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Proposal of a methodology for achieving a LEED O+M certification in historic buildings

E. Mazzola, T. Dalla Mora*, F. Peron, P. Romagnoni

Department of Design and Planning in Complex Environments, University IUAV of Venice, IT

Abstract

Nowadays resources are running out quickly, it's necessary to consider how the construction industry influences the environment using different materials and sources during all the building's life cycle. For this reason, in every transformation phases it's necessary to consider concepts as sustainability and green buildings. These are diffused from hundreds kind of green assessment tools, developed to measure sustainability goals in building sector and to compare the project with possible best practices or other green buildings.

In this background, the rating system LEED (Leadership in Energy and Environmental Design) aims to examine and classify buildings according to energetic and environmental requirements. The particular LEED O+M (Building Operations and Maintenance) is developed for existing buildings undergoing improvement work or little to no construction and is based on the operative and management aspects.

The certification process results, at a first analysis, hard to follow due to the complexity of internal parameters and the documentation required. The paper consists in a methodology and in an univocal work program of LEED O+M, trying to obtain the minimum requested certification score with optimization of the technical resources and documents. This methodology has application in a case study of historic building: the Ca' Rezzonico Museum, in the center of Venice.

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Keywords: Green Buildings, LEED Rating System, methodology, workflow, historic buildings

* Corresponding author. Tel.: +39-041 2571302
E-mail address: tdallamora@iuav.it

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1. Introduction

The sustainability in building construction can be defined as: the development of a design system structured and controlled through the integration of different knowledge, so as to provide a product able to satisfy the user's needs (indoor environmental quality) with a minimum commitment of natural resources is being built that year and with a significant reduction of environmental impacts [1]. The first impact to be analyzed shall be the energy consumptions. The Directive 2010/31/CE states that buildings consume 40% of energy in the European Union [2].

Indeed, in the life cycle of buildings, they consume 30-40% of all primary energy worldwide, from the production and transportation of construction materials to its demolition [3]. These heavy consumption of energy is one of the reasons causing the growing interest worldwide of sustainability and green buildings.

The concept of sustainability concerns the continuity of economic, social and environmental aspects of human society and non-human environment, without compromising these aspects for future generations [4].

A green building is the practice of creating structures and using processes that are environmentally responsible and resource-efficient throughout a building's life-cycle from siting to design, construction, operation, maintenance, renovation and deconstruction. This practice expands and complements the classical building design concerns of economy, utility, durability and comfort [5].

The awareness of the importance of green buildings and the effects of their energy efficiency are diffused from hundreds kinds of certification systems around the world [6].

In general, the role of these green assessment tools is the develop of a system of measure for all the sustainability goals in a building and more easily compared with current and past building practices and other green buildings. The main thematic areas are energy, water, material use, indoor quality and comfort: each area is evaluated on its net use; in other words, if the building produces or reuses resources, the evaluation is about its efficiencies and its percentage of reused, recycled or virgin materials.

Green assessment tools needed to be easy and inexpensive to use and they attempt to provide a process in which to compare different buildings and to associate a numerical value to compare with other assessed buildings [7]. The general criticisms about these methods of buildings analysis are the not consideration of durability, lifecycle cost and the effects of premature building failures [4]. Indeed, during the life cycle of a building, there are a lot of events that can change the internal system and the costs, like a failure or a breaking of an installation.

In this scenario, LEED (Leadership in Energy and Environmental Design) rating system is added. It was developed in the United States and it was first pilot tested in 1998 by United States Green Building Council (USGBC). This is a voluntary, market-driven and consensus based tool that serves as a guideline and assessment mechanism to optimize the use of natural resources, promote regenerative and restorative strategies, maximize the positive and minimize the negative environmental and human health consequences of the building industry, and provide high-quality indoor environments for building occupants. These are the main goals of the rating system and the basis for LEED prerequisites and credits. Based on the number of points achieved, a project receives one of four LEED rating levels: Certified, Silver, Gold or Platinum [8].

This certification system was developed to address all buildings; indeed, it has different types of rating system, from hospital to data center, from historical buildings to those still in the design phase. At the moment, this is the world's most used system and it aims to use resources efficiently by using less energy and water, reducing greenhouse gas emission and pollution for transportation, and focusing on materials to reduce the effects of their harmful components. According to USGBC database, 103.506 projects are registered or certified through this system as of January 12, 2017 [9].

A criticism about this system is the difficult to follow the process, due the complexity of internal parameters and the documentation required, which can deter surveyors and technicians from obtaining certification.

For these reasons, this paper consists in the proposal of a methodology to apply a LEED rating system in an univocal work program in order to obtain the minimum requested point by optimization of the technical resources and documents, through the examination, deconstruction and reformulation of the internal difficulties. In particular LEED v4 for Building Operations and Maintenance (O+M) is applied: it's used for existing buildings undergoing improvement work or little to no construction and is based on the operative and management aspects.

2. LEED v4 for building Operations and Maintenance's (O+M) structure

In LEED v4 for Building Operations and Maintenance (O+M) there are twelve (12) prerequisites and thirty-seven (37) credits within the structure: prerequisites are the mandatory part of the rating system; credits are the part where points are awarded. Prerequisites and credits are categorized in: Location and Transportation (LT), about building position and how that site affects commuting patterns; Sustainable Sites (SS), about the environment surrounding the building, emphasizing the vital relationship among buildings, ecosystems, and ecosystem services; Water Efficiency (WE) addresses water holistically, looking indoor use, outdoor use, specialized uses, metering and recognizes the use of no potable and alternative sources of water; Energy and Atmosphere (EA) addresses energy use reduction, energy-efficient design strategies and renewable energy sources; Materials and Resources (MR) focuses on the constant flow of products being purchased and discarded to support building operations; Indoor Environmental Quality (EQ) about indoor air quality, thermal and visual comfort, and occupants' satisfaction; Innovation (IN) to recognize projects for innovative and exemplary building features or practices that generate environmental benefits beyond those addressed or specified in the other credit categories; Regional Priority (RP) about specific priorities according to the location and type of rating system.

LEED v4 for Operations & Maintenance: Existing Buildings
Project Checklist

Project Name:
Date:

Y	?	N			
0	0	0	**Location and Transportation**		15
			Credit	Alternative Transportation	15
0	0	0	**Sustainable Sites**		10
Y			Prereq	Site Management Policy	Required
			Credit	Site Development-Protect or Restore Habitat	2
			Credit	Rainwater Management	3
			Credit	Heat Island Reduction	2
			Credit	Light Pollution Reduction	1
			Credit	Site Management	1
			Credit	Site Improvement Plan	1
0	0	0	**Water Efficiency**		12
Y			Prereq	Indoor Water Use Reduction	Required
Y			Prereq	Building-Level Water Metering	Required
			Credit	Outdoor Water Use Reduction	2
			Credit	Indoor Water Use Reduction	6
			Credit	Cooling Tower Water Use	3
			Credit	Water Metering	2
0	0	0	**Energy and Atmosphere**		38
Y			Prereq	Energy Efficiency Best Management Practices	Required
Y			Prereq	Minimum Energy Performance	Required
Y			Prereq	Building-Level Energy Metering	Required
Y			Prereq	Fundamental Refrigerant Management	Required
			Credit	Existing Building Commissioning—Analysis	2
			Credit	Existing Building Commissioning—Implementation	2
			Credit	Ongoing Commissioning	3
			Credit	Optimize Energy Performance	20
			Credit	Advanced Energy Metering	2
			Credit	Demand Response	3
			Credit	Renewable Energy and Carbon Offsets	5
			Credit	Enhanced Refrigerant Management	1
0	0	0	**Materials and Resources**		8
Y			Prereq	Ongoing Purchasing and Waste Policy	Required
Y			Prereq	Facility Maintenance and Renovations Policy	Required
			Credit	Purchasing- Ongoing	1
			Credit	Purchasing- Lamps	1
			Credit	Purchasing- Facility Management and Renovation	2
			Credit	Solid Waste Management- Ongoing	2
			Credit	Solid Waste Management- Facility Management and Renovation	2
0	0	0	**Indoor Environmental Quality**		17
Y			Prereq	Minimum Indoor Air Quality Performance	Required
Y			Prereq	Environmental Tobacco Smoke Control	Required
Y			Prereq	Green Cleaning Policy	Required
			Credit	Indoor Air Quality Management Program	2
			Credit	Enhanced Indoor Air Quality Strategies	2
			Credit	Thermal Comfort	1
			Credit	Interior Lighting	2
			Credit	Daylight and Quality Views	4
			Credit	Green Cleaning- Custodial Effectiveness Assessment	1
			Credit	Green Cleaning- Products and Materials	1
			Credit	Green Cleaning- Equipment	1
			Credit	Integrated Pest Management	2
			Credit	Occupant Comfort Survey	1
0	0	0	**Innovation**		6
			Credit	Innovation	5
			Credit	LEED Accredited Professional	1
0	0	0	**Regional Priority**		4
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
			Credit	Regional Priority: Specific Credit	1
0	0	0	**TOTALS**	Possible Points:	110

Certified: 40-49 points, Silver: 50-59 points, Gold: 60-79 points, Platinum: 80+ points

Figure 1 – From the website of USGBC, this is the image of the project checklist for LEED v4 for Building Operations and Maintenance. "Required" identifies prerequisites; points identifie credits.

However, each category shows a different weigh according to its total credits score; indeed, in LEED O+M Energy and Atmosphere and Indoor Environment categories weigh together more than total of other categories.

Each prerequisite and credit is broken down into sections: intent and requirements, behind the intent, step-by-step guidance, further explanation, required documentation and related credit tips (identify the relation between prerequisites and other prerequisites or credits), changes from LEED 2009, referenced standards, exemplary performance and definitions. In the intent and requirements section, it's possible to choose among different options as well as the establishment and the performance period for reaching intent and/or score. The establishment period is the

time when building infrastructure is assessed, policies are drafted, and programs and processes are put in place to enable ongoing performance measurement. The performance period is the continuous implementation of the strategies set during the establishment period [8]. An example of this partition is the prerequisite Minimum Energy Performance inserted below (Figure 2).

3. Methodology

The research aims to classify the prerequisites and credits in order to identify those that could achieve the minimum score to get the LEED certification of the building. The proposed methodology has been taken up by previous studies and research applied to another rating system [10] and allows the identification of an operating strategy for the achievement of credits based on the classification obtained by calculation.

The research proposes a methodology composed by two phases: phase 1 concerns the classification of prerequisites, employing a score system for each parameter inside; in phase 2 a couple of mathematical approaches is followed: the sub-phase 2A regards a selection of LEED O+M credits, the sub-phase 2B considers the same approach of the prerequisite's classification and applies it to selected credits.

3.1. Prerequisite's classification

Paying attention to the prerequisites and the sections contained therein, a specific process is developed, employing a score system according to internal options, see Table 1: for each document requested (one point for each document), considering prerequisites within prerequisites (one point for each internal prerequisite), performance period (No points if not present, two points for every five-yearly audit or maintenance after the certification and three points for the collection of data before the certification) and also the type of form requested from USGBC, (one point if easy to fill in or two points if calculation is required and three points if the form is more complex).

Table 1. Score system for prerequisites according to internal options: parameters are the requirements contained in every prerequisites and score is the score system.

PARAMETERS	SCORE
Documents requested	1 point = 1 document
Prerequisites within prerequisites	1 point = 1internal prerequisite
Performance period	0 point = not present 2 points = five-yearly audit or maintenance after certification 3 points = collection of data before the certification
Type of form	1 point = easy to fill in 2 points = calculation required 3 points = form is more complex

This procedure can be explained by an example of the score system. The prerequisite Minimum Energy Performance includes:

- Two cases and three options for the case two.
- Required documentation, explained in the guide of LEED O+M. It's possible to see a request between four and eight documents, according to cases or options.
- Related prerequisites are Building Energy Metering and Energy Efficiency Best Management Practices, found inside the step-by-step guidance in the guide of LEED O+M.
- Performance period consists to meter the building's energy use for a full 12 months.
- Type of form is made of data about Energy Star Rating or other type of audit, energy bill summary and other types of data don't always easy to find.

ENERGY AND ATMOSPHERE PREREQUISITE

Minimum Energy Performance

This prerequisite applies to:

Existing Buildings	Data Centers
Schools	Hospitality
Retail	Warehouses and Distribution Centers

INTENT

To reduce the environmental and economic harms associated with excessive energy use by establishing a minimum level of operating energy performance.

REQUIREMENTS

ESTABLISHMENT E

Calibrate meters within the manufacturer's recommended interval if the building owner, management organization, or tenant owns the meter. Meters owned by third parties (e.g., utilities or governments) are exempt.

PERFORMANCE P

Meter the building's energy use for a full 12 months of continuous operation and achieve the levels of efficiency set forth in the options below. Each building's energy performance must be based on actual metered energy consumption for both the LEED project building(s) and all comparable buildings used for the benchmark.

Case 1. ENERGY STAR Rating

For buildings eligible to receive an energy performance rating using the Environmental Protection Agency (EPA) ENERGY STAR ® Portfolio Manager tool, achieve an energy performance rating of at least 75. For projects outside the U.S., consult ASHRAE/ASHRAE/IESNA Standard 90.1–2010, Appendixes B and D, to determine the appropriate climate zone.

Case 2. Projects Not Eligible for ENERGY STAR Rating

Projects not eligible to use EPA's rating system may compare their buildings' energy performance with that of comparable buildings, using national averages or actual buildings, or with the previous performance of the project building.

OPTION 1. BENCHMARK AGAINST TYPICAL BUILDINGS

Path 1. National Average Data Available
Demonstrate energy efficiency performance that is 25% better than the median energy performance of similar buildings by benchmarking against the national source energy data provided in the Portfolio Manager tool.

Path 2. National Average Data Not Available
If national average source energy data are unavailable for buildings of similar type, benchmark against the building site energy data of at least three similar buildings, normalized for climate, building use, and occupancy. Demonstrate a 25% improvement.

OPTION 2. BENCHMARK AGAINST HISTORICAL DATA

If national average source energy data are unavailable, compare the building's site energy data for the previous 12 months with the data from three contiguous years of the previous five, normalized for climate, building use, and occupancy. Demonstrate a 25% improvement.

Figure 2 – An example of partition inside each prerequisite and credit, reference Minimum Energy Performance.

	OPTIONS (a)	DOCUMENTATION (b)	PREREQUISITES INSIDE (c)	PERFORMANCE PERIOD (d)	FORM REQUESTED (e)	TOTAL	
EA p2 Minimum Energy Performance	1.1.	4	2	3	2	12	14,4 (f)
	1.2.	4	2	3	2	12	
	2.1.1.	6	2	3	3	15	
	2.1.2.	8	2	3	3	17	
	2.1.2.	7	2	3	3	16	

(b)

	Documentation (a)	Case 1, streamlined	Case 1	Case 2, Option 1, Path 1	Case 2, Option 1, Path 2	Case 2, Option 2
E	Meter calibration report, as applicable	X	X	X	X	X
E	Access to ENERGY STAR Portfolio Manager account (see Further Explanation, Sharing Access)	X	X	X	X	X
P	Statement of energy performance stamped by professional engineer or licensed architect	X				
P	Letter from ENERGY STAR, copy of ENERGY STAR recognition certificate, or screenshot of ENERGY STAR website	X				
P	Data verification checklist		X	X	X	X
P	Copies of utility bill summary pages or cover pages for 3 months of performance period for each fuel source		X	X	X	X
P	Weather-normalized source EUI			X	X	X
P	Weather-normalized source EUI from 3 similar buildings				X	
P	Descriptions of 3 similar buildings and comparability to project building				X	
P	Weather-normalized source EUI from 3 recent years					X
P	Calculations supporting additional normalization (if applicable)			X	X	X

(c) EA p3 - Building Level Energy Metering
EA p1 - Energy Efficiency Best Management Practices
EQ p1 Minimum Indoor Air Quality Performance

(d) **PERFORMANCE** P

Meter the building's energy use for a full 12 months of continuous operation and achieve the levels of efficiency set forth in the options below. Each building's energy performance must be based on actual metered energy consumption for both the LEED project building(s) and all comparable buildings used for the benchmark.

(e)

Project building gross floor area (sq ft)

Calculated total annual purchased site energy usage (TMBtu) 0

Select one of the following:

- **Case 1.** ENERGY STAR rating (0-20 points)
- **Case 2, Option 1, Path 1.** Benchmark against typical buildings - National average data available (0-20 points)
- **Case 2, Option 1, Path 2.** Benchmark against typical buildings - National average data not available (0-14 points)
- **Case 2, Option 2.** Benchmark against historical data (0-14 points)
- **Case 2, Option 3.** Benchmark against both similar buildings and historical data (credit only) (0-20 points)

Figure 3 – Example of the use of procedure for prerequisite EA p2 Minimum Energy Performance: on a) options inside the prerequisites; on b) table inserts in section "documentation required"; c)number and types of internal prerequisites; d)period and description of performance period; d) form requested from USGBC; e)normalization of total scores.

At the end of this procedure, each prerequisite could achieve a single score given by the normalization of scores of all options. In this way it's possible to create an order of workflow starting from the prerequisite that has a higher score till the smaller or to the related prerequisite; indeed, prerequisites related to other prerequisites lose their scores and they follow the related prerequisite, because their relation allows to take on the same theme only once. This methodology is applied for LEED O+M v4 and it gives a classification of prerequisites, as seen in the Figure 4 below.

This methodology rewards energetic aspects in prerequisites and, indeed, the results of work classification confirms LEED's goals: to optimize the use of natural resources, promote regenerative and restorative strategies, maximize the positive and minimize the negative environmental and human health consequences of the industry, and provide high quality indoor environments for building occupants.

WORK CLASSIFICATION

	PREREQUISITE	SCORE
EA p2	Minimum Energy Performance	14,4
EA p1	Energy Efficiency Best Management Practicies	~~9~~
EQ p1	Minimum Indoor Air Quality Performance	~~9~~
EA p3	Building-Level Energy Metering	~~10~~
MR p1	Ongoing Purchasing and Waste Policy	9,25
EQ p3	Green Cleaning Policy	7
MR p2	Facility Maintenance and Renovation Policy	~~2~~
EA p4	Fundamental Refrigerant Management	6,6
WE p1	Indoor Water Use Reduction	6,5
WE p2	Building-Level Water Metering	~~6~~
EQ p2	Environmental Tobacco Smoke Control	6
SS p1	Site Management Policy	3

Figure 4 – Work classification of prerequisites for LEED O+M; scores of prerequisites related to other prerequisites are crossed.

3.2. Credit's selection and classification

LEED's goals, explained in the introduction, drive the weighting of points toward certification. Each credit in the rating system is allocated points based on the relative importance of its contribution to the goals. The results is a weighted average: credits that most directly address the most important goals are given the greatest weight [8].

Credits are the part where points are awarded and each credit has a different score. Since to follow all credits can deter surveyors and technicians from obtaining certification, it's necessary to create a selection with the purpose to obtain the LEED certification considering minimum number of documentation for each credit according to its weight.

The selection is created with a mathematical calculation, considering the score and other two new characteristics: relation and frequency. Relation affects how many relations the credit has with other credits; frequency regards instead how many times the credit is mention in other credits.

According to the proposed methodology, the phase 2A regards the process of selection, as described subsequently. First, within the credit, the options are selected on the base of containing the minimum and the maximum number of documents. Then a new parameter of credit is proposed: the so called "summary" credit is defined by the consideration of the given score (maximum points achievable) and by the evaluation of the relation between credit and prerequisite alongside the frequency, and relation of a single credit within other credits.

$$Summary\_Credit = point + frequency + relation \qquad (1)$$

For example, the credit EA c4 Optimize Energy Performance has a weight of 20 points, is mentioned 10 times and has 4 relations with other credits or prerequisites. This evaluation gives the basis to choose one or another option within the same credit, due to the weight of the three parameters in the same credit.

Suddenly, to obtain a choice of credits, a mathematical calculation considers the sum of previously defined characteristics of each single credit ("summary credit"), the two types of option selected (minimum and maximum documents required) in relation with the required documents. If x is the summary credit and y is the documentation required, the function (2) calculates the selection of credits: it is defined only for this type of rating system because it contains the ten best credits.

$$y \leq 3/10\, x \qquad (2)$$

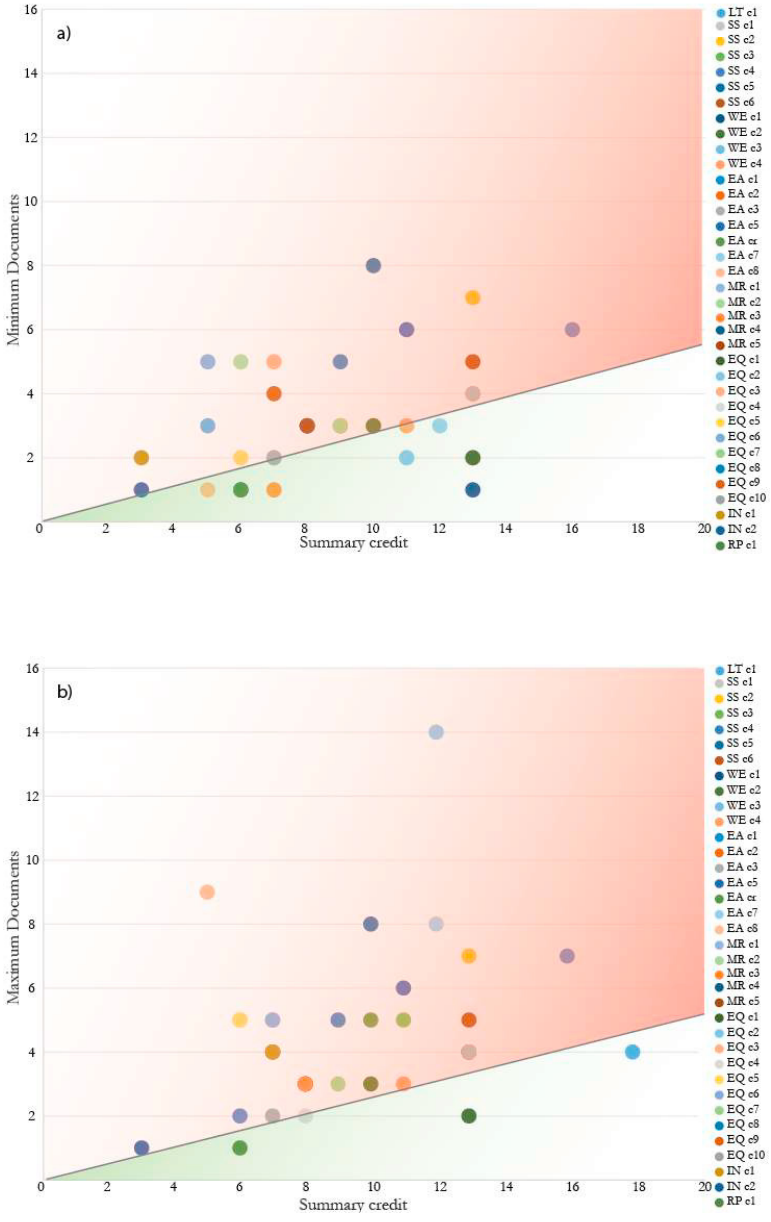

Figure 5 – Selection of ten important credits: on x axis, number of summary credit, on y axis, number of documents, in particular minimum documents in a) and maximum documents in b); the chosen credits lay below the line, according to function $y \leqslant 3/10x$.

This method allows to identify a selection of ten credits with best value. In Table 2 they are showed from the higher score.

Table 2. Ten selected credits with best value of ratio summery credit/number of documents; score a) minimum number of document, score b) maximum number of documentation.

Credit	Score a)	Score b)
WE c1 Outdoor Water Use Reduction	11	
EA c4 Optimize Energy Performance	8	
MR c3 Purchasing – Facility Maintenance and Renovation	5	
EQ c4 Interior Lighting	5	
SS c1 Site Development – Protect or Restore Habitat	5,5	
EQ c1 Indoor Air Quality Management Program	5,5	5,5
SS c4 Light Pollution Reduction	4	
EQ c2 Enhanced Indoor Air Quality Strategies	4,5	
EA c7 Renewable Energy and Carbon Offsets	3,34	
LT c1 Alternative Transportation		4

For example, the credit EA c4 Optimize Energy Performance is selected due to the achievable point 8,5 referred to 34 points from the summery score and 4 required documents. According to the proposed methodology, the phase 2B consists in a workflow that organizes the ten selected credits in a chronological and operative order. Indeed, a new type of order and score is assigned to the credits selected in phase 2A.

Suddenly, a process is developed for organize credits, employing a score system according to internal options, see Table 3: for each document requested (one point for each document), considering relation with prerequisites (one point for each relation with prerequisites), credits inside (one point for each internal credit), performance period (No points if not present, two points for every five-yearly audit or maintenance after the certification and three points for the collection of data before the certification) also the type of form requested from USGBC (meaning one point if easily to fill or two points if calculation is required and three points if the form is more complex).

Table 3. Score system for credits according to internal options: parameters are the requirements contained in every credits and score is the score system.

PARAMETERS	SCORE
Documents requested	1 point = 1 document
Relation with prerequisites	1 point = 1 relation with prerequisite
Credits inside	1 point = 1 internal credit
Performance period	0 point = not present 2 points = five-yearly audit or maintenance after the certification 3 points = collection of data before the certification
Type of form	1 point = easy to fill in 2 points = calculation required 3 points = form is more complex

This process, applied to classify credits, differs from the previous method, developed for prerequisites, because in the case of credits classification the relation between both credit and prerequisite is considered.

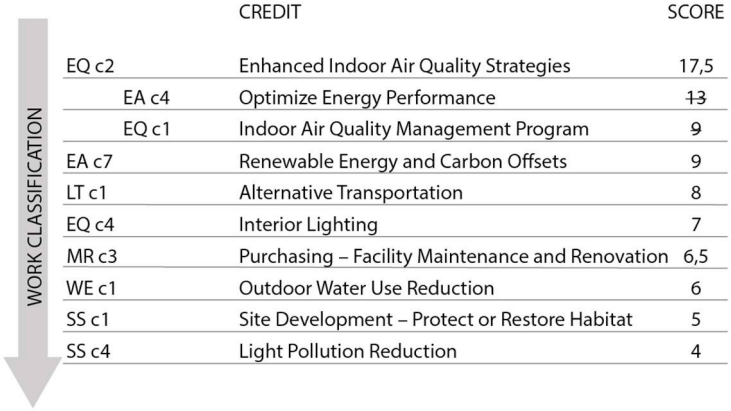

Figure 6 – Work classification of credits for LEED O+M; scores of credits related to other credits are crossed.

4. Case study: Ca' Rezzonico

The method is being validated on a case study: Ca' Rezzonico, Museum of 18th Century Venice, in Venice. The building is the subject of the certification process in LEED O+M: a preliminary assessment has been developed according to the evaluation and the selection criteria of credits as exposed in this research. This palace was designed in Baroque period and after some restoration works it was adapted to serve as the museum opening to the public on 1936: the quality of the numerous works exhibited, together with the extraordinary quality of the architecture and the setting, made Ca' Rezzonico a veritable temple of the Venetian 18th century.

The Fondazione Musei Civici Venezia manages and promotes the museum; the foundation selected this building as pilot case to verify the possibility to access to LEED for all his museum system with the aim to achieve a certification.

According to the method, phase A has been applied, in order to achieve the prerequisites collecting all documents required for checking the access to certification. Following the Work classification of prerequisites on Figure 4, prerequisite EA p2 is the first one to be developed, considering the operating energy performances. In this case Ca' Rezzonico museum presents characteristics such that it's not eligible to receive an energy performance rating using the Environmental Protection Agency (EPA) Energy Star Portfolio, so the prerequisite has been achieved by the collection and the evaluation of the energy performances of the last years and by the comparison with similar buildings. the building's site energy data for the previous 12 months has been compare with the data from three contiguous years of the previous five, normalized for climate, building use, and occupancy, and it was demonstrated a 25% improvement.

Table 4. Example of relation between the first four prerequisites according to the work program inserted in Figure 4. The required documentation is listed for each prerequisites and the relations are shows by colored words.

	REQUIRED DOCUMENTATION
EA p2	• meter calibration report • Energy Star Portfolio • utility bill summary pages of performance period for each fuel source • weather-normalized source EUI • calculation supporting additional normalization
EA p1	• preliminary energy use analysis • energetic audit • current facility requirements and operations • and maintenance plan
EA p3	• confirmation of permanently installed meters • letter of commitment • confirmation of data sharing source
EQ p1	• measured outdoor airflow rates • information about ventilation • ventilation maintenance program • table with occupied rooms, spaces, or zones

In the next step the work program considers the real relations with other prerequisites in terms of documentation and evaluation of data. In fact, the elaboration and the development of documents for the prerequisite EA p2 could be useful for subsequent prerequisites (see Table 4), for example the meter calibration report assumed the collection of documents of permanently installed meters as required in prerequisite EA p3; the utility bill summary pages of performance period for each fuel source represents the preliminary assessment of energy performance in prerequisite EA p1; the energy audit required the setting up of schedules about occupation of the building could be interesting for the prerequisite EQ p1, regarding the minimum indoor air quality Performance. These could be considered as example about existing connections the first prerequisites and confirm the need to be addressed as explained and organized in the methodology.

5. Conclusions and recommendations

This methodology has proposed a simplified application of LEED rating system and the mathematical approach allows to select a list of useful credits and to organize the requested documentation to fill for achieving the certification. In fact the methodology gives major attention to the strongest credits that have the most points and, in the best case scenario, require the least work in terms of documentation. Due to the workflow obtained by the application of these processes, the technicians can make efficient and conscious time-management choices from the difficult first steps through to the culmination of the certification.

This research achieves the aim of identifying a list of 10 credits representing the starting point for the LEED O+M certification; as consequence the gained LEED score could be expanded by adding more credits to be achieved.

The selection system proposed in the research is based on the characteristics of the LEED O+M: each LEED rating system presents the same structure and the same categories, but the requirements, correlations, the weighing and the scores are different. For this reason, one of future developments will be the verification of the validity of the method for identifying the selection system of credits for LEED protocols. As seen this study has already been proposed for new LEED rating system, GBC Historic Building protocol; a work in progress concerns others rating systems: it will be necessary to proceed the method, to create the ratio (3) and to find the selection of ten best credits.

$$ratio = \frac{Summary\_Credit}{required\_documents} \qquad (3)$$

The methodology has been evaluated by a preliminary assessment of prerequisites testing on an historic building, the Ca' Rezzonico Museum of Venice, the next steps concern the validation of the work frame also in relation to the credits and the whole rating system, with the aim to optimize the elaboration of data for achieving the certification.

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