Dynamic Facility Condition Index calculation for asset management

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Abstract. Aim of this research is to investigate the possibility of dynamically computing the Facility Condition Index (FCI) using a database of maintenance operations and costs of fabric and services components. This would lead to an instrument able to support decision making during asset and portfolio management because FCI is widely considered a good indicator for monitoring assets and portfolios conditions; so being able to efficiently calculate and update it is fundamental for a proper asset management. There are many ways to benchmark assets condition, but most of them are qualitative and lead to ratings in percentage, that need to be further elaborated to be connected to annual OM&R costs. The FCI can be considered an economic rating, based on money paid for maintenance, repair and replacement performed over the current asset value. The objective is to make an appraisal of the maintenance costs in a dynamic way, so to be able to examine multiple scenarios and make forecasts; the facility value comes from market appraisals with some coefficient applied, if need be. This calculation procedure, together with a maintenance operations and costs database developed by the authors (either forecasted or real costs), can be used by asset managers to support decisions about maintenance and repair actions to be undertaken. This paper shows preliminary results of this research, with the help of a case study. Further correlations should be investigated, even if this calculation procedure leads to an effective management. The calculation procedure and the database organization are an original work of the authors, as well as the case study used to show the results. In addition to this, connections among the indicators provided and BIM (Building Information Modelling) models are analyzed.

Introduction

Most of the times, excluding operations needed to correct severe damages to an asset (e.g. water leakages, detachments, structural problems, etc.), maintenance operations and refurbishments are planned on an economic basis, looking at minimizing costs, both initial and during asset life, as exemplified e.g. by Ferrara *et al.* [1]. This is the reason why the FCI can be considered a reliable indicator to guide asset managers through their choices at the portfolio level.

Authors previously worked on the development of some condition indexes able to benchmark assets and portfolios current physical state and documents situation [2,3]; these Key Performance Indicators (KPIs) could help in the definition of the maintenance operations to be performed and in the appraisal of the market value. These KPIs have been also connected to maintenance operations lists targeted to the main components [4], so to allow users to define a set of operations to be done to restore the problems detected.

Previous works showed the necessity of connecting indicators related to assets condition to economic values, so to provide the basis for budget allocation and maintenance operations planning.

Context. This research can be included in the framework provided by the Annex B of the ISO 55000:2013 [5] related to asset and portfolio management, precisely in the part related to "Performance evaluation and improvements".

Even considering a wide portfolio, it is difficult to talk about "big data", which are characterized by a high acquisition frequency (e.g. sensors sending constant flux of data each minute or less), but nevertheless asset managers are asked to deal with many data, coming from different sources in different formats; so they are currently in strong need of instruments able to deal with current data sources, elaborating synthetic indicators to support their decisions, with an easy-to-use interface.

Research methodology. This research is part of a wider work, started with the definition of some indicators related to buildings degradation and documents consistency, then followed by the definition of procedures and tools to calculate maintenance costs connected to planned and corrective operations.

This papers presents, after a brief state of the art related to main topics held in the paper, a reliable and objective way to calculate the FCI and to evaluate some different scenarios, so to support asset managers' decisional process. A case study is used to demonstrate the applicability of the developed procedures and tools and to show the main steps to be followed.

State of the art

Asset managers are frequently asked to make decisions without having the clear picture of their portfolio; this could be due to the lack of knowledge regarding assets (and their components) physical condition. The FCI could be a good starting point to objectively assess the physical health of an asset, providing a reliable basis for decision making.

This chapter contains a brief state of the art related to the main topics held in this paper, so to provide a context for this research.

Asset management. Decision making is considered a relevant theme in many research sectors: business, health, construction and in general wherever is required to make a decision – there are more than 10'000 results for each sector in the ScienceDirect database [6]. According to a definition given by BBC [7] and related to the business sector, "decisions are part of the remit of managers. Difficult choices may have to be made for the common good of the organization.". In the AEC sector, asset management is turning more and more from a technical to a managerial activity, looking for aggregated data enabling decision at an high level. According to the BBC [7], there are three types of decisions, from simple to complex: (1) "strategic decisions: long term, complex decisions made by senior management. These decisions will affect the entire direction of the firm. An example may be to become the market leader in their field; (2) tactical decisions: medium term, less complex decisions made by middle managers. They follow on from strategic decisions and aim to meet the objectives stated in any strategic decision. For example, in order to become the market leader, a firm may have to launch new products/services or open new branches; and (3) operational decisions: day to day decisions made by junior managers that are simple and routine. This could involve the regular ordering of supplies or the creation of a staff rotation schedule."

Strategic decisions, both in business and in the construction sector, must be based on reliable data, summarized in some KPIs. This because the senior management cannot make their decisions based on raw and sparse data, useful for day-to-day decisions but not for planning long term activities. This concept is reported also by the UNI EN 15221-1:2007 [8], which divides the Facility Management in strategic (processes), tactical and operational (activities), with KPIs to control assets and service levels. Objectives, activities to be performed and KPIs to be provided are listed in the ISO 21504:2015 [9]. These objectives, to be decided in advance by the portfolio manager, can be summarized in: (1) ensuring that investment in portfolio components is aligned with the organization's strategy and risk tolerance; (2) optimizing organizational capability and capacity; (3) maximizing benefits from investment; and (4) identify and manage stakeholders' interests.

Facility Condition Index. The FCI has been developed by the US Navy to assess the condition of vessels and strategically prioritize renewal spending; its use in the building sector dates back to the early 1990s [10]. The FCI has been then used to analyze the condition of large portfolios, like for schools [11]; Roberts [11] also highlighted the importance of the connection of the FCI with indicators measuring students' learning performance. This connection is really relevant, especially now that many studies [12,13,14] on learning performances, together with sustainability and energy optimization, brought innovations in schools, like: new spaces and functions aggregation (e.g. open spaces), different uses of the schools out of the learning hours (e.g. as civic centers) and, more in general, energetic and functional retrofit strategies to cut costs and environmental impacts on the life cycle.

Even as a stand-alone indicator, the FCI is used since many years to assess the plant replacement value [15], so to decide if the system is worth to be replaced or not.

Another index, the Building Condition Index (BCI) can be used to perform scenario analysis, looking at run-to-failure versus the best maintenance practice [16]; the connection among BCI, FCI and other condition indexes developed by the authors could bring an improvement in the field of Building Condition Assessment (BCA), so providing more reliable data for maintenance management.

Lavy [17] showed the importance of using the FCI to analyze different scenarios, so to provide year by year the forecasted expenditure for maintenance operations. Despite the importance of the FCI over the years, Fagan and Kirkwood [18], together with Teicholz and Edgar [19], highlighted an issue that is still actual, even after 20 years: the FCI can be used in the process of assessing a facility, but it is frequently not well integrated into current Computerized Maintenance Management Systems (CMMS) or Computer-Aided Facility Management (CAFM) software. FCI assessment, even if considered relevant, is frequently left apart respect to the scheduled FM activities, seeking help of an external professional only when needed; this leads to an occasional use of these instruments, less useful for managing decisions. They also highlighted a possible connection with building adaptability, as defined by Kincaid [20], which assessment could be a good indicator if a fabric or service component should be replaced, maintained or improved.

The FCI, in essence, is the ratio between the sum of building components repair and improvement needs and the sum of building components replacement value [21]. This value can be calculated for the single component (eq. 1), but the sum at the component level (eq. 2) and at the building level (eq. 3) provide the whole situation, more useful for the comparison at the portfolio level, necessary to guide strategic decision making.

$$FCI^{single\ component} = \frac{\sum_{i=1}^{n} C_i^{repair} + \sum_{j=1}^{m} C_j^{improvement}}{\sum_{k=1}^{l} C_k^{replacement}} [\%] \tag{1}$$

$$FCI^{component} = \sum_{c=1}^{o} FCI_c^{single\ component} [\%] \tag{2}$$

$$FCI^{building} = \sum_{d=1}^{p} FCI_d^{component} [\%] \tag{3}$$

As said before, these values can be used to compare different asset at the same time and to compare the same asset at different times [22]. The result of the calculation is usually divided [10] in 3 to 4 steps in a qualitative scale: (1) good: 0%-5%; (2) fair: 5%-10%; (3) poor: 10%-30%; and (4) critical: >30%. This scale can be slightly changed according to type and condition of the assets under assessment. Eventually, the FCI at the building level is influenced by the quantity of components inspected, as the FCI analysis could be performed gradually, without checking all the components at once; this leads to the need of carefully understanding the object of the comparison before making important decisions.

Dynamic FCI calculation

The idea behind this research is to provide procedures and tools to support asset managers in making their decisions. Fig. 1 contains a scheme of the main topics held in this work; the aim is to provide users with all the data about building condition, which can be summarized in: (1) maintenance operations performed; (2) synthetic indicators about building condition (e.g. degradation, obsolescence/ageing, market value); and (3) synthetic indicators about maintenance (e.g. FCI).

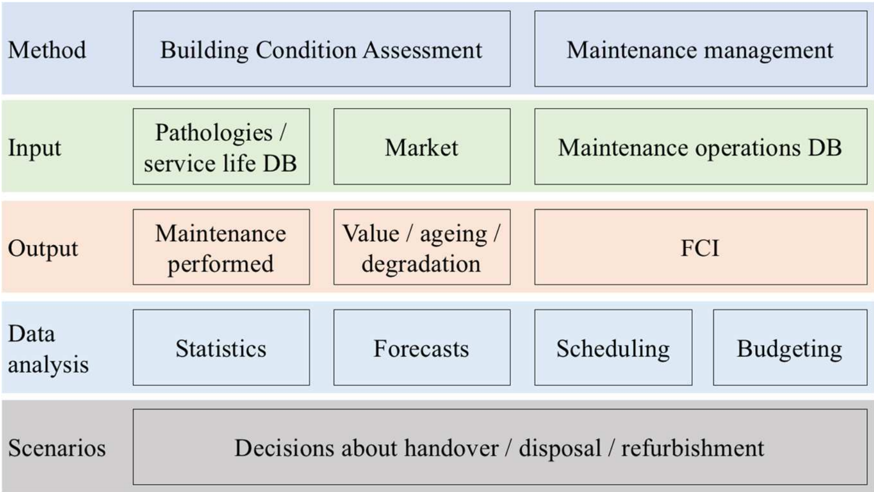

Fig. 1: Scheme of the research

The procedures developed are based on a set of tools and documents, which include: (1) work breakdown structure of major building (fabric and services) components; (2) list of reference service life (RSL, according to ISO 15686-8:2008 [23]); and (3) list of corrective and preventive maintenance operations associated to each component pathology.

Aim of this paper is to describe only the part of the process related to use and calculation of the FCI and its relation with the other condition indexes developed. In Fig. 2 the main steps to follow for the FCI calculation are described: (1) building survey is mandatory to assess the condition with a standardized BCA procedure based on diagnostic forms filling; (2) according to the condition (pathologies and old components), the list of corrective maintenance operations to be performed is defined; (3) this list is the basis for the calculation of the FCI at different levels (e.g. technological units and building); (4) the indicators provided can be used by the management to decide, as instance, which assets is worth to be maintained first and how much budget is required.

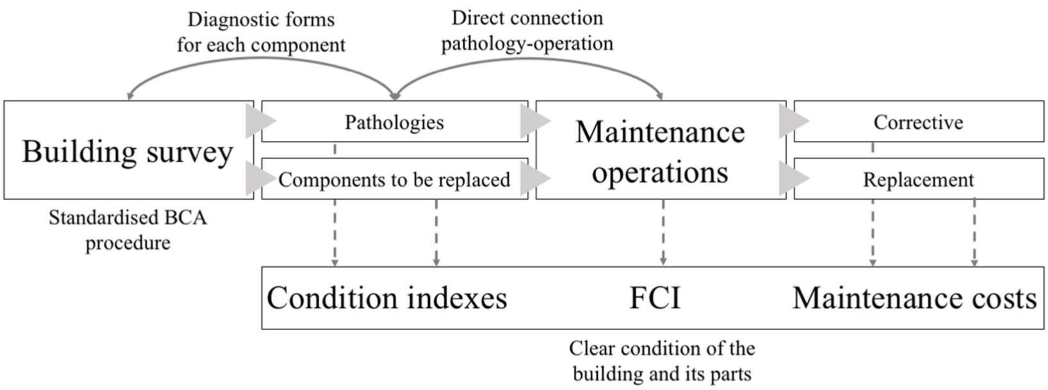

Fig. 2: Main steps for FCI computation

The steps described in Fig. 2 are partially automated, first of all because this research does not involve the development of a software and subsequently because not all the main passages could be automated: the user (a competent professional) has to decide if a component needs to be either replaced or restored, while the system is made to suggest the operations connected to the pathologies encountered.

In this paragraph, the FCI, intended as an economic indicator of the asset condition, has been always presented together with qualitative indicators, like the condition indexes; this is due to the fact that the FCI could be influenced by the components typology and maintenance costs. An example is provided by services small components, like valves, pumps, fan coils, etc., which have a low restoration/replacement cost (compared to the entire system cost), but they are critical for the correct functioning of the building; an anomaly in these critical components could not be highlighted by the only use of the FCI, which should be checked in comparison with building condition indicators and the related restoration/replacement costs.

Calculation procedure. The calculation procedure consists mainly in the summation of the costs related to the operations required to restore the components correct functioning, aesthetics and performances. Obviously these costs are strictly related to the maintenance operations to be carried out, which can vary according to technology, quantity, condition, building location and function.

The user demanded to calculate the FCI at the building level must perform the following steps:

1. to define number, type and condition of all the components to be inserted in the analysis;
2. to define the operations (repair, upgrade or replacement) associated to each of the components analyzed;
3. to define the costs connected to the selected maintenance operations;
4. to calculate the FCI at different levels, as instance at the building level and at the technological units one (e.g. to understand the FCI of the heating system or the HVAC);
5. last optional step, is to make an appraisal of the index, making a forecast of the maintenance costs in the future years, so to understand, with different scenarios, possible strategies.

This assessment could be incremental, acting first on the most critical components and zones (e.g. roof, services, public areas, etc.), and then on the rest of the components (e.g. finishing, façades, external zones, etc.). BCA on an ongoing basis is considered a reliable and effective source of information [24] and it allows to plan the assessment during inspections over the year, instead of performing the activity all at once.

The innovation of this research does not belong to the calculation procedure itself, which follows the steps provided by the literature and neither in the qualitative scale in which the results are classified; the turning point, described in the next paragraph, relays on the fact that the FCI calculation procedure is included in an process of asset management, going from scheduled building surveys to the acquisition of data about pathologies, maintenance costs and economic indicators.

Instruments and tools. Developing an asset management software or tool is not part of this research, which aims at investigating possible benefits of the use of the FCI, together with other indicators, in the management of existing assets. Notwithstanding this, authors created some instruments allowing to manage calculation and decision processes and to demonstrate the applicability of the work in real applications. Among instruments and tools developed, here there are the most important: (1) list of pathologies, divided by components and technological units; (2) list of operations, divided in corrective and preventive and associated to each component of a defined WBS; (3) costs associated to each of the previous operations; (4) connection (one to many) of each operation to the pathologies that correct; and (5) a simple algorithm to semi-automatically associate the operations to be done to a component, to calculate corrective and planned maintenance costs.

Costs associated to maintenance operations are taken from a regional price list [25], but they can be updated to meet the requirements of other regions or Countries; on the opposite, pathologies and WBS components can be considered valid at the international level. Various lists and connections, together with the connections among them, have been inserted for a better handling, in a relational database, from which, time by time, data are extracted according to the needs.

The tools developed could be advantageously connected, or inserted, in CAFM (Computer Aided Facility Management) software, to solve a problem that affect them since many years: facility and asset managers claim for more integrated software, able to deal with daily activities (space management, cleaning, bills, etc.), but also able to perform calculations at an higher level, providing KPIs to support decision making processes. This integration should be developed with an wider view of the topic, looking as instance at the major themes currently addressed by academies and private companies [26].

Another relevant integration of the FCI inside the FM processes is provided by the use of BIM (Building Information Modelling) [27]. The use of BIM is still not consolidated in the FM sector, probably because it requires in the beginning a strong effort in terms of models productions and reorganization of the processes, but the potential is great; it is sufficient to think about the direct connection of the FM attributes to the objects in the model (geo-localized and connected to historical data), the augmented reality and the possibility of having an up-to-date as-built model to use in the preparation of tenders and contracts.

In this paper, as it does not aim to investigate the use of BIM in the FM field, the model is considered as an instrument from which extract data useful for the calculation, but the integration with the database could reach deeper levels, using it as a repository of information during the building use phase. Another useful application of BIM for FM, and especially for KPIs calculation, is to use web applications (on mobile devices) connected to the model to support the surveys on site. In the scheme of Fig. 3 the connections among the developed KPIs, CAFM software and BIM are outlined.

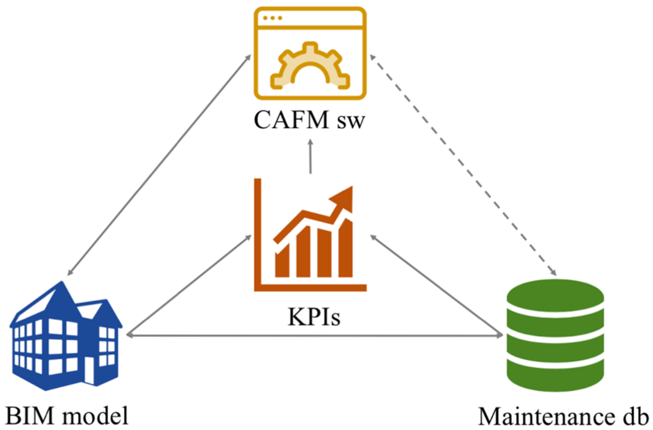

Fig. 3: Relationship among BIM, CAFM software and the proposed KPIs and instruments

The relationships outlined in the scheme of Fig. 3 will be object of a wider research; the dashed line means that, depending on managers' and clients' needs, there will be only an exchange of synthetic data (the KPIs) or also of the raw data (maybe for a more complex life cycle analysis).

In the next chapter, with the help of a case study, calculation procedure, instruments and tools presented will be used to demonstrate the feasibility of this process.

Case study

This chapter provides an application of the procedures explained above, with the aim of demonstrating their effectiveness in real world applications. In the next paragraphs case study, calculations performed and results are presented.

School building. The building is a primary school built in the 1946 with approximately 400 users (students, teachers and administration), two floors (classrooms mainly, services and few offices), one underground (canteen, storage and some rooms dedicated to laboratories), around 3'600 m^2 heated with radiators (no cooling). The structure is made of reinforced concrete, the envelope of clay bricks with plaster finishing, wooden windows with single glazing, internal partitions of clay bricks and slabs with hollow clay blocks; in essence a typical Italian school, both for shape and technology used.

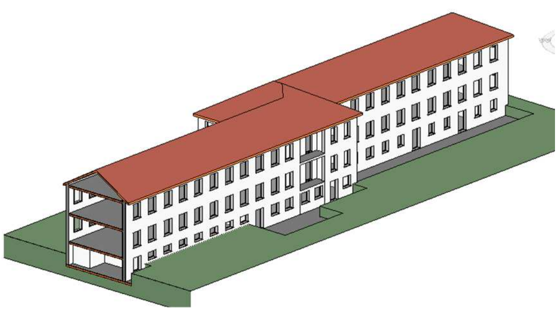
Fig. 4: BIM model of the case study

Fig. 5: Maintenance operations in the database linked to the BIM model

To perform the calculations a BIM model with a low level of detail has been created (Fig. 4); this model contains the main fabric and services components and the spaces (useful for other analysis). The relational database of Fig. 5, developed in Microsoft Access, contains the quantities, coming from the model thanks to the use of the Autodesk Revit plugin DBlink, and the data about maintenance operations and costs.

About the physical condition of the asset, 26 high-criticality pathologies have been found, with also many components with an Actual Service Life (ASL) over the Reference one (RSL), calculated according to the ISO 15686-8:2008 [23]. In essence, building envelope and interior finishing either need to be restored or refurbished; the services do not need urgent maintenance.

Calculation. It is now possible to connect the operations to be done to the components in the BIM model (Fig. 5); this passage is not fully automatized because only the professional can decide what is the right operation to be done – a system fully automated could lead to potentially wrong results. Anyway, the tool suggests to the user a limited panel of options that can be chosen.

The operations have been associated to prices coming from the Milan price list 2014 [25], which has been divided in macro-categories associated to each component, so to have a quick listing of the possible prices connected to each operation. The total cost for corrective maintenance is 264’677€, which means approximately 74€/m^2 or 661€/student. Indirect and general costs are excluded from this cost analysis. This expense could be divided in more years, as instance the façade is more urgent, so it should be done first, and then the rest. To be noticed that cleaning was not included among the costs as the client has a specific contract for these kinds of activities.

Table 1: Maintenance costs of the case study and FCI

TU	Comp	Pathology	Maint. type	Synthetic description	UoM	Quantity	Unitary cost	Total cost [€]	Unitary replacement cost [€]	Total replacement cost [€]	FCI
Opaque envelope	Plaster	Crumbling	Partial replacement	Localised restoration of the damaged surface	m^2	2955	24.43	72,191	38.81	114,684	63%
Opaque envelope	Plaster	ASL>RSL	Complete replacement	Complete repainting	m^2	2955	12.21	36,081	12.21	36,081	100%
Transp. envelope	Metal doors	Finishing degradation	Partial restoration	Finishing renovation	m^2	16	13.42	215	266.44	4,263	5%
Transp. envelope	Metal doors	-	-	-	m^2	64	0	0	266.44	17,052	0%
Transp. envelope	Wooden windows	ASL>RSL	Complete replacement	Complete replacement of the window	m^2	524	201.81	105,748	269.44	141,187	75%
Transp. envelope	Wooden louvers	ASL>RSL	Complete replacement	Complete replacement of the louvers	m^2	524	72.98	38,242	90.81	47,584	80%
Transp. envelope	PVC louvers	ASL>RSL	Complete replacement	Complete replacement of the louvers	m^2	137	72.98	9,998	90.81	12,441	80%
Transp. envelope	Window sill	Flaking and chipping	Partial restoration	Partial replacement of the damaged finishing	m^2	53	26.56	1,408	241.3908	12,794	11%
Transp. envelope	Window sill	-	-	-	m^2	53	0	0	241.3908	12,794	0%
Roof	Steel gutter	Damages due to impacts	Partial restoration	Re-keeping of damaged and dislocated elements	m	107.6	7.39	795	14.72	1,584	50%
Roof	Steel gutter	-	-	-	m	430.4	0	0	14.72	6,335	0%
							Maintenance cost	**264,677**	**Repl. costs**	**406,798**	**65%**

In the Table 1 there is the list of the corrective maintenance operations to be done to restore the pathologies. The FCI has been computed, in the last column, as the ratio between the corrective maintenance costs and the replacement ones. This calculation does not include the maintenance already performed on these components, as the data were not available at the time of the analysis. It is necessary to notice that the FCI has been computed only for the inspected components (the envelope, both opaque and transparent); this analysis should be continued gradually to reach the totality of the components of the building under analysis. The FCI has been computed at the component level (according to eq. 2) and at the building level (according to eq. 3). The calculation at the building level consists in the ratio between the totals reported in Table 1.

Results. The result is that the building requires several maintenance operations to restore the pathologies detected. The final result of the FCI is 65%, with components with no maintenance required (FCI=0%) and components with complete replacement need (FCI=100%). As written before, this FCI is partial and calculated for the analyzed components; the final FCI could vary according to the condition of all the other components of the building.

Partial results (at the component level) are really important, as they allow to understand where the criticalities are located in the asset.

The FCI is anyway connected to the other important indicators (according to Fig. 2) of the building condition: pathologies, ageing and maintenance costs. With this set of data, asset managers are able to wisely make their decisions about asset renovation, retrofit or even disposal.

Discussion

Aim of this paragraph is to discuss both the procedure adopted and the results gathered from the case study.

First of all, the procedure proposed allows to calculate the FCI at different levels and for different components, providing also information about building conditions and maintenance costs. This set of indicators is considered relevant for FM activities, which need physical, functional and financial indicators [28].

Instruments and tools provided demonstrated the applicability in real case studies, nevertheless further research is required to improve the calculation method, as the computed FCI is still too much influenced by the quantity/extension of components analyzed; furthermore, the FCI at the building level could be aggregated in different ways, as instance with a weighted average of the FCI at the components level. This kind of analysis will be carried out in the future development of this research.

Regarding the results of the case study, the building is of course in strong need of a restoration, including also an energy retrofit. This need is highlighted by the FCI at the building level, which is abundantly above the 30% limit, so in the critical condition.

With more statistics about pathologies of the components (of the specific building), the FCI could be used also to make appraisals on the future condition of the building, using as input the planned maintenance costs. In a large portfolio, an analysis of this type helps in the definition of the priorities on the long run.

Conclusions

The proposed procedure and tools are an useful instrument for facility and asset managers who want to control the conditions of their portfolios. Despite the fact that the tool provided are just meant to demonstrate the feasibility, users are able, with a clear process, to understand main criticalities, pathologies and therefore to decide the best maintenance strategy that fits their needs.

In addition to this, the data provided can be understood, better if accompanied by a short explanatory report, by clients and users of the asset, without specific knowledge. On the opposite, as far as the procedure is guided, a professional, without specialized skills can perform the assessment.

The use of BIM is not an added value, but a powerful solution to speed up and improve the entire process of information acquisition, storage, elaboration and delivery; BIM, in connection with existing and innovative CAFM software can provide the basis for a reliable knowledge of the real estate, together with an improved decision making ability.

The research on the use of the FCI index, together with other physical, functional and financial indicators is still ongoing, aiming at providing a complete set of instruments in a BIM environment to deal with existing portfolios.

References

[1] M. Ferrara, E. Fabrizio, J. Virgone and M. Filippi, Energy systems in cost-optimized design of nearly zero-energy buildings, Autom. Constr. 70 (2016) 109–127.

[2] M.C. Dejaco, F. Re Cecconi and S. Maltese, Logbook's dynamic structure in building process, proceeding of the 39th World Congress on Housing Science – IAHS, Milan (I) (2013) 447-454.

[3] F. Re Cecconi, M.C. Dejaco and S. Maltese, Efficiency Indexes for Building Condition Assessment, proceeding of the 39th World Congress on Housing Science – IAHS, Milan (I) (2013) 455-462.

[4] S. Maltese, BIM maintenance management for real estate, proceeding of the iiSBE Forum of Young Researchers in Sustainable Building 2016, Prague (CZ) (2016) 223-232.

[5] International Organization for Standardization (2013), ISO/FDIS 55000, Asset management – Overview, principles and terminology.

[6] ScienceDirect (2013), ScienceDirect. [ONLINE] Available at: http://www.sciencedirect.com. [Accessed 17 July 2015].

[7] BBC Bitesize (2013), Decision-making in business. [ONLINE] Available at: https://goo.gl/RqDznh. [Accessed 17 July 15].

[8] Ente Italiano di Unificazione (2007), UNI EN 15221-1, Facility Management – Part 1: Terms and definitions.

[9] International Organization for Standardization (2015), ISO 21504, Project and programme portfolio management.

[10] BC Housing (2011), Facility Condition Index. [ONLINE] Available at: https://goo.gl/o1nF2s. [Accessed 10 October 2016].

[11] L.W. Roberts, Measuring school facility conditions: an illustration of the importance of purpose, J. Educ. Adm. 47 (2009) 368–380.

[12] National Research Council, Green Schools: Attributes for Health and Learning, first ed., The National Academies Press, Washington D.C., 2006.

[13] S. Khan and R. Kotharkar, Performance Evaluation of School Environs: Evolving an Appropriate Methodology Building, Procedia - Soc. Behav. Sci. 50 (2012) 479–491.

[14] M.N.M. Salleh, M.Z. Kandar and S.R.M. Sakip, Benchmarking for Energy Efficiency on School Buildings Design: A Review, Procedia - Soc. Behav. Sci. 222 (2016) 211–218.

[15] G.R. Ottoman, W.B. Nixon and S.T. Lofgren, Budgeting for facility maintenance and repair. I: methods and models, J. Manag. Eng. 15 (1999) 71–83.

[16] M.N. Grussing and L.R. Marrano, Building Component Lifecycle Repair/Replacement Model for Institutional Facility Management, Comput. Civ. Eng. (2007) 550–557.

[17] S. Lavy, Facility management practices in higher education buildings, J. Facil. Manag. 6 (2008) 303–315.

[18] M.M. Fagan and D.M. Kirkwood, Facility Condition Assessments: More than Just Making a List, Am. Soc. Healthc. Eng. 34th Annu. Conf. Technical Exhib. (1997).

[19] E. Teicholz and A. Edgar (2011), Facility Condition Assessment Practices. [ONLINE] Available at: http://www.graphicsystems.biz/gsi/articles/faccondassessprac_ifma_01sept.pdf. [Accessed 10 October 2016].

[20] D. Kincaid, Adaptability potentials for buildings and infrastructure in sustainable cities, Facilities. 18 (2013) 155–161.

[21] D.W. Kincaid (2013), Standardized Current Replacement Value Calculations Make Facility Condition Index More Effective. [ONLINE] Available at: https://goo.gl/Fs0bJR. [Accessed 10 October 2016].

[22] Assetinsight (2013), Facility Condition Index (FCI). [ONLINE] Available at: https://goo.gl/Y7rQgn. [Accessed 10 October 2016].

[23] International Organization for Standardization (2008), ISO 15686-8, Buildings and constructed assets – Service-life planning – Part 8: Reference service life and service-life estimation.

[24] Asset and Building Policy Production (1996), Condition assessment – a strategic look at your constructed assets. [ONLINE] Available at: https://goo.gl/OPaXVN. [Accessed: 30 April 2015].

[25] Comune di Milano, Area territorio direzione central tecnica (2014), Listino prezzi per l'esecuzione di opera pubbliche e manutenzioni, Edizione 2014, Milano.

[26] P.A. Jensen, T.J.M. Van Der Voordt, C. Coenen and A.-L. Sarasoja, Reflecting on future research concerning the added value of FM, Facilities 32 (2014) 856–870.

[27] B. Becerik-Gerber and F. Jazizadeh, Application areas and data requirements for BIM-enabled facilities management, J. Constr. Eng. Manag. 138 (2012) 431–442.

[28] M. Pitt and M. Tucker, Performance measurement in facilities management: driving innovation?, Prop. Manag. 26 (2008) 241–254.