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Building Envelope: Assessment and Certification of Its Performance — The Rating

Valentina Puglisi

Polytechnic of Milan, Department of Architecture, Built Environment and Construction Engineering, Italy

Abstract: High quality buildings are usually qualified by the real estate market with the term “Class A”. This definition, taken from models of financial rating, doesn’t correspond to a precise, objective and scientific identification of the elements that determine it: elements as the “flexibility of the surfaces”, “high standard plants”, the presence of “raised floors” or other features that characterize the building’s equipment, are generically listed.

The envelope rating system’s aim is to spot elements that can objectively identify the level of “quality” of a building envelope.

The purpose of this system is to support the design of building envelopes and it wants to clarify if indeed a redevelopment may or may not be functional in terms of technology in order to reduce energy consumption of buildings.

Starting from the study of the national and international rating systems existing, five areas of analysis have been identified in the envelope rating system and each of them has been divided into groups and subgroups. Each area of analysis has received a weighted score according to its level of importance. In conclusion the rating system enables to obtain a total score that classifies the level of “quality” of the building envelope.

Key words: rating system, building envelope, performances of building envelope, re-development of buildings, curtain wall

1. Introduction

A building's envelope, in modern architecture and in the construction market, is now not thought of as a simple division from the outside, but has acquired multiple functions due to the evolution of both buildings and materials [1].

“It is more and more significant the fact that the building envelope is defined not as an isolated object that is self-related, but as a “skin” or “membrane”, something that breathes and controls the mechanisms of exchange with the outside environment, in the sense of a building, as a living entity, guaranteeing the upkeep of optimal living conditions inside it, thanks to a metabolic exchange of mass and energy with the surroundings” [2].

The re-development of buildings now represents an innovative approach that pays particular attention to the potential for transformation of the property, placing it in relation to the urban context and the needs of the market, increasing its profitability [3].

In the re-development process, the renovation of the building envelope has a decisive role. A product that is correctly enhanced is subject to a simple insertion in the market and it adds value to the investor and to the context where it is set.

2. The Building Envelope in the Italian Market

According to the Uncsaal report, the sector related to the production of façade components, despite a physical decrease in production due to the ongoing economic crisis, is following a path towards a constant evolution and innovation of products, which aims to produce innovative and energy-efficient components [4].

Corresponding author: Valentina Puglisi, Ph.D., Research Fellow and Lecturer at ABC Department, Polytechnic of Milan (Italy); research areas/interests: building envelope, rating systems, refurbishment. E-mail: valentina.puglisi@polimi.it

Today the sector of the building envelope is characterised by a high fragmentation of supply and by the predominance of small companies, often generic ones. Data supplied by the *Agenzia delle Entrate* (Inland Revenue) in 2011 indicate that there are 12,068 companies in clusters related to the production of metal doors and windows. In the majority of cases, these were individual firms (6,687 companies) or small artisan companies (3,525 companies). Only 1,857 companies (15% of the population) are corporations, of which most are small [5].

The companies that operate in the sector of metallic doors and windows are of two types: non-specialised producers of doors and windows (generic companies that produce doors and windows) and companies focused on the continuous façade (curtain wall companies). The average size of the curtain wall companies are considerably larger than those of companies producing doors and windows, with an average production turnover over 11 million euros with approximately 50 employees, versus 3.7 million euro production and around 25 employees for generic door and window producers [5].

Table 1 Breakdown of companies in cluster linked to the production of windows.

Activity	Number of companies
Manufactures of metal frames and curtain walls:	12.086
Company capital	1.857
Partnership	3.525
Sole traders	6.687

(Source: Uncsaal, “Rapporto Italiano sul mercato dell’involucro edilizio”, num 1, 2013, pp. 4-5).

Table 2 The size and the number of employees in companies operating in the field of frames.

	Average value of production	Average number of employees
Manufacturers of windows and facades	5.6	30
Manufacturers of windows	3.7	25
Manufacturers of facades	11.4	47

(Source: Uncsaal, “Rapporto Italiano sul mercato dell’involucro edilizio”, num 1, 2013, pp. 4-5).

3. International and National Rating Systems

In order to develop a rating model for the building envelope, systems used at a national and international level for the evaluation of the performance of the buildings, by functional and/or technological criteria, have been analysed.

“The majority of systems deal only with some of the variables considered fundamental for an overall valuation of the performance of a building: particularly spread are the aspects related to the containment of energy consuming and the compatibility with the environment” [6]. None of the analysed systems has the aim of evaluating the performance according to “transversal” criteria, regarding different thematic or scientific areas of the building envelope.

Today the valuation methods that are used are very varied and not well known; very often, especially in small companies, there is no knowledge of such methods. The reason for this is probably that the market itself does not contain systems that are recognised on an international level: in fact, some of these methods are strongly based on the national context where they have been developed. Fueling the uncertainty of companies who undergo the selection of a valuation method is the presence on the market of two types of methods:

(1) the “standards”: are systems that evaluate the presence of building services, types of services, infrastructure, etc. and are derived from “best practices” in the selection of building adopted by the major companies in the property market;

(2) the “labels”: are tags recognised by the market but, very often, evaluate only the environmental aspects of the building and can be applied to all buildings.

4. The Building Envelope Rating System

The rating system of the building envelope is sustained and is a completion of the BRaVe system (Building Rating Value) offered by the Polytechnic of Milan and is the result of a working group of the

	Location	Architecture	Technological flexibility	Furniture interior design	Structure	Building comfort	Care facility staff	Energy performance	Security	Safety	Rental value	Facility & building management	Year	Classification methods	Total number of parameters	Web based system	Benchmarking of buildings
BOSTI													1980	Different from building to building			
BQA													1985	Numerical scale	137		
BQI													2004	A, B, C, U			
BOMA													2007	A, B, C	100		
DQI													2007	Graphics			
International classification office													2006	A, B, C			
Logometrix													2006	Report indicating score			
Office class Bulgaria													2006	A, B, C	26		
Office classification ABCD													2006	A, B, C, D	50		
REN													1990	Comparison with examples	150		
Star office rating													2008	Stars from 3 to 5			
Politecnico di milano													2008	AAA, AA, A, BBB, BB, B, CCC, CC, C, D			

Fig. 1 The standards systems. (Source: processing author).

	Location	Architecture	Technological flexibility	Furniture interior design	Structure	Building comfort	Care facility staff	Energy performance	Security	Safety	Rental value	Facility & building management	Year	Classification methods	Total number of parameters	Web based system	Benchmarking of buildings
3^o system													2006	Stars from 1 to 3			
BREEAM													1990	Sufficient, good, very good, excellent			
DGNB													2008	Gold, silver, bronze			
EU Energy Pass													2002	A+, A, B, C, D, E, F, G			
Green building challenge													2000	Score scale			
HK BEAM													2003	Platinum, gold, silver, bronze			
LEED													2000	Platinum, gold, silver, certified			
NABERS													2009	Stars from 1 to 5			
Protocollo ITACA													2002	Scale scores and examples of buildings			

Fig. 2 The labels systems. (Source: processing author).

laboratory Gesti.Tec. The rating of the envelope represents an analytic system through which it is possible to examine in depth the elements that contribute to identifying objectively the level of “quality” of a building envelope with the aim of aiding the design of the systems of vertical closure so that it is possible to identify (clearly state) if a specific re-development can or cannot be functional with regard to the technological aspect. The system identifies different areas of analysis, each of them

distinguished by variables that contribute to determining the “performance” level of the envelope [7].

The system can be applied on tertiary building envelopes and, particularly on:

- (1) building envelope re-development in order to evaluate achieved improvements or reduction in performance;
- (2) pre-existing buildings to evaluate the performance characteristics of the envelope;

(3) buildings in design phase with the purpose of simulating various scenarios and implement the most suitable type of envelope.

The system requires the completion of a questionnaire that, for each item, offers a choice of responses or the simple indication of “yes/no”.

The survey questionnaire is filled in directly by the designer or by the person who has at his/her disposal the data of the original project and of the re-development project. It is composed of two parts:

(1) descriptive sheet that contains the general data of the property to be analysed;

(2) series of sheets regarding the technological/descriptive aspects of the envelope, its performance, intelligent characteristics, the security and maintenance regarding the property before and after the re-development.

The rating system that is proposed considers 5 families (envelope, technological performance, intelligence, security and maintenance), each of which is divided into different groups (factors) and subgroups (parameters), for a total of 45 entries examined.

Specific scores are allocated for each family, factor and parameter, each of them weighted by its level of importance. The criteria that led to the definition of the scores was that of pairwise comparison, that has allowed the classification of families, factors and parameters in relation to the importance attributed to them in contributing to the determination of the quality of the building envelope of a tertiary building, in terms of performance. Specifically, the envelope has received a score of 30 points, with 35 points for technological performance, 14.50 points for intelligence, 10.50 points for security and 10.00 points for maintenance. The sum of these points is equal to 100.

Upon receipt of the completed questionnaire, the data is entered into a database from which an output is generated that allows you to represent numerically and graphically, the result of the evaluation.

In the tables generated by the system for each factor and parameter the following are represented:

(1) the maximum achievable score;

(2) the score the building has achieved before the re-development operation;

(3) the score the building has obtained after the re-development operation.

The total mark generated by the rating system, expressed as a percentage, classifies the “quality” level of the building envelope. On the basis of the score obtained it is possible to associate the analysed building to a marking scheme that defines the value of the rating (AAA, AA, A, BBB, BB, B, CCC, CC, C, D). This score is then described by a radar chart that represents the result obtained for each family in percentages. The representation of the results of the rating system is derived from histogram charts where are highlighted as an absolute value: the maximum score that can be obtained (left column), the markings that are actually obtained by every factor and parameter that have been analysed before (central column) and after (right column) the valorisation operation.

This allows a clearer view of the improvements/worsening that have occurred as a result of the re-development operation for the five analysed families.

5. The Generali's Building in Milan



Fig. 3 The property in via Vespucci before the re-development operation to the building envelope. (Source: General Planning).



Fig. 4 The property in via Vespucci after the re-development operation to the building envelope. (Source: General Planning).

The property in via Vespucci was built in 1969 as a project of the Social Study of Architecture. At the beginning of 2006 the property in via Vespucci became inadequate to host companies requiring modern offices. However, the location on the axis of Porta Nuova and the proximity to the central station, allowed the property to return to being competitive on the market.

The re-development project, as well as giving a new identity to the property, should have turned it into a building oriented to energy saving. The intervention adopted, proposed by the General Planning study, was inspired by the particular urban context in which the property is situated and the angular and irregular geometries of building elevations that follow the trapezoidal lot.

The architectural concept interprets the dialectic between the historic town and the new Milan skyscrapers, creating a virtual "bridge" between the two urban realities. The design is characterized by the modern profile of the volume and the use of materials with two different colours, white and dark blue, giving the complex a captivating look. The areas of intervention that the study General Planning has identified as a source of increase of the value of the property were:

- architectural redesign of the facades and modification of the roof structure;

- translation of the gross floor area on the top floor and extension of the atrium;
- transformation of the small portion of residential area in offices;
- design of a new bright hall;
- redesign of all the areas of common use and renovation of services;
- renovation of the public area outside the building and of the access to the underground parking;
- reduction and improvement of the commercial image of the ground floor.

The project involved the construction of different types of facades according to the orientation of the building.

On the South, East and West elevations a ventilated façade was provided featuring two-tone bands that demarcate the floors with white painted aluminium shading blades to counter the solar radiation of the glass. The facade consists of a series of functional layers bound to the building by means of a metal structure and an air gap which improves the thermal comfort. The parapets are covered with bands of industrial serena blue granite slabs together with protective elements of horizontal anodised aluminium. The windows (with thermal break) are of painted aluminium with transparent tempered glass double glazed units. Glass partitions both fixed and openable ensure high performance in terms of air and water impermeability, safety, thermal and acoustic insulation.

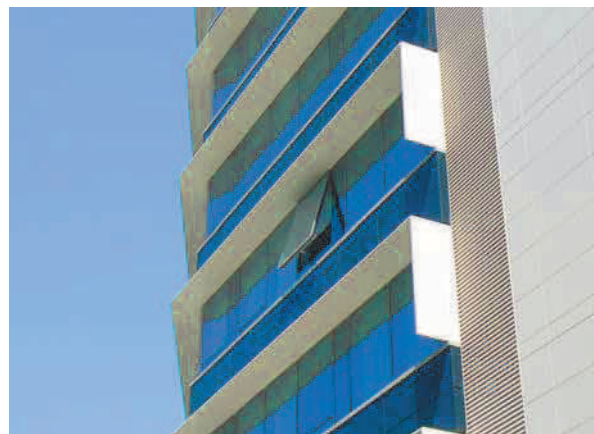


Fig. 5 Particular of the parapets of the building. (Source: General Planning)

On the north side a continuous structural facade has been built, made of fixed glass units that can be opened to protrude from mullions and transoms of painted aluminium. The transparent surfaces utilise selected low emissivity glazing with a thermal conductivity of $1.10 \text{ W/m}^2\text{K}$, while the total conductivity of the elevation is approximately $1.58 \text{ W/m}^2\text{K}$. The matt surfaces are formed by sandwich panels of about 5 cm width with a smooth pre-painted finish with an extra layer of high density isolating material of 8 cm giving a total width of 13 cm, with a total thermal conductivity of around $0.34 \text{ w/m}^2\text{K}$.

The facade that overlooks the internal terrace is instead made out of glass elements, that are fixed or openable and formed with extruded aluminium profiles, with semi-structural technology. The parapets external panels are similar to those of main facade with modules of dark blue Serena stone. The insulating material of the roofs and terraces is an insulated panel of expanded volcanic rock (perlite) of 7 cm width and asphalt binders.

The rating system of the building envelope applied to the building in via Vespucci has led to the identification of two markings:

- before the re-development operation the building achieved a score of 22.7;
- after the re-development operation the building achieved a score of 84.2.

		BEFORE		MAX	AFTER		
Type 1	Type 2	%	Score	Max Score	%	Score	
1	ENVELOPE	1.1 Relationship with Form	67%	2	3	67%	2
		1.2 Type of envelope	20%	1,5	7,5	100%	7,5
		1.3 Openings	42%	4	9,5	95%	9
		1.4 Facade Shading	83%	7,5	9	89%	8
		1.5 Roof Shading	10%	0,1	1	90%	0,9
2	TECHNOLOGICAL PERFORMANCE	2.1 Energy Class of the Building	3%	0,1	4	70%	2,8
		2.2 Thermal Conductivity	7%	1,5	20,5	100%	20,5
		2.3 Light Transmission	33%	1	3	67%	2
		2.4 Sound Insulation	9%	0,5	5,5	100%	5,5
		2.5 Meccanical ventilation	0%	0	2	100%	2
3	INTELLIGENCE	3.1 Intelligent Systems	0%	0	6	83%	5
		3.2 Photovoltaic system and presence of renewable energies	0%	0	7	0%	0
		3.3 Communication	0%	0	1,5	67%	1
4	SECURITY	4.1 Security glass	0%	0	8,5	100%	8,5
		4.2 Control systems	0%	0	2	0%	0
5	MAINTENANCE	4.3 Ordinary maintenance	0%	0	5	90%	4,5
		4.4 Maintenance Systems and tools	90%	4,5	5	100%	5
TOTALE		21%	22,7	100	77%	84,2	

Fig. 6 The results of the rating system. (Source: processing author).

The situation has changed from a classification of the envelope that would have been “C” to a stage greater than an “A”. The building, before the re-development operation, was globally represented by a very low quality level. Each family is in fact represented by a quality level inferior to 50%. In particular the technological performance and the level of intelligent systems do not reach 10%.

After the re-development operation, the gaps have been reduced, even if not in a thorough way, enabling the envelope to reach a high qualitative level.

While the 4 families related to the envelope, technological performances, security and maintenance reach scores greater than 80%, the family related to the presence of intelligent systems remains a weak spot where there have been few enhancements.

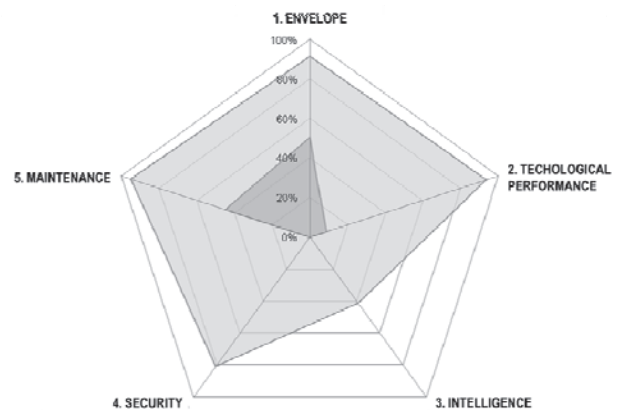


Fig. 7 Radar representation of consequent score in different families. (Source: processing author)

RATING	SCORE
AAA	100 - 95
AA	94 - 90
A	89 - 80
BBB	79 - 70
BB	69 - 60
B	59 - 50
CCC	49 - 40
CC	39 - 30
C	29 - 20
D	< 20

Fig. 8 Envelope rating of via Vespucci building before and after the re-development operation. (Source: processing author)

The quality level of the envelope, thanks to the building re-development, has increased from 50% to 91%.

The main points noted after the re-development are:

- type of envelope: the existing curtain wall, characterised by projections and thermal bridges over its entire surface, has been substituted by various types of façade (structural, ventilated and continuous);
- openings: new windows have been installed with thermal breaks and selected glass;
- façade shading: white shading blades were introduced along the lines of windows instead of the more common venetian blinds;
- roof shading: shading has been added with a southerly orientation.

The things that have remained unchanged, even if they are not weak spots, are:

- the proportion of the building, since no volumetric changes have occurred in the building;
- the material of the window frames that has remained aluminium.

The building re-development has resulted in a clear improvement in technological performance of the building envelope. The quality level of these has increased from 9% to 94%.

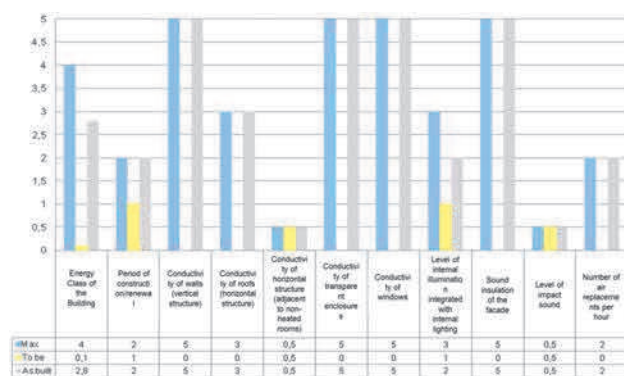


Fig. 9 Histogram representation of the maximum score achievable and of achieved scores before and after the re-development operation, of the parameters related to the family “technological performance”. This graph, in the envelope rating system, is displayed for every family examined. (Source: processing author)

The main points noted after the re-development are:

- the energy class of the building has improved from an unclassified level to a class “C”;
- thermal conductivity: due to the redevelopment the values of conductivity of the opaque horizontal structures (roofs), of the transparent enclosures and of the windows have all been lowered beneath legal limits (D.L.gs. 29/12/06 n.311);
- light transmission: the levels of internal illumination, due also to the integration of artificial light systems, has been improved from an average of 240 lux to approximately 350 lux in working stations (Norma UNI EN 12464-1);
- façade sound insulation: this has also met legal requirements (DPCM 5/12/1997 “Determination of passive acoustic requirements of buildings”);
- the number of air changes per hour, which before the redevelopment were inexistent, now meet current legal requirements (D.M. 05/07/1975 e Canada Labour Code [8]).

The only aspect that has remained unchanged is the thermal conductivity of the horizontal opaque structures adjacent to non-heated rooms, where no structural/typological changes have occurred. Also in this case no weak spots have been identified.

The quality level of the intelligence of the envelope, following the redevelopment, has increased from 0% to 41%. The main points noted are:

- intelligent systems: systems for heat recovery were introduced for the different plants of the different areas and control systems for cooling, ventilation, heating which were previously absent;
- communication transmitted by the building: this has seen a qualitative leap but only due to the impact of the architectural design.

The things that have remained unchanged, but represent weaknesses, are:

- the absence of a photovoltaic system and renewable energy sources;
- the absence of communicative systems on the façade such as rear projection, screens, etc. that would

enhance the communicative capacity of the building with its surroundings.

The level of security around the envelope, thanks to the building re-development, has increased from 0% to 81%. The main points noted after the redevelopment are:

- the using of security glass like anti-injury, anti-fall and anti-burglar-vandalism-crime;
- the CE branding of the glass.

The thing that has remained unchanged, and remains a weakness is the absence of security (anti-burglar) control systems directly applied to the envelope.

The quality level of the family regarding maintenance has passed from 54% to 95%. The main points registered after the building re-development are:

- the constant implementation of a maintenance program during the years considered;
- the possibility of lowering mobile scaffolding from the roof and allowing a ladder within 5 m of the building so that some external maintenance can be easily done;
- a high availability on the market of replacement components for the envelope.

The main issue which has remained unchanged and is a weakness for the building is that the building does not use self-cleaning glass which would ease the cleaning maintenance of the envelope.

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