Sebastiano Maltese
Giovanni Branca
Fulvio Re Cecconi
Nicola Moretti

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Ifc-based Maintenance Budget Allocation

KEYWORDS: BIM, IFC, budget allocation, Facility Condition Index, Facility Management.

Maintenance budget appraisal and allocation is a fundamental activity for the definition of an effective Facility Management (FM) strategy. Once the maintenance policy is set by the assets' owner, facility managers are asked to compare different maintenance strategies (i.e. preventive vs. corrective) in order to provide a reliable and cost-effective maintenance budget. This can be hindered by unavailability of data for maintenance of building components. Nowadays, Building Information Modelling (BIM) provides plenty of data, but procedures are seldom focused on maintenance costs appraisal and this frequently leads to an intensive data re-elaboration. The objective of this research is to provide a precise maintenance budget appraisal according to different maintenance strategies through the Facility Condition Index (FCI), calculated starting from data stored into an Industry Foundation Classes (IFC) model. Data are stored in IfcAsset elements, using the related property sets. To overcome calculation needs, some additional attributes may be associated to elements and stored in custom property sets. The results of this research are a set of data, procedures and tools that allow the quantification and planning of maintenance expenditure, allowing a proper budget allocation. These procedures and tools answer the need of both designers during new constructions (to prepare the maintenance plan, as required by current Italian laws for public buildings) and asset managers during the digitisation of existing buildings (to store maintenance data and to rely on better appraisals). In this paper a demonstration is presented, with the purpose of showing the proposed methodology and tools. The demonstration has been carried out on some of the architectural and Mechanical, Electrical, Plumbing (MEP) components that mainly contribute to the annual maintenance expenditure.

INTRODUCTION

The built environment is currently characterised by an increasing complexity(Lu, Clements-Croome and Viljanen, 2010). On one hand the building is no longer featured only by physical characteristics,it is more and more included in an array of services to be provided to the users. On the other hand, the building intended as a physical entity, is being subject to a process of digitisationstemming from the massive use, in new buildings, of components and technologies requiring anICT-based (Information and Communication Technology) management approach. Within this context, the facility manager has to face a more and more complex physical asset producing and gathering a huge amount of data every day. Therefore, tools and techniques that should be employed for an effective Facility Management (FM) implementation must be addressed information complexity and uncertainty. Facility maintenance management (FMM) constitutes most (65%~85%) of the total costs incurred by FM activities(Lavy and Jawadekar, 2014). In this context effective methodologies and procedures for building management should be adopted for saving resources and for an improved sharing of information among stakeholders. Therefore, a BIM approach can be employed as basis for effective FM implementation(Pärn, Edwards and Sing, 2017). BIM can be defined as a digital based approach for management of information related to the buildings and the built environment(Re Cecconi, Maltese and Dejaco, 2017). Recently some demonstrations have proved the possibility to implement this approach also in the use phase of assets(Volk, Stengel and Schultmann, 2014; Chen et al., 2018). Therefore, this research addresses the issues related to the effective budget allocation through the use of the BIM approach. For this purpose, the IFC schema has been employed. IFC allows data exchange and interoperability through different professionals, software and phases of the Architecture, Engineering Construction and Operation (AECO) sector(ISO, 2013). For effective budget allocation and prioritisation of maintenance interventions, IFC schema has been employed in order to store the information related to maintenance planning and scheduling. IfcAsset has been associated to components belonging to the same building entity on which to perform homogeneous maintenance interventions. For that maintenance entity has been defined the standard maintenance profile and thanks to a Condition Assessment campaign the current maintenance status has been identified. These operations allow to define the Facility Condition Index (FCI) value of every single maintenance

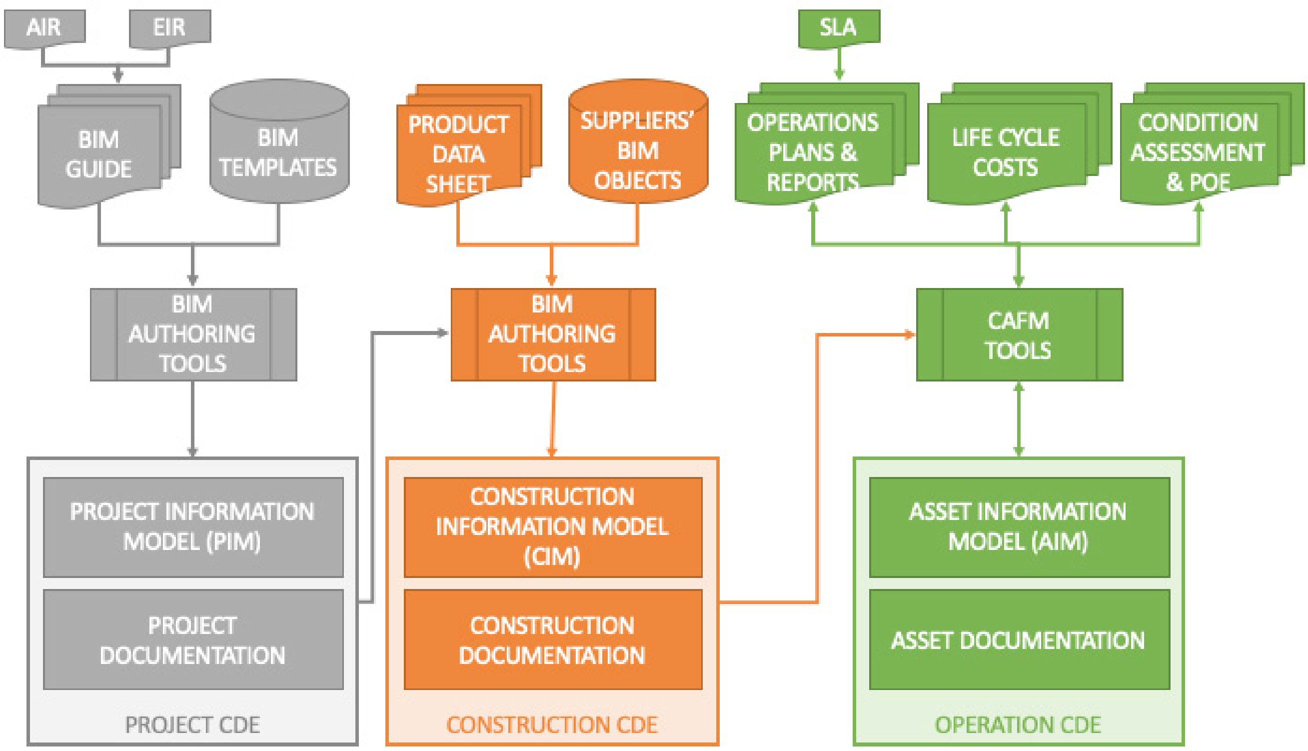


Figure 1: Information flows in design, construction and operation

entity. The FCI is one of the most used Key Performance Indicators (KPIs) for assets' assessment(Lavy, Garcia and Dixit, 2014), thanks to the possibility to scale the indicator from the single entity to the whole buildings portfolio(Re Cecconi, Maltese and Dejaco, 2017).In its basic form it is used for evaluation of cost of deferred maintenance (DM), over the Current Replacement Value (CRV) of the component(Rush, 1991).The FCI allows to quantify the maintenance expense in a scale from 0 to 100 (where 0 represents the best value) (Rush, 1991). The FCI, in this research, is used for a two folded aim: the maintenance budget allocation and the prioritisation of maintenance interventions. This approach has been tested on a case study concerning an office building in Erba, Italy. The paper concludes with some insights and further developments of the research.

STATE OF THE ART

BIM has shifted the way building information is managed, exchanged and transformed to enhance collaboration among project stakeholders(Eastman C, Teicholz P, 2011). Especially for what concerns the implementation of FM processes, the use of methodologies based on BIMis gaining momentum(Pärn, Edwards and Sing, 2017). This approach provides valuable support for the management of the large amount of data related to the planning, management and implementation of FM services (Re Cecconi, Maltese and Dejaco, 2017). However, from the very beginning, FM has been supported by the use of information management tools: from the first Computer Aided Facility Management (CAFM), to CAD, Integrated Workplace Management Systems (IWMS) and Computerised Maintenance Management Systems (CAFM)(Volk, Stengel and Schultmann, 2014). More recently, furthertheories and practices involving the use of BIM tools for FM have been developed(Chen et al., 2018). Theymainly deal with the possibility of integrating information on maintenance and management of building stocks and their parts into the collaborative approach typical of the BIM methodologies(Hosseini et al., 2018). This trend has led to the definition of a specific characterisation of the BIM approach(Volk, Stengel and Schultmann, 2014). The use of BIM for maintenance has also been promoted through the use of simplified IFC models like COBie(BSI, 2014), a subset of the IFC model, based on the Facilities Handover model view definition. Moreover,many examples of BIM use in the FM process can be found in literature, from the use of BIM in the condition assessment of existing buildings (Bortolini and Forcada, 2019) (Ani et al., 2015)to the automatic scheduling of facility maintenance work orders (Chen et al., 2018), from safety/ emergency management(Nicał and Wodyński, 2016) tothe creation of an asset register (Patacas et al., 2015).

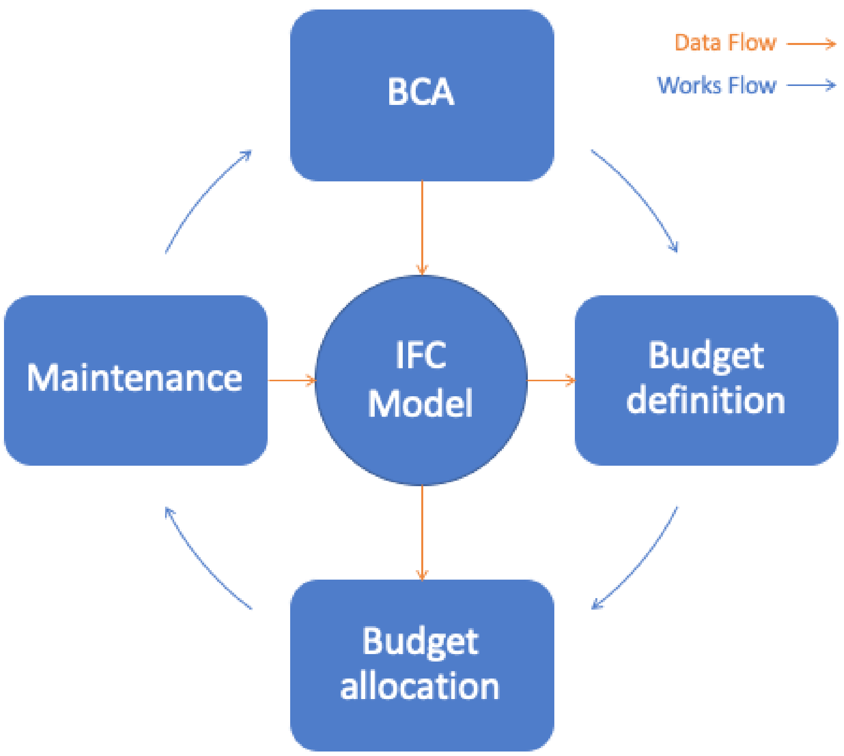


Figure 2: Research schema

RESEARCH METHOD

This research is part of a wider study exploring the use in FM of OpenBIM: a universal approach to the collaborative design, realization and operation of buildings based on open standards and workflows. This paper investigates the use of IFC, the core of OpenBIM, as the central source of information regarding the asset during its whole life cycle. Authors believe that many IfcPropertySetsand IfcEntitiescan be exploited to improve current FM practice, so the main objective of the research is to show how an IFC model can be the real centre of data aggregation.
The model and the documentation, contained in the Common Data Environment (CDE), is changing through the phases of the project (i.e. project, construction, operation) and are managed with different software (i.e. BIM authoring tools, CAFM tools) (Figure 1).

In this paper, only the part related to maintenance budgeting and scheduling is developed (Figure 2), aiming at scaling this process to other several activities, commonly time and effort consuming during assets operations (e.g. space management, contracting, rent, renovation, energy monitoring, etc.). The exchange of information is guaranteed using the IFC protocol: IFC allows not only the exchange of information but also the storage of relevant data about maintenance cost (i.e. maintenance budget) and scheduling (i.e. maintenance scheduling).

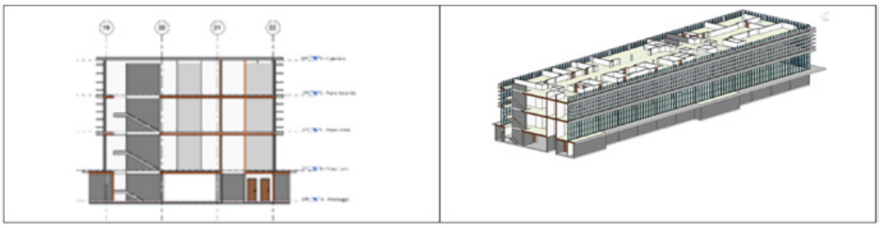
The research is willing to overcome an important limit of many BIM authoring tools: the association of data to groups of objects. For this purpose, the *IfcAssetcan* be employed, since it can be associated to single elements (e.g. *IfcMechanicalEquipment*) or to groups of objects (e.g. curtain wall, heating system). So, the IfcAssetcan bridge the gap between BIM authoring tools (object-centred) and management software (cost-centred): the *IfcAssetcould* be used as a centre of cost, with a budget assigned and maintenance scheduled.
In the demonstration section it is shown how to store maintenance operations datafor a curtain wallin an IFC model (2x4 Design Transfer View) and how to work on these data. The entity used for maintenance management, in this research, connected to the *IfcAsset* by the global identifier, is the *IfcProjectOrder*.

It is also possible to store list of data on a time series (*IfcIrregularTimeSeries*), by using *IfcAsset* in combination with the property set *IfcPerformanceHistory*, which allows to save one or more data with a time stamp (*IfcDateTime*[1:1], *IfcValue*[1:?]).

DEMONSTRATION

The methodology depicted in the previous paragraph has been validated through a demonstration on an office building located in Erba, Italy. The building is characterised by three floors above the ground and one underground. Currently, it is occupied by a construction firm and a notary firm. The BIM model has been created using as-built 2D drawings following the information requirements analysis: the objective was to create a low LOD and high LOI model with all the data needed for the operational phase. All spaces and main components (architectural and MEP) have been modelled. In Figure 3 the BIM model of the case study is presented.

The IFC model of the building has been developed and all data concerning maintenance management and implementation have been collected and stored. The IfcAssetattributes has been used to match BIM objects with costs associated to maintenance operations done or to be done (Figure 4).
Table 1 shows in a simplified way how the maintenance cost profile for each component to be maintained (*ifcAsset*) has been developed. For synthesis reasons,Figure 5represent the IFC characterisation of maintenance operations for the curtain-wall (south façade). *IfcAsset* has been used as the maximum level of aggregation for components, which allows to define homogeneous maintenance interventions.



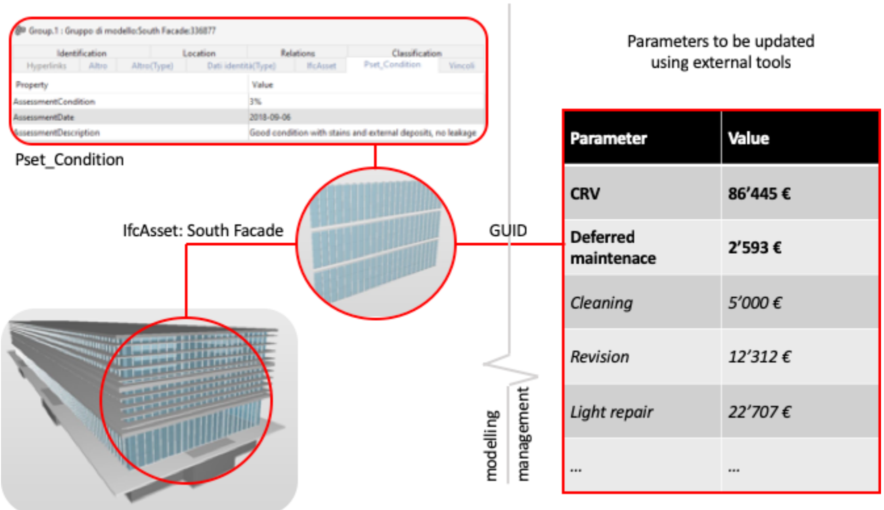
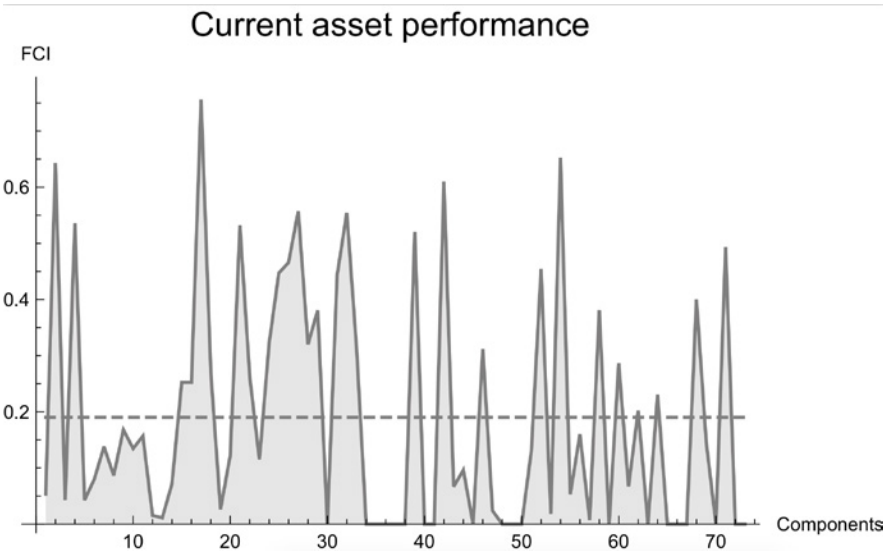


Figure 3: BIM model of the case study
Figure 4: IfcAsset implementation and external parameters

Entity		*Name*	*Maintenace operations*				
			Cleaning	*Revision*	*Light Repair*	*Medium repair*	
Project Order (IfcProjectOrder)	*Attributes*	Predefined Type (IfcProjectOrderTypeEnum)	MAINTENANCEWORKORDER	MAINTENANCEWORKORDER	MAINTENANCEWORKORDER	MAINTENANCEWORKORDER	...
		Status (IfcLabel)	PLANNED	PLANNED	PLANNED	PLANNED	...
		Long Description (IfcText)	Pulizia lato esterno dei vetri e della struttura con detergenti appositi	Revisione montanti e traversi in alluminio, cerniere e gurnizioni	Piccole riparazioni di infissi in metallo, compresa raddrizzatura di bordi, regolazione della chiusura,	Medie riparazioni di infissi in metallo, compresa raddrizzatura di bordi, battute, montanti,	...
	Pset_ProjectOrderMaintenanceWorkOrder	Work Type Requested (IfcText)	Light intervention	Light intervention	Light intervention	Medium-level intervention	...
		Contractual Type (IfcText)	Global Service contract	Global Service contract	Global Service contract	Global Service contract	...
		Maintenace Type (PEnum_MaintenanceType)	SCHEDULED	SCHEDULED	SCHEDULED	CORRECTIVE	...
		Fault Priority Type (PEnum_PriorityType)	LOW	MEDIUM	MEDIUM	MEDIUM	...
		Location Priority Type (PEnum_PriorityType)	LOW	LOW	LOW	MEDIUM	...
		Scheduled Frequency (IfcTimeMeasure)	12,0	24,0	24,0	36,0	...
Cost schedule (IfcCostSchedule)	*Attributes*	IfcCostScheduleTypeEnum (IfcCostScheduleTypeEnum)	ESTIMATE	ESTIMATE	ESTIMATE	ESTIMATE	..
Cost Item (IfcCostItem)	*Attributes*	Name (IfcLabel)	Total cost	Total cost	Total cost	Total cost	..
Cost Value (IfcCostValue)	Attributes	Applied Value (IfcText)	5.000,00	12.312,00	22.707,00	20.277,00	..
		Cost Type	NULL	NULL	NULL	NULL	..



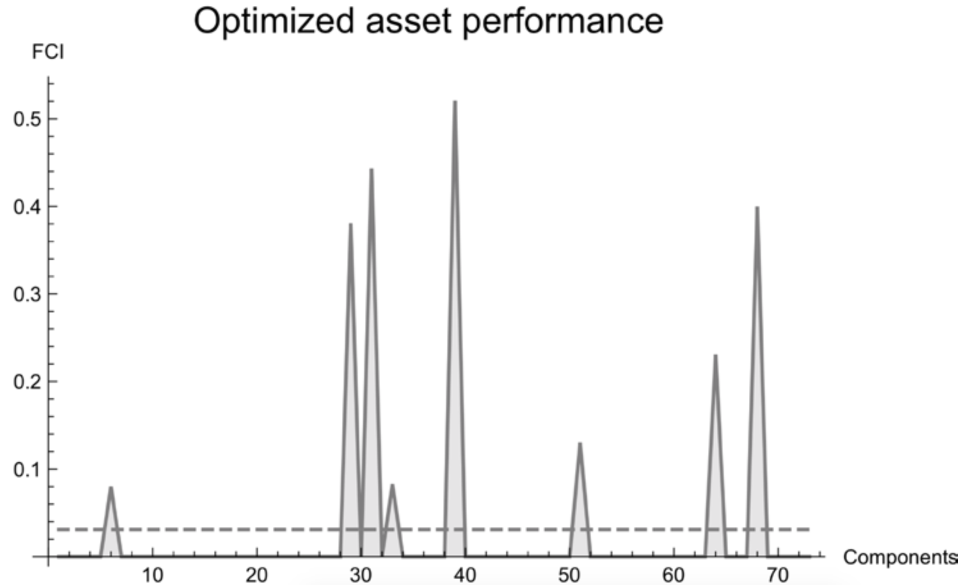
DISCUSSION AND CONCLUSIONS

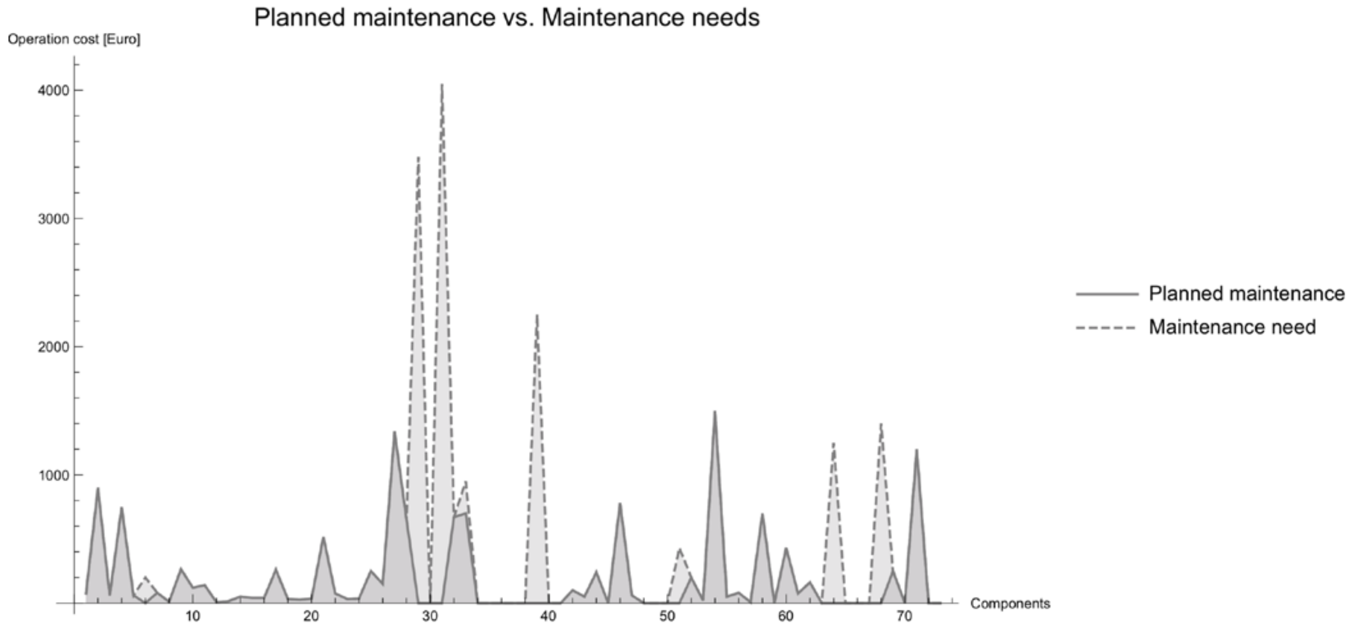
The data inserted in the model thanks to a Building Condition Assessment (BCA) procedure, the survey and the analysis of FM documents, resulted in 85 deferred maintenance operations. These have been found during the BCA on 73 components surveyed. The total average FCI resulted equal to 19%, as shown inFigure 6.

A simulation with a budget constraint, set to half of the deferred maintenance costs has been carried out. Therefore, an optimization algorithm has been run. This led to schedule 69 out of 85 maintenance operations. The new FCI after the computation is 3.11% (Figure 7), which means an FCI decrease of more than 83%, with half of the economic resources required to perform all deferred maintenance operations.

Figure 8 shows the overlapping of the curve related to the total maintenance interventions to be accomplished to restore the FCI value equal to 0 (dashed line)and the curve representing the

Figure 5: Definition of curtain-wall facade maintenance profile trough IFC.
Figure 6: Components' FCI computed after the BCA



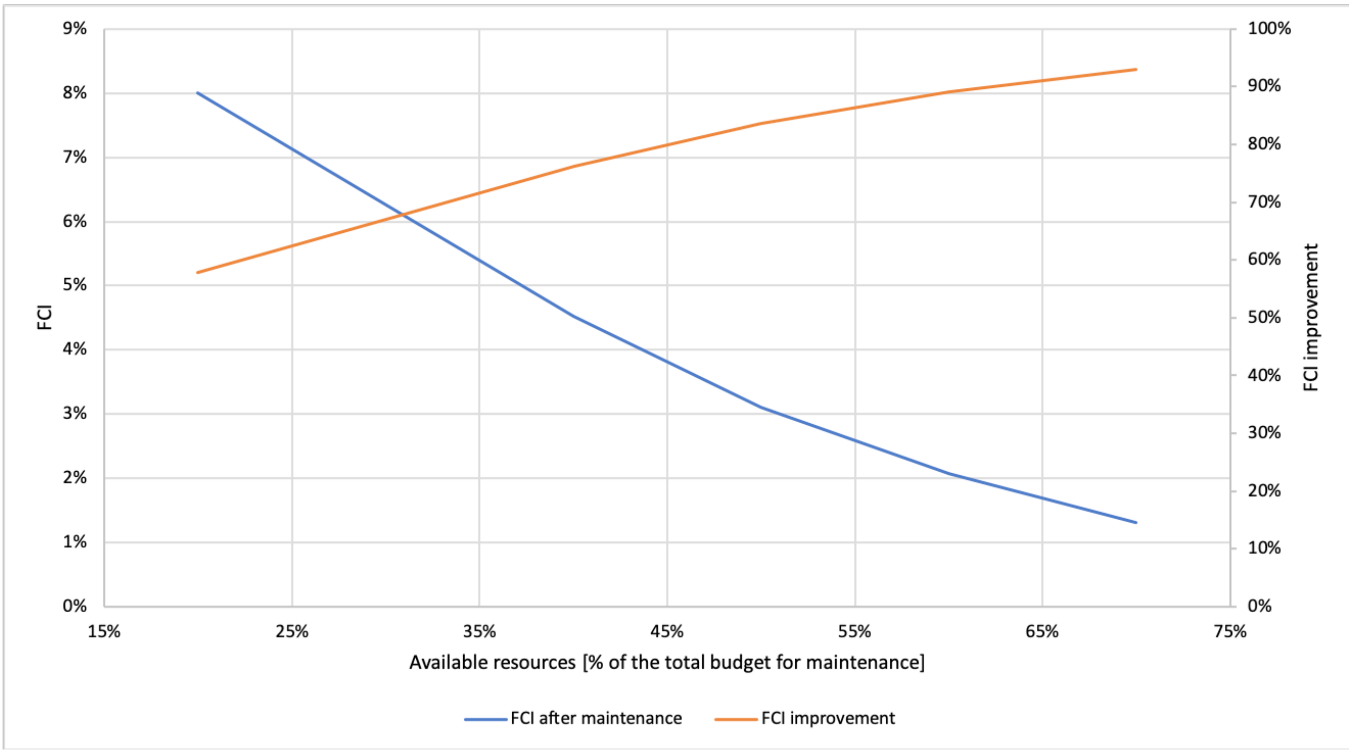


interventions carried out with the DM recovering budget set to 50% (solid line). The optimisation algorithm allows to significantly reduce the maintenance expense for each IfcAsset and reducing spending peaks.

Thanks to the data inserted in the model and a further elaboration is possible to evaluate the FCI according to budget changes (Figure 9). This allows to allocate the budget over different years and to compare different assets/buildings of a portfolio. Moreover, it can be the basis for the creation of scenarios and for the annual budget allocation, providing a reliable basis for assets comparison.

To conclude, it can be stated that through the research presented in this paper the possibility to exploit OpenBIM and IFC for facility maintenance management has been demonstrated. In particular, the case study showed the possibility to handle data contained in IFC both as input and output of the process (e.g. initial and final FCI of an IfcAsset). It is important to remember that IFC is an exchange protocol and the data must be elaborated with an external software, tool or plugin.An algorithm has been developed by the authors, but this has

Figure 7: FCI of each component after the scheduled maintenance
Figure 8: Planned (optimized) maintenance vs. Maintenance need (deferred maintenance)



to be implemented into a management software, to be exploited into the market.Moreover, the methodology allows also to reduce the costs related to inefficientdata management (loss of information) through the whole life cycle of the building. nevertheless, to implement effectively the proposed methodology, it is necessary that the owner defines precise guidelines for modelling and updating the BIM model.

Figure 9: FCI after maintenance and FCI improvement according to the maintenance budget

Bibliografia
Bibliography

Ani, A. I. C. et al. (2015) "Building information modeling (BIM)-based building condition assessment: A survey of water ponding defect on a flat roof", *Jurnal Teknologi*, 75(9), pp. 25–31. doi: eISSN 2180–3722.

Bortolini, R. and Forcada, N. (2019) "Building Inspection System for Evaluating the Technical Performance of Existing Buildings", 32(5), pp. 1–14. doi: 10.1061/(ASCE)CF.1943-5509.0001220.

BSI (2014) "BS 1192-4 : 2014 Collaborative production of information Part 4 : Fulfilling employer' s information exchange requirements using COBie - Code of practice", p. 58. Available at: http://shop.bsigroup.com/forms/BS-1192-4/.

Chen, W. et al. (2018) "BIM-based framework for automatic scheduling of facility maintenance work orders", *Automation in Construction*. Elsevier, 91(March), pp. 15–30. doi: 10.1016/j.autcon.2018.03.007.

Eastman C, Teicholz P, S. R. and L. K. (2011) *BIM Handbook: A Guide to Building Information Modelling for Owners, Managers, Designers, Engineers and Contractors*. John Wiley and Sons.

Hosseini, M. R. et al. (2018) "Integrating BIM into facility management: Typology matrix of information handover requirements", *International Journal of Building Pathology and Adaptation*, 36(1), pp. 2–14. doi: 10.1108/IJBPA-08-2017-0034.

ISO (2013) "ISO 16739:2013. Industry Foundation Classes (IFC) for data sharing in the construction and facility management industries".

Lavy, S., Garcia, J. A. and Dixit, M. K. (2014) "KPIs for facility's performance assessment, Part II: identification of variables and deriving expressions for core indicators", *Facilities*, 32(5/6), pp. 275–294. doi: 10.1108/F-09-2012-0067.

Lavy, S. and Jawadekar, S. (2014) "A Case Study of Using BIM and COBie for Facility Management", *International Journal of Facility Management*, 5(2), pp. 13–27.

Lu, X., Clements-Croome, D. and Viljanen, M. (2010) "Integration of chaos theory and mathematical models in building simulation. Part II: Conceptual frameworks", *Automation in Construction*, 19(4), pp. 452–457. doi: 10.1016/j.autcon.2010.01.003.

Nicał, A. K. and Wodyński, W. (2016) "Enhancing Facility Management through BIM 6D", *Procedia Engineering*, 164(June), pp. 299–306. doi: 10.1016/j.proeng.2016.11.623.

Pärn, E. A., Edwards, D. J. and Sing, M. C. P. (2017) "The building information modelling trajectory in facilities management: A review", *Automation in Construction*. Elsevier B.V., 75, pp. 45–55. doi: 10.1016/j.autcon.2016.12.003.

Patacas, J. et al. (2015) "BIM for facilities management: Evaluating BIM standards in asset register creation and service life planning", *Journal of Information Technology in Construction*, 20(August 2016), pp. 313–331.

Re Cecconi, F., Maltese, S. and Dejaco, M. C. (2017) "Leveraging BIM for digital built environment asset management", *Innovative Infrastructure Solutions*, 2(1), p. 14. doi: 10.1007/s41062-017-0061-z.

Rush, S. C. (1991) *Managing the facilities portfolio: a practical approach to institutional facility renewal and deferred maintenance*. National Association of College and University Business Officers.

Volk, R., Stengel, J. and Schultmann, F. (2014) "Building Information Modeling (BIM) for existing buildings - Literature review and future needs", *Automation in Construction*. Elsevier B.V., 38, pp. 109–127. doi: 10.1016/j.autcon.2013.10.023.