water content	Water embodied	FW (kg H_2O/ton)	Var.
Waste production	Recoverability	Potential material recovery	Coeff. recoverability (adim)	Var.
	Repairability	Potential material recovery	Coeff. recoverability (adim)	Var.
	Substitutability	Potential material recovery	Coeff. recoverability (adim)	Var.
	Reduction of pollutant emissions	Potent. soil water acidification Quantity of waste produced	AP (kg PO_4 eq/ ton) HWD (kg/ton) NHWD (kg/ton) RWD (kg/ton)	Var. Var. Var. Var.
	Durability	Useful life of the material	Duration (years)	Var.
Landscape protection	*Protection and enhancement of biological diversity*	Bioregionalism	Distance (km)	Var.
Socio-cultural protection	Protection and enhancement of local traditions	Use of traditional techniques Processing at local companies	Traditional construction technique Distance (km)	Att. Var.

Tab. 3 - Needs, requirements, indicators and parameters taken into consideration in the proposed method.

ronmental Product Declarations (EPDs): in this way the procedure can advance more quickly, and the information used is certified by a third party that guarantees its veracity (UNI EN ISO 14025:2010). Note that some parameters occur in more than one requirement; however, it should be noted that the score attributed to them depends precisely on the requirement to which they refer. For example, a high ‘vapor resistance factor’ will have a high ‘score’ in the ‘salubrious air’, where ‘closures’ are required not to allow external fluids to enter environments, while receiving a low score in the Thermal comfort, where it is preferred that indoor humidity is quickly disposed through the perimeter walls. This ‘programmatic redundancy’ should not give rise to surprise, because in the design activity the use of a datum that is repeated in itself in different contexts is recurrent (Mecca, 1991).

Secondly, the assessor must then determine the attributes expected in the model; some of these, like the ‘Risk of freezing’, are obtained in an objective way by subjecting the material to specific tests; for others, such as ‘the use of traditional techniques’, a ‘subjective’ assessment is required, but which must however comply with a specially developed protocol. By entering all the data in a special ‘software’, which is ideally structured as a dynamic spreadsheet able to update the evaluation by modifying the ‘weights’ of the individual needs or their classes, it is possible to interface the ‘database’ of the materials with a BIM program. In this way, the choice of the materials included in the design automatically generates a sort of Environmental Computation’ where the relative ‘EP_m’ performances, multiplied by the used quantities, return an estimate of the environmental impact of the materials of the entire building.

The proposed method, therefore, lies halfway between the multicriteria systems and the product environmental labels, deriving from the first the matrix and weight structure, and from the second both the parameters to be included in the evaluation grid and the LCA optics. In this way, the research has tried to make an evolutionary step in a direction common to the two systems: this is because – contrary to the ‘classic’ methods that designers use to have an environmental estimate of the building – in this case the evaluation of a product for which a specific knowledge of the entire production chain is required; product labels, controlled by third parties, allow for the collection of a reliable and verified data set. This path, even if defined in its methodology – borrowed precisely from the multi-criteria systems and the EPD label, will require further steps in the near future: it will be necessary to define the evaluation of the parameters related to the material put in place, and in particular to its maintenance, repair and disposal: these phases are in fact linked to the use with which the designer uses them.

Content interpretation through BIM interface – The need to use materials with high structural, energy and environmental performance, to design increasingly efficient, flexible and integrable technical and plant systems, to share information according to standardized and implementable parameters, represent the essence of the project and the built environment. The ideational and realization process of a work (architectural, territorial, infrastructural) involves, among other things, a number of actors proportional to the entity of the project itself, pushing the solutions identified towards a sustainable approach that also concerns the phases of management, operation, maintenance and possible future disposal. It is therefore necessary to compare oneself on the basis of a standardized language that allows everyone to extrapolate and/or modify and/or integrate specific information by managing, in fact, the entire life cycle of the building. A 'process' of development, growth and multi-criteria analysis capable of returning a 'different data model' of the work to the different scales that define it.

The BIM supports communication, cooperation, simulation, design and optimization of the work to be built or already built in a facility management perspective. A sort of 'revolution' that for decades has invested the construction sector through the evolution of the design elaboration process, with the transition from simple 2D and 3D visualization, to the management and sustainability of the building through all that concerns it. Stating the definition dictated by the European Community, «the BIM is a digital modeling process that deals with information relating to the commissioning, the design, the implementation of an intervention and the management of a work concerning a building or an infrastructure. It concerns processes and technologies in order to radically improve the results of the intervention for the clients, as well as the management of a work. BIM is a strategic facilitator for improving decision-making in relation to both buildings and public infrastructures during their entire life cycle. It applies, first of all, to orders and new construction procedures, as well as to the conservation, recovery, requalification and maintenance of the built environment, a fundamental aspect for the entire market» (European Community, 2017, p. 4).

With the BIM, in fact, it is possible to generate a 3D model of the work characterized by all the inputs and outputs that concern it and to which, in a dynamic way, different databases and software for the virtual modeling of the project are connected (from properties and certifications of materials, fluid dynamics, thermodynamics, structure, lighting, acoustics, economic-management computation, maintenance). All with the sole purpose of: i) increasing the productivity, the efficiency of the work and the effectiveness of shared choices; ii) reducing costs in the design and construction phases; iii) facilitating the subsequent management and maintenance phases of the work; iv) guaranteeing the easy reading and sharing of all the information, parameters and features that detail a specific work.

Important guidelines on the dissemination of BIM exist as rules, starting from the indications of the European Community and, in particular, on the progressive compulsory use of this 'strategic facilitator'. In fact, on behalf of the European Union Public Procurement Directive 2014/24 of 26 February 2014[3], Member States are invited to 'encourage, specify and/or impose' specific standards that ensure or increase interoperability between different technical formats. The objective is to promote measures that facilitate the use of up-to-date electronic information, reinforcing all those instruments able to easily access virtual databases and/or 'similar accompanying measures' and, at the same time, to define evaluation parameters for the rewarding requirements. In fact, as stated in Article 22, paragraph 4 «[...] Member States may require the use of specific electronic tools, such as electronic simulation tools for building information or similar tools [...]».

In Italy, with the New Code of Public Contracts[4], BIM definitively enters the debate oriented towards new methodologies and technologies at the service of the construction supply chain. The restriction on the use of the BIM method is defined by Ministerial Decree 560/2017[5] which «defines the methods and timing for the introduction, by contractors, of the granting administrators and economic operators, of the mandatory methods and instruments specific electronic devices, such as modeling for construction and infrastructure, in the design, construction and management phases of the works and related checks»[6], with particular reference to the so-called 'complex works'.

In this context, the need and capacity of the Contractors – and of all the operators in the sector – is configured to govern these electronic instruments, training the personnel[7], acquiring hardware and software for the management of decision-making, control and management. In this sense, important details and rules are collected in the regulatory framework of the UNI 11337:2017 Standard (Digital management of information processes of buildings), according to a principle of standardization of information, acquisition and exchange platforms, archiving codings and data analysis. While with the most recent UNI EN ISO 19650-1:2019[8] standard, recommendations are dictated concerning a conceptual framework for information management, which includes the exchange, registration, updating and organization for all actors. This rule is applicable to the entire life cycle of a 'fixed asset', including strategic planning, initial design, engineering, development, preparation of documentation for credit lines and construction, daily operating, the maintenance, renovation, repair and end-of-life.

Based on the regulatory indications and in line with the evolution of the digital system (IoT - Internet of Thinks and Industry 4.0), various 'interoperability platforms' have been developed and/or are being optimized, as well as various software that can be used and implemented within BIM, able to create 'connections' between organizations, companies, professions and the world of knowledge. The pioneer project in this sense is the national digital platform INNOVAnce (2014), which lasted only three years, which aimed to create the first national database containing all the technical, scientific and economic information useful to the construction supply chain, favoring the integration of all the subjects of the constructive process and eliminated all the misunderstandings that generate inefficiencies.

More current, the DigiPLACE research project, which sees Italy as leader and involves three European Ministries, is «[...] aimed at creating a digital platform conceived as a large 'warehouse' where it is possible to place an infinite number of materials and products for construction. The dimension is the virtual one, the language is digital, interoperable and open, to allow the consultation, the identification and the choice of any element by companies and designers» (Frontera, 2019a). And, again, reference is made to the 'new distributed platform' for SMEs and professionals, WebIM, funded by MIUR (Ministry of Education, University and Research), with the aim of enabling digital collaboration in construction, «synchronize and manage the processes, starting from the design phase, through the execution phase up to that of managing the work, also integrating monitoring over time» (Frontera, 2019b).

Finally, starting from the represented premises and from the citation of some important designs, we understand how the digitalisation of public contracts and the construction sector in general remains one of the strategic objectives for the building sector in Italy as in Europe. Current methodological practices tend to modify and improve, by simplifying and accelerating it, the relationship between organizations, companies, designers and technical operators thanks to the unique language that is emerging on several fronts (technical-regulatory-practical-performance), as well as configuring the need to encourage the training of new professional figures[9] able to manage these connections.

In this sense, we share the need to develop a standardized interoperability system able to link the different competences, the different involved subjects and the different phases of the project. It is necessary to identify a shared BIM oriented evaluation model that allows the parties to define the environmental performance of the technological project. «Each project is [in fact] an opportunity to test new tools and methodologies» (Pierotti, 2019) and, above all, a moment of implementation-management facilitation that knows how to intercept and make use of increasingly advanced and enabling technologies such as, for example, prototyping, immersive reality, construction robotics, 'agile' management models. In this sense, these assumptions can stimulate and encourage experimentation in the academic field, as well as the application of the BIM methodology also in the context of the requalification of the existing or of the valuable architectural heritage, of the designing and territorial planning, of the infrastructures of the 'end of life' of the buildings, supporting the designer – or the decision maker – in the choice of certified and guaranteed products, in view of a systemic and bio-regionalist approach.

At the same time, the manufacturing companies and building companies will be stimulated to provide all the technical-performance and economic details of a given material and/or component, with a view to increasingly updated and qualitatively selectable proposals. Finally, while noting a regulatory, technological and operational acceleration in the increasingly sophisticated development of the BIM methodology, a possible in-depth analysis could be represented by the implementation of the method, considering, for example, the phase of disposal of the building and the cataloging of its single material components and/or technological ones that can, among other things, re-enter the project cycle, implementing the already known seven levels of the building information process.

Fig. 1 - Next page. SKY-Tower Bietigheim-Bissingen *(2014-2016), Germany, designed by the KMB studio in Ludwigsburg through the use of the Allaplan Architecture software. A three-dimensional BIM model was created to facilitate collaboration between the various competences involved and to better study all parts of the building in relation to critical actions such as, for example, wind action and noise protection.*

In fact, the possibility of accessing a specific database similar to a 'warehouse' – of the aforementioned type – of the resulting materials that can be reused in the design/construction cycle of a new building, would open the way to greater awareness in the direction of sustainable and biocompatible design.

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NOTES

1) BREEM, LEED, ITACA and CasaClima are examples of 'multi-criteria' methods applied to the entire construction.
2) The requirements in italics have been reworked starting from what indicated in UNI 11277, those underlined are newly introduced, while the others are among those listed in UNI 8290. Among the indicators, Dynamic Olfactometry was taken from UNI EN 13725:2004, while Global Warming Potential, Ozone Reduction P., Tropospheric Ozone Transformation P., Material Recovery P., M. Repair P., M. Replacement P., P. of soil and water acidification, Incorporated energy, Incorporated water, and Quantity of waste produced, were taken from UNI 14020:2002.
3) See Directive 2014/24 / EU of the European Parliament and of the Council of 26 February 2014 on public procurement and repealing Directive 2004/18/EC. The first countries to implement these indications were those of Northern Europe, in particular the United Kingdom, the Netherlands, Denmark, Finland and Norway.
4) See Legislative Decree 18 April 2016 n. 50 – Contracts and concessions code. In particular, the art. 23 – Design levels for contracts, for works concessions as well as for services, paragraph 1), letter h) states the following: «The planning in the field of public works is divided, according to three levels of subsequent technical investigations, into project of technical and economic feasibility, final design and executive project and is intended to ensure: [...] the rationalization of design activities and related checks through the progressive use of specific electronic methods and tools such as building modeling and the infrastructures [...]».
5) See the Ministry of Infrastructure and Transport (2017), *Ministerial Decree No. 560/2017*. The Decree imposes a precise timeline on the mandatory use of the BIM method, indicating the following scheduled deadlines: (i) from 1st January 2019 for all those works for an amount equal to or greater than 100 million euros; (ii) from 2020 for complex works over 50 million; (iii) from 2021 for complex works over 15 million; (iv) from 2022 for works over 5.2 million; (v) from 2023 for works over 1 million; (vi) from 2025 for all new works. [Online] Available at: http://www.mit.gov.it/sites/default /files/media/normativa/2018-01/Decreto%20Ministro%20MIT%20n.%20560%20del%201. 12.2017.pdf [Accessed 12 Jenuary 2019].
6) See *Ivi*, art. 2 (Definitions).
7) See Standard UNI 11337-7:2018, *Construction and civil engineering works – Digital management of construction information processes – Part 7: Requirements of knowledge, skills and competence of the figures involved in information management and modeling*, which establishes the requirements related to the professional activity of the figures involved in the management and information modeling, in terms of knowledge, skills and competence according to the European qualifications framework

(EQF). [Online] Available at: https://store.uni.com/ [Accessed 12 January 2019].
8) The standard is addressed to all the actors involved in the design, implementation, management and operation of the work. It also emphasizes the importance of collaboration between the participants involved, in order to achieve high quality levels, reducing the risk of losses, contradictions or misinterpretations.
9) In this sense, the aforementioned UNI 11337-7:2018 standard regulates unregulated professionalism in information management and, specifically, proposes four professional profiles, three of which are known (BIM Specialist, BIM Coordinator, BIM Manager), and an unpublished fourth (CDE Manager).

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