INTERNATIONAL JOURNAL OF INTERDISCIPLINARITY IN THEORY AND PRACTICE
ITPB - NR.: 10, YEAR: 2016 – (ISSN 2344 - 2409)

BENCHMARKS DEFINITION: METHODOLOGY FOR ASSESSMENT OF ECONOMIC PERFORMANCE (MAEP-RB)

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Abstract: *Standard EN 16627:2015 was created to support the development of assessment methodologies for the economic performance of buildings, within the sustainability concept. It is based on a life cycle analysis where the impacts and aspects that allow characterization of the economic performance, but it does not have valorisation methods neither define reference values (benchmarks). The purpose of this paper is to present the benchmarks used for the normalization of the parameters of the hierarchic structure of a Methodology of Assessment of Economic Performance – Residential Buildings (MAEP-RB). This methodology implements a systematic and simultaneous assessment of the performance and economic sustainability of buildings.*

Keywords: Assessment, benchmarks, economic, life cycle, sustainability, building

1 INTRODUCTION

The European Standards framework developed by CEN / TC 350 "Sustainability of construction works", proposes a system for assessing the sustainability of buildings based on life cycle analysis (LCA). Based on LCA in the *before use* phase as defined in EN 15643-4:2012 [1] and EN 16627:2015 [2], a new approach has been developed for systematically assess the economic performance of a building within the concept of sustainability *(Methodology of Assessment of Economic Performance - Residential Buildings: MAEP-RB).*

The methodology follows the principle of modularity, where aspects and impacts that influence economic performance and building sustainability index during the *before use* phase, are assigned to the categories in which they occur. The hierarchical structure of the methodology directs the flow of information relating to aspects and impacts that influence the economic performance of the indicators, modules and stages of the life cycle, based on the quantification of the 65 parameters of the MAEP-RB methodology. The parameters provide accurate information for indicators from observable or measurable data from the project or existing building. In MAEP-RB, for assessing the economic performance in the *before use* phase, all parameters are expressed in monetary units, i.e. in euros. According to the hierarchical structure of the methodology and the flow of information therein defined, economic performance at the level of the indicators, of the modules and of the stages in the *before use* phase is obtained by direct aggregation, without any consideration of the results obtained in hierarchically lower levels. To obtain the sustainability index there is a need for normalization of all the values of the parameters and to develop a system of weights applied to the hierarchical structure. Normalization of parameters aims to set a dimensionless value that reflects the economic performance of the building under assessment in relation to the reference performance (benchmarks) It should be kept in mind that for some parameters "bigger is better" and for other parameters "bigger is worse" and, accordingly, the effects of scale in aggregate indicators should be prevented. The weighting system of the MAEP-RB methodology was assigned to all levels of the hierarchical structure, i.e. all the normalized values of the parameters, indicators, modules and stage. To determine the relative weights, it was used the tool AHP (Analytical Hierarchy Process) [3]. This paper aims to present the methodology and calculation of the reference values (benchmarks) of the 65 parameters of the hierarchical structure of the MAEP-RB methodology.

2 METHODOLOGY MAEP-RB

The MAEP-RB methodology was developed in order to allow the assessment of economic performance and the level of economic sustainability of a residential building during the design phase, based on the expected behaviour for the entire building life cycle. It is a modular approach for the compilation of information throughout the building's life cycle including the four phases of the life cycle of a building: *before use* phase, *use* phase, *end of life cycle* phase and *beyond life cycle* phase. Each phase of the life cycle is divided into stages, modules, indicators and parameters. For the moment, MAEP-RB is developed only for the before use phase. The object of assessment is the building, including its foundations and landscaping within the building perimeter [4]. Table 1 shows the hierarchical structure of the method (stages, modules, indicators and parameters) that correspond to the *before use* phase. At each level, information is obtained by aggregation of information at the lower level. For example, each of the twenty-one economic indicators (Level 3, indicators A0.1 to A0.2, A1.1, A2.1, A3.1, A4.1 to A4.2 and A5.1 to A5.14) is estimated by aggregating the results of one or more parameters (Level 4, parameters P1 to P65), following the hierarchical structure presented in Table 1.

Table 1 Stages, modules, indicators and parameters of the MAEP-RB Methodology [5]

Level 1 Stages	Level 2 Modules	Level 3 Indicators	Level 4 Parameters
Pre-construction stage	A0:site and associated fees and counselling	A0.1: cost of purchase and rental incurred for the site or any existing building.	P1: costs with the site P2: imt - municipal tax on onerous transfer of property P3: is - stamp tax
		A0.2: professional fees related to the acquisition of land.	P4: costs related to real estate P5: costs of viability studies P6: costs of legal support P7: costs related to the notary fees P8: costs related to the land registry fees
Product Stage	A1:supply of raw materials	A1.1: cost of raw materials.	P9: percentage cost of each type of material used
	A2:transport of raw materials	A2.1: cost of transportation of raw materials.	P10: percentage cost of each type of material used
	:manufacturing	A3.1: cost of transformation raw materials.	P11: percentage cost of each type of material used
Construction process Stage	A4:transport	A4.1: cost of transport of materials and products from the factory gate to the building site	P12: percentage cost of each type of material used
		A4.2: cost of transport of construction equipment such as site accommodation, access equipment and cranes to and from the site.	P13: percentage of the cost of the building site
	A5:construction-installation process	A5.1: costs with exterior works and landscaping works.	P14: cost for the earthmoving work P15: cost of support structures and sealing P16: cost concerning pavements P17: cost relative to hydraulic networks P18: cost related to outdoor lighting P19: cost related to recreational equipment P20: cost of sowing and planting
		A5.2: cost of storing products including the prevision of heating, cooling, humidity etc.	P21: percentage of cost for each type of material used
		A5.3: cost of transportation of materials, products, waste an equipment within the site.	P22: cost of equipment related to the achievement of the subcomponents of the building
		A5.4: cost of temporary works including temporary works off-site as necessary for the construction.	P23: cost construction site percentage of the total value of direct costs
		A5.5: cost on site production and transformation of a product.	P24: cost of hand labor P25: cost of equipment P26: cost of fuel P27: cost of water
		A5.6: cost of heating, cooling, ventilation, humidity contro etc. During the construction process.	P28: cost of equipment P29: cost of electricity
		A5.7: cost of installation of the products into the building including ancillary materials.	P30: cost of hand labor P31: cost of equipment P32: cost of auxiliary materials
		A5.8: cost of water used for cooling, of the construction machinery or on-site cleaning.	P33: the cost of cooling water and cleaning
		A5.9: cost of waste managing processes of other wasters generated on the construction site (RCD).	P34: cost of the screening process of RCD P35: cost of packaging of RCD P36: tax amount
		A5.10: transportation cost of waste RCD.	P37: cost of transporting the RCD
		A5.11: costs of commissioning and handover related costs.	P38: cost of the extension of domestic wastewater sanitation. P39: cost of the extension of sanitation storm water P40: cost of extension of water supply P41: cost of extension of electricity P42: cost of extension of gas supply P43: cost of extension of telecommunication P44: cleaning cost
		A5.12: cost for professional fees related to work on de project.	P45: fees of the project team P46: fees of the inspection team P47: fees the technical director P48: fees of the health and safety at work team
		A5.13: costs of the taxes and other costs related to the permission to build and inspection or approval of works.	P49: value of the license fee projects P50: value of building permit fee P51: exchange certifications gas project P52: certification fee thermal design P53: certification fee of electrical design P54: rate design verification of fire safety P55: certification fee of telecommunications project P56: national health service project certification fee P57: certification fee of the gas network P58: rate of energy certification P59: certification fee electricity grid P60: certification fee telecommunications network P61: rate survey of municipal services P62: rate survey of the firefighters P63: survey national health service fee P64: vat rate
		A5.14: incentives or subsidies related to the installation.	P65: value of the incentive

The assessment of the economic performance of the before use phase is by obtained the aggregation of the results of each stage of the building's life cycle (Level 1). The parameters (CPis) are quantified by data obtained directly from the "building record" or "building database" evaluation generated by the methodology support software based on "general database" of MAEP-RB in accordance with the calculation process shown in Figure 1.

The assessment of economic sustainability with assignment of a sustainability index for requires the standardization of parameters and the definition of a system of weights for the hierarchical structure of the MAEP-RB methodology.

The normalization and weighting system enables the integration of this methodology in assessing the sustainability of buildings in which they are jointly evaluated the economic, social and environmental dimension, with allocation of sustainability indexes individually for each dimension and/or global.

The weighting system applied the hierarchical structure of the methodology defined by the application of Analytic Hierarchical Process (AHP) and presented in a previous article [5]. The weighting system of the MAEP-RB methodology was assigned to all levels of the hierarchical structure that is all parameters, indicators, modules and stage are relative weights assigned. Knowledge of the relative weights allowed determining the overall weight and to clarify the influence of a parameter, an indicator of a module or a step in the sustainability index obtained for the building at the *before use* phase. This information, when available in the design phase, is of the utmost importance, as it will serve as a guide for the design team, in order to improve sustainability, because there are parameters that have more influence on the final assessment than others.

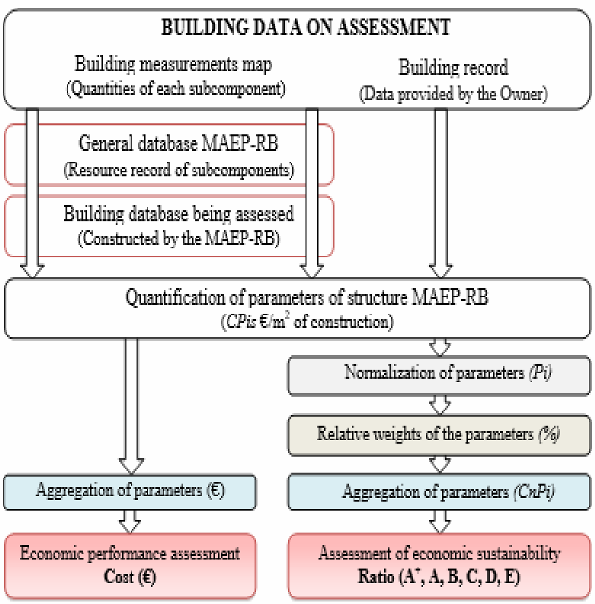

Fig. 1 Application procedure of the method MAEP-RB

The results of the assessment of economic performance and economic sustainability are broken down into multiple levels, namely the level of the *before use* phase of the building's life cycle, each stage of each module and each economic indicator. As the MAEP-RB assesses performance and economic sustainability of buildings, the result of economic performance is expressed in monetary unit and the sustainability of an economic sustainability index (A^+, A, B, C, D, and E). It allows also to make an analysis of the normalized value of each particular parameter.

3 NORMALIZATION

Normalization of parameters aims to set a dimensionless value that reflects the building's performance assessed in relation to the reference performance (benchmarks) CPic (Cost of conventional practice) and CPim (best practice cost) defined for each of the parameters hierarchical structure of the methodology.

The MAEP-RB methodology allows to perform a sensitivity analysis of the normalized values of the parameters, indicators, modules and stages, not limited to display their contents. More importance is given to the analysis of normalized values, because they reproduce the design options and determine the course of the outcome of the assessment of economic sustainability.

Knowledge of these values already in the design phase allows designers to adopt design solutions that can achieve a certain goal in economic sustainability in the before use phase, eliminating or reducing all design solutions that contribute to normalized values of the worst parameters. In the standardization process Equation 1 was used to normalize the indicators [6]:

$$CnPi = \left(\frac{CPis - CPic}{CPim - CPic} \right) \quad (1)$$

Where:

CnPi = Pi parameter normalization of results;

CPis = Project solution cost (€/m2 of building area).

CPim = best practice cost (€/m2 of building area).

CPic = Cost of conventional practice (€/m2 of building area).

As can be observed in Figure 2 the normalization of a parameter is just determining a percentage between two "distances", that is, between the "distance" separating the solution cost to the cost of conventional practice (CPis - Cpic) and the "distance" that separates the cost of the best practical to the cost of conventional practice (CPim - Cpic), that is, the distance between the benchmarks Pi parameters.

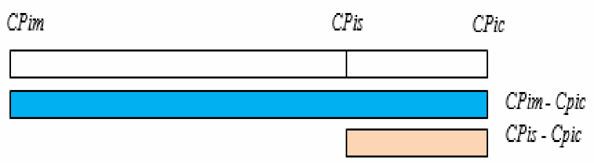

Fig. 2 Graphical representation of normalization

In Equation 1, CPim and CPic are the benchmarks i parameter, and respectively represent the levels of best practice and conventional practice. Their use converts the value of the parameters in a dimensionless scale, where the value 0 corresponds to the level of conventional practice and the value 1 to the level of best practice. Should the performance parameter be greater than a best practice or lower than the conventional practice, the normalized value of the parameter will take, respectively, a value greater than 1 and less than 0. In any case, in order to avoid distortions in the aggregation of parameters / indicators, normalized values should not be smaller than -0,2 or bigger than 1,2.

To facilitate understanding of the results obtained, the normalized values are converted to a qualitative scale, graduated from "E" (lowest economic sustainability) to "A+" (bigger economic sustainability), using the equivalences shown in Table 2. In the qualitative scale presented, "D" index corresponds to conventional practice and the "A" to the best practice. The conversion range of normalized values used in the MAEP-RB methodology presented in Table 2 was adopted from SBToolPT system. The scale thus assumes a linear evolution in building performance between the index "D" and "A". This methodology considers that a building with performance up to 10% higher than the conventional practice has a similar economic performance to a conventional.

Table 2 Conversion of the standard value of a qualitative evaluation scale [7]

Qualitative scale	Value normalized
A^+	P> 1,00
A (Best practice)	0,70 <P ≤ 1,00
B	0,40 <P ≤ 0,70
C	0,10 <P ≤ 0,40
D (Conventional practice)	0,00 ≤ P ≤ 0,10
E	P <0,00

3.1 Definition of CPis - Application MAEP-RB

Bearing in mind the importance that the definition of 65 parameters (Pi) and their values (CPis) have in assessing the performance and economic building sustainability, there is a strong connection to the building under assessment in order to provide accurate information to each parameter (Pis). Therefore, each building under assessment is divided by the level of resources necessary for its materialization, and the data registered in the building database that contains all the information required for accurate determination of the parameters, ie the quantities and unit costs for each resource (such as water, cement, sand, bricks etc.). This database is constructed with use of the software developed for the methodology, after the introduction of data contained in the building measurements map evaluation.

The building database and the elements in the building record contain all the information needed to completely quantify the 65 parameters, and individual quantification of each parameter (CPis) conducted using the methodology.

Costs associated with A0 module (Site and associated fees and counselling) will be obtained directly from the "building record" that contains information provided by the Owner and are, therefore, treated as values that are always negotiated between the Owner and others, because they are extremely subjective: Costs with the site (CP1s); IMT - Municipal tax on onerous transfer of property (CP2s); IS - Stamp tax (CP3s); Costs related to real estate (CP4s); Costs of viability studies (CP5s); Costs of legal support (CP6s); Costs related to the notary fees (CP7s); Costs related to the land registry fees (CP8s). The costs associated with modules A1-A3 (A1: Supply of raw materials, A2: Transport of raw materials, A3: Manufacturing) and A4-A5 (A4: Transport, A5: Construction- installation process) are determined by the software developed for the methodology using the building database.

The CPis calculated values of A0 module do not depend on the materials and constructive solution, while the A1-A3 and A4-A5 modules are dependent on the materials and the constructive solutions adopted in the project assessment.

3.2 Definition of CPic and CPim benchmarks

Since there are no reference values (benchmarks) for the economic sustainability of buildings, it can be extremely difficult to find representative benchmarks for the 65 parameters of the MAEP-RB methodology. Definition of these values was carried out based on the actual costs observed in buildings already built and constructed by conventional methods. The values are expressed in Euros per square meter of construction (see Table 3). The results were defined for the Portuguese conventional practice. The value calculated as best practice it was considered an improvement, that is, a reduction in the cost per square meter by 75%. In defining the benchmarks, the following criteria were considered:

- Conventional practice - costs (CPic) for the construction of residential buildings, using materials, technologies and conventional construction processes based on compliance with regulations and standards of construction of residential buildings in the Portuguese context.

- Best practice - costs (CPim) for the construction of residential buildings using the materials, technologies and construction processes that promote a reduction of 75% in costs, as compared to conventional practice, in order to comply with regulations and rules of the residential buildings construction in the Portuguese context.

Table 3 Reference Values (Benchmarks)

Pi	**CPic (€/m^2)**	**CPim (€/m^2)**	**Pi**	**CPic (€/m^2)**	**CPim (€/m^2)**	**Pi**	**CPic (€/m^2)**	**CPim (€/m^2)**	**Pi**	**CPic (€/m^2)**	**CPim (€/m^2)**
P1	116,91	77,94	*P17*	11,36	2,84	*P33*	2,73	0,68	*P49*	5,80	1,45
P2	0,00	6,26	*P18*	8,36	2,09	*P34*	2,98	0,75	*P50*	33,68	8,42
P3	0,00	0,77	*P19*	12,54	3,14	*P35*	1,09	0,27	*P51*	4,20	1,05
P4	5,78	0,96	*P20*	10,85	2,71	*P36*	0,55	0,14	*P52*	6,35	1.59
P5	5,79	0,96	*P21*	4,05	1,01	*P37*	0,93	0,23	*P53*	6,46	1,62
P6	2,89	0,96	*P22*	5,82	1,46	*P38*	1,35	0,34	*P54*	4,25	1,06
P7	0,09	0,06	*P23*	70,34	17,59	*P39*	1,30	0,33	*P55*	6,25	1,56
P8	0,12	0,09	*P24*	130,26	32,57	*P40*	1,23	0,31	*P56*	6,38	1,60
P9	61,00	15,25	*P25*	18,35	4,59	*P41*	1,64	0,41	*P57*	10,25	2,56
P10	83,00	20,75	*P26*	13,35	3,34	*P42*	1,23	0,31	*P58*	25,69	6,42

As can be observed in Table 3, the CPic and Cpim defined reference values are, for example, for the parameters:

- P24: Cost of hand labour (CP24c=130,26 €/m2, CP24m=32,57 €/m2).
- P25: Cost of equipment (CP25c=18,35 €/m2, CP25m=4,59 €/m2).
- P26: Cost of fuel (CP26c=13,35 €/m2, CP26m=3,34 €/m2).
- P27: Cost of water (CP27c=6,30 €/m2, CP27m=1.58€/m2).

4 CONCLUSIONS

Quantification of the 65 parameters of the MAEP-RB methodology and the respective normalized values are decisive in assessing the performance and economic sustainability of buildings. As all other levels of the hierarchical structure of the methodology (indicators, modules and stage) are dependent on these, they are obtained by aggregation of the respective lower level.

The normalized values of the parameters (CnPi), are strongly influenced by CPic anf CPim reference values of each parameter and determine the evaluation result of the economic sustainability of the building. The development and improvement of CPic and CPim reference values for each parameter are of the highest importance for assessing the economic sustainability of buildings. This improvement is only possible through the implementation of MAEP-RB methodology to real cases, obtaining necessary information for the feedback loop of the reference values.

The relative weights system defined for MAEP-RB methodology allows determining the overall weight, that is very useful in comparative studies of economic sustainability of buildings, since it clarifies how the sustainability index for the building at the before use phase is influenced by a parameter, an indicator, a module or a step. This information, when available in the design phase, is of the utmost importance, as it will serve as a guide for the design team, to improve sustainability, as there are parameters with bigger influence on the final assessment than others. Designers can adopt design solutions in order to achieve a certain goal of economic sustainability in the before use phase, improving all design solutions that contribute to normalized unsatisfactory values of parameters.

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