Cladding Materials in Non-Residential Construction: Choice Criteria for Stakeholder in the Province of Quebec

Samuel Guy-Plourde[1], Pierre Blanchet[2], Michel de Blois[3], François Robichaud[4] and Costel Barbuta[5]

1 Department of Wood Sciences, Industrial Research Chair in Ecoresponsible Wood Construction, Laval University, Pavillon Gene-H.–Kruger, 2425, Rue de la Terrasse, Québec, Québec, G1V 0A6, Canada. (Corresponding author) Email: Samuel.guy-plourde.1@ulaval.ca

2 Department of Wood Sciences, Industrial Research Chair in Ecoresponsible Wood Construction, Laval University, Pavillon Gene-H.–Kruger, 2425, Rue de la Terrasse, Québec, Québec, G1V 0A6, Canada. Email: Pierre.Blanchet@sbf.ulaval.ca

3 Laval University Design School, Édifice La Fabrique, bureau 3132, 295, boulevard Charest-Est – bureau 090, Québec, Québec, G1K 3G8, Canada. Email : Michel.deBlois@design.ulaval.ca

4 Forest Economic Advisors, 298 Great Road, 01460, Littleton, Massachusetts, USA. Email: frobichaud@getfea.com

5 FPInnovations, 319 Rue Franquet, Québec, Québec, G1P 4R4, Canada. Email: Costel.Barbuta@fpinnovations.ca

Abstract

Designing the façade of a building is a complex task due to the number of products that are offered, the multiple criteria to be considered, and the number of stakeholders involved. In this context, from a manufacturer point of view, it is critical to understand the decision-making process. This paper highlights three different categories of choice criteria (influence criteria, requirements, and issues) relative to the selection of cladding material for non-residential buildings. Architects, contractors, subcontractors, and clients provide a systemic view of the situation, based on an analysis of the findings from a mixed-research method combining online survey and semi-structured interviews. The results show that the most important influencing criteria for cladding selection are the building type, client type, project context, personal experience, product reputation, and project delivery methods. For the architects, the most important requirements are, in order, performance, appearance, and good warranties. Contractors and subcontractors look primarily for compliance with the delivery schedule, with an optimal deadline of fewer than three weeks. Regarding installation, subcontractors seek speed of installation, system simplicity, easy coordination with envelope workers, and on-site product modulation. Finally, the main issues with cladding are maintenance, the novelty of cladding systems, lack of construction details, and tendering process. A better understanding of the cladding selection process provides valuable insight to the manufacturer in order to provide the right information to satisfy a particular stakeholder's need.

Keywords

choice criteria, material selection, cladding, non-residential construction, construction stakeholders

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1 INTRODUCTION

The process of selecting materials with respect to their function is a fundamental task for architects in the design process of a building. Designing façades is particularly challenging. The choice must be carefully considered, as the façade becomes the visiting card of the building. The technical and aesthetic elements must be properly balanced " to create the vocabulary for understanding and wielding material" (Borden, 2009). Cladding materials must meet three basic criteria; 1) to protect the enclosure from weathering; 2) to resist shocks; and 3) to satisfy the aesthetic appearance (Herzog, Krippner, & Lang, 2007). The number of stakeholders involved in the decision-making process (client, architect, general contractor, and subcontractor) complicates the material selection process since each of them has specific stakes. This makes it difficult to reach a consensus in a multi-disciplinary team (Šaparauskas, Kazimieras, Zavadskas, & Turskis, 2011).

Successful product development and marketing campaigns are based on the solid identification of stakeholder's needs and an understanding of the decision-making process. Considering the number of competing materials, the variety of factors that drive the design and the number of stakeholders involved in the non-residential construction industry, the aim of this exploratory study is to outline which choice criteria are involved in decision-making for the exterior cladding materials during the construction process phases. To achieve this goal, choice criteria were analysed according to: 1) the criteria that influence the selection of cladding materials; 2) the requirements; and 3) the issues relative to the their selection. The study was undertaken in the province of Quebec, Canada. The proposed study is original since its fills the gap of scientific knowledge, which unifies multiple choice criteria, exterior cladding material, non-residential construction, and multiple stakeholders. Ultimately, the results allow the different stakeholders, mostly the manufacturers, to understand the process of cladding material selection regarding the most important choice criteria. The following sections present a literature review, then the online survey and the interviews methods are covered with their underlying motivations, methodology, and results. Finally, the discussion presents the most important choice criteria of the cladding construction process and presents opportunities for innovation.

2 LITERATURE REVIEW

2.1 CLADDING IN NON-RESIDENTIAL CONSTRUCTION

Cladding is the outermost layer of the envelope of a wall that encloses a building. It is the most visible part of a building and the most exposed to weather. The main function of cladding is to provide shelter from the elements. It protects the inner layers from weather elements. As a decorative function, cladding defines the building's aesthetic. Typically, the cladding is a non-loadbearing component. The cladding is designed to support its own weight, withstand temperature variations, and support loads of wind, snow, and impacts. It is usually used in conjunction with a structural frame for load transfer (Gorse, Johnston, & Pritchard, 2012). In North America, commonly used cladding materials to construct the façades of non-residential buildings are stone, materials with mineral binders such as precast concrete, ceramic materials, glass, metals, timber, synthetic materials, render/plaster, cladding bent in mortar, and thermal insulation composite systems (Hegger, Auch-Schwelk, Drexler, & Zeumer, 2006). Each group has different sub-categories with different characteristics. Therefore, the specifications and constraints of each project must be well analysed and understood by the decision makers in order to meet client's objectives.

It is important to distinguish the single household market from the non-residential market. Non-residential buildings include buildings designed for commercial, industrial, and institutional purposes. In building codes, large residential buildings are mostly treated like non-residential buildings, and as such can be included as part of the investigation. This study focuses on non-residential buildings since they are considerably different from residential buildings in terms of building size, materials, specifications, design, and cost (O'Connor, Fell, & Kozak , 2003). From the manufacturer's point of view, non-residential construction has a important economic potential as its value typically equates the residential market and tends to be less cyclical than the housing market (Kozak and Cohen 1999; O'Connor et al., 2004). Moreover, the non-residential market is strongly increasing due to densification of urban centers (FPAC, 2013; UNESCO, 2010).

2.2 SUPPLY NETWORK AND PROCESS

The supply chain of cladding includes the client, the architect, the general contractor, the subcontractors, the distributor, and the manufacturer (Fig. 1). Because of its high complexity, this supply chain would be better described as a supply network (Ledbetter, 2003). The nature of exchanges between stakeholders involves topics such as information, costs, production, services, and value (Du, 2009). The traditional mode, also known as design-bid-build, is the most common method in the province of Quebec. There are possible variations of the traditional model for delivery method and manufacturer structure (Fig. 1). The traditional model relies on fixed contracts. First, the client awards the contract to professionals (architects and engineers) for the design stage. Then, the client awards the second contract to the general contractor for the construction stage (For reading clarity, the term "contractor" will be used).
Stakeholders have well-defined roles in non-residential building projects.
The client is generally the one who sponsors the real estate project. There are two types of clients: public and private. Architects are the main decision-makers for the prescription of non-structural materials in non-residential buildings (Garmston, Pan, & De Wilde, 2012). The contractor's major role is to plan, coordinate, and supervise the work of the subcontractor. Then, the subcontractor purchases the cladding system from a distributor and installs it. Usually, the distributor is different from the manufacturer. The distributor can be a general building materials distributor such as a hardware store or a cladding specialised distributor. Fully integrated manufacturer companies are only encountered in large and expensive contracts (Ledbetter, 2003).

2.3 MATERIAL SELECTION CRITERIA

A non-exhaustive literature review revealed different strategies for the characterisation of the main choice criteria for cladding materials. Major databases in construction sciences (Compendex, ScienceDirect, Web of sciences) were searched using specific keywords (decision-making, material selection, building, façade, cladding, siding, criteria, and issues). Because of their accurate description of very important building construction selection criteria, seven documents were considered major and relative to the subject under study. The studies, summarised in Table 1, were analysed according to the four dimensions: the domain, the object, the subject, and the results. This method for analysing literature content was inspired by Kassem and Mitchell study (2015).
The domains are the type of building analysed. It can be general buildings, single-home residential buildings, or non-residential buildings. The object can be as general as the material, or be specific to the façade function, or even more related to the exterior cladding. Finally, the subject refers to

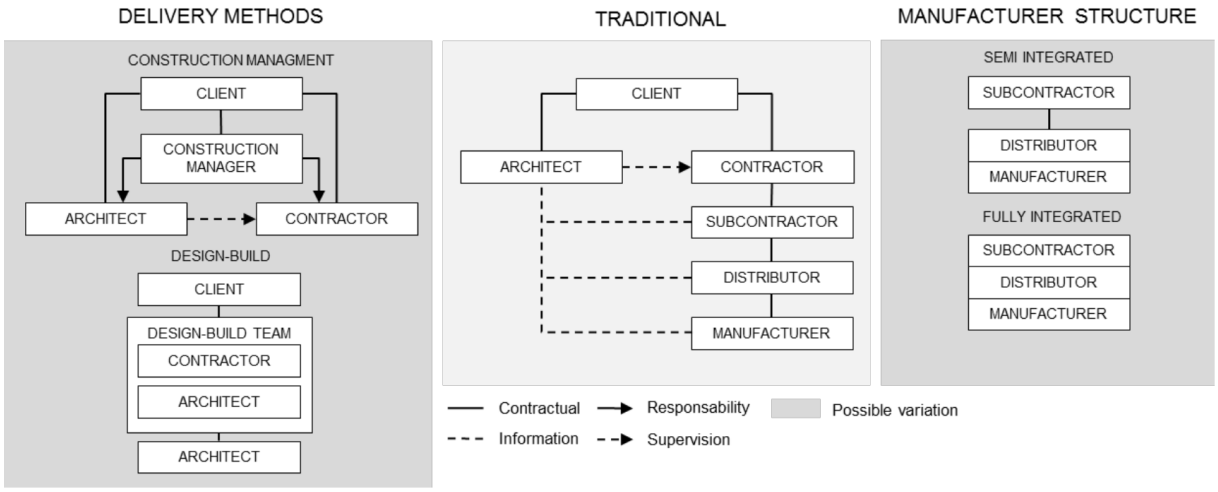

FIG. 44 Supply networks for exterior cladding and possible modifications for project delivery method and manufacturing structure (adapted from Royal Architectural Institute of Canada (2009))

the actors involved in the study. Studies generally focused on architects since they are the main specifiers of materials in a construction project. Other subjects included contractors, specialist subcontractors, clients, and engineers. The analysis of three dimensions showed a lack of scientific knowledge for the exterior cladding material specifically in the non-residential construction. Table 1 also highlights other studies that consider the whole value network (client, architect, contractor, and subcontractor).

3 METHOD

To find relevant and effective answers/solutions to the diversity of problems observed and cited in the research questions, this study draws on the strengths of the instrumental collection of quantitative and qualitative research. This method allows a more exhaustive and differentiated knowledge of an observed phenomenon and problems herein. This mixed research method consisted of an online survey and semi-directed interviews (Amaratunga, Baldry, Sarshar, & Newton , 2002). Chronologically, the online survey preceded the semi-structured interviews. It was a process that aimed to gradually deepen the subject under study.

This study focuses on stakeholders from an East North American context (Quebec, Canada). The information gathered is based on a demanding northern climate characterised by a mix of cold and very cold climate zones (ASHRAE, 2007). Although the results of this study are of greatest interest for North Americans, they are also valuable for stakeholders in similar contexts.

3.1 ONLINE SURVEY

Architects are the main specifiers in the selection of a cladding material in non-residential construction. To better understand their principal choice criteria, an online survey was conducted. The online survey was selected as a first data collection method because it provides preliminary information quickly and inexpensively. Only the architects were targeted for the online survey since they are the main specifier of exterior cladding materials. Considering the exploratory nature of the survey, the architects were more easily reachable since they are all grouped under a professional body. The survey revealed that choice criteria were related to influence, requirement, and appearance during the cladding selection process. These results served as a basis for the development of the semi-structured interviews.

	DAMERY ET FISETTE (2011)	KASSEM & MITCHELL (2015)	WASTIEL & WOUTERS (2011) ARCHITECTS	HEGGER ET AL. (2007)	AKADIRI & OLOMOLAIYE (2012)	PAN EL AL. (2012)	SINGHAPUT-TANGKUL ET AL. (2014)
Domain							
Building		X	X	X	X		X
Residential	X					X	
Non-Residential	Identified gap						
Object							
Material			X	X	X	X	
Façades		X					X
Cladding	X	Identified gap					
Subject							
Client	X	X					
Architect	X	X	X	X	X		X
Engineer						X	X
Contractor	X	X				X	
Subcontractor	Identified gap						

TABLE 20 Literature review resumé according to the domain, the object, and the subject investigated

AUTHORS	CHOICE CRITERIA IDENTIFIED	
Damery et Fisette (2011)	Attribute Influence	Appearance and performance Product reputation and respondent's first-hand knowledge of the product. Less concerned with environmental record and service life
Kassem and Mitchell (2015)	Issues Influence	Inadequate knowledge of stakeholder and the late involvement of specialist façade Cost, familiarity and past experience, and aesthetics
Wastiel and Wouters (2011)	Selection	Context, manufacturing, material aspects and experience
Hegger, Drexler, & Zeumer. (2007)	Selection	Context of use, perception and ecological, economic, and technical properties
Akadiri and Olomolaiye (2012)	Selection	Aesthetics, maintainability, and energy saving
Pan, Dainty, and Gibb (2012)	Decision	Cost coupled with time and quality
Singhaputtangkul, Low, Teo, & Hwang (2014)	Selection	Appearance, initial cost, and health, safety, and security

TABLE 21 Literature review results according to the type of choice criteria

3.1.1 Method

To better identify important research themes and accurately represent stakeholder opinion, a high response rate was necessary. To maximise the response rate of the survey, the survey was designed according to the method devised by Dillman, Smyth, and Christian (2014). Completing the survey was simple and required little time (approx. 10 mins.) for the respondents. The questionnaire was devised in three parts. The first part collected information such as the profession and the region in which they practice in order to characterise the sampling. The second part aimed to understand the importance given by the respondents to different influences, requirements, and appearance criteria. Finally, the third part was open-ended and asked the architects to identify reasonable expectations for the long-term durability and the maintenance cycle of exterior cladding material in non-residential buildings. The questionnaire was tested with an architect and an external research manager in business intelligence to ensure the criteria and questions were clear and relevant. To measure and understand the opinion of architects, multiple-choice questions were based on a balanced Likert gradient scale (*i.e.* 1 = not important, 2 = somewhat, 3 = average, 4 = very, and 5 = extremely important). A free online-software (Lime Service) was used to conduct the survey. The architects were joined using a mailing list of the *Ordre des architectes du Québec* (OAQ). An Internet link was included in the bi-weekly newsletter sent to 3621 architects. Participation in the online survey was based on willingness. The voluntary participation induced the assumption that the respondents were concerned with the research question.

Results were analysed using the IBM Statistical Package for the Social Sciences (SPSS) Statistic 24 software program (International Business Machines Corporation, USA). The study selected the severity index analysis (SI) to rank the criteria for each category. The non-parametric procedure is more suitable than parametric statistics (mean, standard deviation, etc.) to rank the criteria and produce meaningful results (Chen, Okudan, & Riley, 2010; Johnson and Bhattacharyya, 1996.; Singhaputtangkul, Low, Teo, & Hwang, 2014). Equation 1 was used to calculate the SI value for each criterion.

$$\mathrm{SI} = \left(\frac{\sum_{i=1}^{a} \omega_i \frac{f_i}{n}}{a} \right)$$

Where i = point given to each criterion by the respondent, ranging from 1 to 5; ω_i = weight of each point; f_i = frequency of the point i by all respondents; n = total number of responses (n = 67 in this study); and a highest weight (a = 5 in this study). Chen et al. (2010) use the calculated SI value to categorise the criteria into five importance levels: High (H) ($0.8 \leq SI \leq 1$), High–Medium (H–M) ($0.6 \leq SI < 0.8$), Medium (M) ($0.4 \leq SI < 0.6$), Medium–Low (M–L) ($0.2 \leq SI < 0.4$), and Low (L) ($0 \leq SI < 0.2$).

3.1.2 Results

Sixty-seven architects completed the online survey. The response rate (1.72%) was not consistent with the literature (Akadiri and Olomolaiye, 2012; Damery and Fisette, 2001; Singhaputtangkul et al., 2014) but the number of respondents is still higher than in some studies (Damery and Fisette, 2001; Kassem and Mitchell, 2015; Singhaputtangkul et al., 2014). Moreover, the number of architects

Number of responses	Architects (%)	Sampling size	Response rate (%)	Region			
				Montreal	Quebec	South	Other
67	100	3621	1,86	35	11	9	12

TABLE 22 Characteristics of the respondents of the online survey

CHOICES CRITERIA	SEVERITY INDEX	IMPORTANCE LEVEL
Influence		
Personal experience	0,675	H-M
Product reputation	0,651	H-M
Municipal regulations	0,618	H-M
Client's choice	0,618	H-M
Technical data	0,573	M
Colleague's experience	0,570	M
Manufacturer reputation	0,552	M
Building Code	0,540	M
Cases studies	0,466	M
Manufacturer representation	0,412	M
Builder's choice	0,293	M-L
Publicity	0,281	M-L
Requirement		
Performance (long-term durability)	0,851	H
Appearance	0,806	H
Warranties	0,696	H-M
Design possibilities	0,687	H-M
Installation cost	0,645	H-M
Material cost	0,642	H-M
Environmental footprint	0,618	H-M
External recommendations		
Appearance		
Durability over-time	0,764	H-M
Fit with other materials	0,731	H-M
Possibility of changing color	0,675	H-M
Texture	0,660	H-M
Color weathering	0,642	H-M
Constructive truth	0,621	H-M
Related to building function	0,576	M

TABLE 23 Severity Index (SI) values and importance obtained for the different choice criteria

PERFORMANCE CRITERIA	MEAN YEARS (SD)
Long-term durability	40 (20)
Maintenance cycle	14 (8)

TABLE 24 Average values for the reasonable expectations for the two performance criteri

contacted represents the entire population of architects in the province of Quebec. The aim of the survey was not to create a statistical database but rather provides insight into choice criteria. Table 3 shows the general characteristics of the respondents. As shown in Table 4, the online survey identified the product's reputation and architect's personal experience as being the most important influencing criteria. Online survey results also show that municipal regulation is the third most considered influencing criterion tied to the client choice. Results also revealed that architect's three most important requirements in the choice of a cladding material are performance, appearance, and warranty. Conversely, the environmental footprint is the least important criterion. With regard to performance, Table 5 results indicated, on average, a 40-year period of long-term durability and a 14-year maintenance cycle to be reasonable expectations. Appearance is the second most important requirement. Appearance is a priority and serves the interest of the overall concept. The durability over time of the appearance is the most important concept. Another important aspect of the appearance is the fit with the other materials.

3.2 SEMI-STRUCTURED INTERVIEWS

Semi-structured interviews were the second data source used to investigate the different stakeholders' criteria for choice of an exterior cladding material during the construction process. Interviewed stakeholders included clients, architects, contractors, and subcontractors. This method was used to put the results of the online survey into perspective. It enriches the understanding of the data, completes it and contributes to their interpretation (Blanchet and Gotman, 2007). The semi-structured interviews were used to structure the conversation on specific subjects as well as to obtain in-depth information by offering the respondents the freedom to express their opinions in their own words.

3.2.1 Method

The interview questions were identical for all the stakeholders: clients, architects, contractors, and subcontractors. As shown in Table 2, it was important to have at least two participants for each group of stakeholders. The sampling includes stakeholders working in the province of Quebec who had relevant experience in the specification, design, and construction process of exterior cladding. In order to properly represent industry practices, it was important to interview clients from the public and the private sectors. Thirteen interviews were carried out with thirteen professionals, all from different companies. It was also important for participants to have been involved in the construction of different types of buildings. Participants were contacted by email from an internet industry listing data bank (iCRIQ) or because of their participation in a project whose construction site had been visited. Participation was based on willingness.

The interviews took place at the premises of the participants and lasted from 45 to 75 minutes. The interviews covered three topics. First, the questions were related to the role associated with different stakeholders in the decision-making process of choosing materials. Then, the interview discussed the influence, requirement and issues at different stages of a project: client's need, concept, technical design, call for tenders, distribution, installation, and maintenance. Finally, the innovation potential of the cladding industry was discussed. Interviews followed the approach advocated by Oppenheim (2000) that consists of diminishing the interviewer's contribution by minimising interactions while ensuring that the interviewee responds to the chosen theme.

The interviews were recorded and transcribed. The content analysis of the interviews validated, qualified, and deepened the results of online surveys. The methodology used for content analysis followed the coding approach proposed by Groat and Wang (2002). The analysis of the semi-structured interviews followed an iterative approach, which consisted of identifying the main themes, regrouping the data that had a similar meaning, synthesising the information, and finally interpreting the results according to themes and stakeholders. The software package N'Vivo (QSR International Pty. Ltd. Doncaster, Australia) was used to facilitate data coding. When subsequent participant interviews revealed no new information, data saturation was reached, which marked the end of the analysis (Mucchielli, 1996; Pires, 1997).

STAKEHOLDERS	POSITION	EXPERIENCE (YEARS)
Architect	Associated architect	20
Architect	Associated architect	20
Architect	Associated architect	17
Architect	Associated architect	20
General contractor	Project Manager	8
General contractor	President	30
General contractor	Project Manager	20
Subcontractor	Project Manager	8
Subcontractor	Project Manager	10
Subcontractor	Owner	10
Client	Strategic Planning Advisor	12
Client	Project Manager	5
Client	Construction Supervisor	8
Client	Architect	7

TABLE 25 Interview sample group: stakeholder, position in the enterprise and experience

3.2.2 Results

The results of the interviews made it possible to deepen several choice criteria and discover new criteria. Table 7 summarises the results of the interviews with a brief description of each criterion. For the influence criteria, the interviews mainly allowed to the improvement of the context of the project criteria, and the discovery of the project delivery method criteria. One limit of the online survey is that requirement criteria are only ranked relative to the early design stage of the cladding construction process. The interviews allowed a better understanding by producing new requirement criteria and including other project development stages (call for tender, delivery, installation). Finally, the issues criteria emerged exclusively from the interviews. Issues criteria occur at different stages of the construction process and they will be covered in depth in the next section.

4 INTEGRATED RESULTS AND DISCUSSION

Based on the findings from the online survey and refined by the semi-directed interview, this section presents a final categorisation of the stakeholder's choice criteria for the cladding

attainment process in a non-residential context. Choice criteria were regrouped in three groups: influence criteria, requirement, and issues. This section ends by discussing innovation potential in the cladding industry.

4.1 INFLUENCE CRITERIA

Influence criteria are parameters that vary according to each project. They have a direct impact on the concept development stage and the material choice. The following section clarifies the most important influence criteria for the concept development: type of client, project context, and personal experience.

CHOICE CRITERIA	DETAIL
Influence	
Client type	Public, private or real estate developer, budget
Building type	Design parameters, use, and building code
Project delivery method	Different stakeholders have influence on the material choice
Personal experience	Highly correlated to product reputation
Product reputation	Related to reliability/constancy and history of the product
Requirement	
Performance	No absolute value. Maintenance-free period of 25-year is acceptable
Appearance	Serves the overall concept. Architects look for unique materiality
Warranty	Could "kill" a choice of cladding. Crucial to understanding the warranty clauses
Information	Information data must be verifiable
Delivery schedule	Contractors and subcontractors expect honesty and rigor
Delivery delay	Less than 3 weeks represents a reasonable period
Supplier competition	Contractors and subcontractors seek for diversity for a type of material
Speed of installation	Products with low installation tolerance are cited as an example
Simple fastening systems	Avoid unique systems from a single company
Minimal coordination effort	Few workers and materials resources are preferred materials
Modulated on-site	Minimize the loss rate and offer modularity in case of breakage
Issues	
Novelty of a product	Stakeholders do not want to play the role of "product tester"
Construction details	Caused by a lack of experience, time and budget
Cost war	Engendered by the rule of the lowest bidder
Manufacturer integration	Complicated because of the rule of the lowest bidder
Oversea/custom product	Longer delivery delay
Maintenance culture	Knowledge transfer. Transmitted documents are not consulted
Manufacturer representative	Perceived like sellers instead of technical advisor

TABLE 26 Refined and new criteria from the interviews with the stakeholders

4.1.1 Type of client

The type of client influences the cladding selection process mainly by controlling the budget, dictating the needs, choosing the project delivery system, and, at the end of the project, by managing the maintenance cycle.
The architect's job to meet the client's objectives through design strategies; according to architect #3, "a project is successful when the objectives are met". Since it is the client who dictates the requirements, his choices and expectations have a big influence in the selection of a cladding material. Different types of clients have different priorities and often the cladding is targeted by cost reduction strategies in the early design stages.

Public clients may represent governments or municipalities, which have specific goals and performance expectations for institutional, industrial, or multi-residential buildings. Public clients give precise guidelines on the life cycle through a programme. For cladding materials, there is generally no material selection but overall intentions. For example, the programme could require cladding with a 25-year maintenance-free warranty. Public clients are mostly reluctant to experiment with new products and if they do, they tend to favour installation on small surfaces. They are looking for proven cladding systems.
In some ways, private clients might be seen as more economically driven. For commercial and industrial buildings, the building is used to sell or produce goods or services. Cost reduction is a high priority goal. The money invested in the cladding is not used for production or sale. The private client is greatly influenced by his own value, preconceived ideas, and by the prescriber's expertise and preferences. For some businesses, branding is important and they make choices based on aesthetics, environmental aspects, and performance. Private multi-residential builders are usually accustomed to the construction process and they work with overall intentions on a project depending on the price range of the dwellings. Time and cost reduction are strongly considered.

The tendering process depends on the type of client and the project delivery system. The project delivery method also has an influence on the project. In a traditional design-bid-build method, the general contractor does not give input. In a construction management or design-build project (Fig. 1), the general contractor advises and enhances the design with recommendations based on assemblies, own experience, simplicity, construction details, and optimisation of the work sequence. The contractor has also a strong concern about cost reduction. The subcontractors have little to say in the choice of material. Usually, they live with the choices of the architect and make sure to order the materials and install mouldings, furring, anchoring, and cladding.
Generally, the client pays little attention to maintenance and problems are identified too late. Thus, the client type has an impact on the maintenance of the façades. Generally, private clients think short term. On the other hand, public clients and seasoned clients who have expertise in the organisation are more concerned about the durability of the cladding.

4.1.2 Project context

The project context is subdivided in two criteria that influence the concept development stage: the physical context and the type of building. It is inspired from Wastiels and Wouters (2012).
The physical context describes the site of the project. It refers to the environment of the building. Cladding choice will be different for a project located in a city centre, near a beach, in the countryside, or near a forest. For a given area, municipal regulations (e.g. Site Planning and Architectural

Integration Programs), may require/prohibit certain types of cladding. As indicated by architects in the interviews, the type of building also greatly influences material choice. The needs are different according to building use and its volume. For instance, although a school and a law court can share the same volume/size, they do not share the same function and thus require different treatment. Moreover, the National Building Code (NRC, 2010) may require the presence of non-combustible cladding in accordance with the following criteria: use, floor number, surface area, sprinklers, neighbouring buildings, and distance from public thoroughfares.

4.1.3 Personal experience

Personal experience also strongly influences material selection in the concept development stage. It was noted that architects often work with the same products since they have to take responsibility for the final product's performance. If the architects had a bad experience with a product, they will be reluctant to use it again. Architects look for tested and standardised products in order to limit and transfer their responsibility. More than two-thirds of the interviewed stakeholders associate personal experience with the product's reputation. In the interviews, contractors agreed with architects regarding the importance of the product's reputation. A good product reputation is related to reliability/constancy and history of the product and the business supplier. Reliability/consistency is important for three parameters: durability, , and physical properties. According to all the contractors interviewed, a good product will react well in a context where temperature variations can reach 60°C.

4.2 REQUIREMENT CRITERIA

The requirements criteria define or represent what stakeholders ask from cladding products. Based on the online survey and the interviews, six basic requirements were identified for exterior cladding in non-residential constructions. Requirement criteria include sub criteria such as performance, appearance, warranties, information, delivery, and installation.

4.2.1 Performance

Performance is the most important necessity for the architects. It is defined in terms of durability and maintenance. As most architects mentioned, cladding and wall performance is very important since deficiencies quickly lead to very high repair costs, which often result in significant monetary losses for the owner. The online survey results indicated an average 40-year lifespan for durability and a 14-year maintenance cycle to be reasonable expectations. On the other hand, when performance was discussed in the interviews with architects and general contractors, it appeared that it was impossible to quantify durability. There is no absolute value or minimum performance (in years) established by stakeholders. Performance is a concept that must be adapted according to criteria such as the type of building, the client, and the budget. Interviews identified a minimum maintenance-free period of 25 years to be acceptable. It corresponds to the amortization time or half time service life of the building in many cases. Unanimously, the interviewed participants talked about system performance and not only cladding performance. This concept is based on the quality of construction details and the installation. Thereupon, stakeholders have suggested manufacturers to increase not only cladding efficiency, but also the efficiency of systems.

4.2.2 Appearance

Appearance is the second most important requirement. Appearance is a priority and serves the interest of the overall building concept. The durability of the appearance over time is the most important concept under the appearance requirement. There is a strong preference for materials that retain their aesthetic appearance. Another important aspect of the appearance is the fit with the other materials. It can be explained by the fact that architects are looking for a unique materiality. Architects look for products with great modularity and several architectural possibilities. The aesthetic flexibility of a material makes it possible to combine it well with the other materials. When architects think about materials and search on a company's website, they quickly want to understand all the design possibilities of a product. Furthermore, interviews revealed that architects do not consider the opinion of contractors and subcontractors on the aesthetic appearance of selected materials.

4.2.3 Warranties

Warranties are the third most important need expressed by the architects. Architect #2 mentioned that the warranty could kill a choice of cladding. The warranty concept is intrinsic to the durability of the material. Architects also mentioned that they do not necessarily work with products offering the best warranties. A 50-year warranty nevertheless reassures architects. Conversely, a 10-year warranty is, in most cases, unacceptable since one has to impose short maintenance cycles on the client. It is crucial for the architects to develop a good understanding of the warranty clauses (finish, material, labour, etc.). Appropriate design details are therefore essential for the warranty to apply. Finally, architects have to understand the limitations of the product itself as well as its installation requirements. In the interviews, Architect #1 revealed that he would appreciate if warranties were adapted according to specific applications (e.g. façade orientation, colour, soffit, etc.).

4.2.4 Information

Accessing product information is generally performed through two main avenues: manufacturers' or distributors' websites and manufacturing representatives. Architects and contractors tend to increasingly rely on websites, as extensive in-house material libraries tend to disappear. Regarding online research, architects stressed the necessity of being able to understand quickly all the visual and aesthetic possibilities of a product (project examples, layouts, shapes, colours, etc.). Other important information relates to performance (guarantees, maintenance, durability, and physical characteristics), costs, delivery time, installation and technical data. Technical data must be verifiable and comparable. Thus, architects are asking manufacturers not to limit themselves to regulatory requirements, but to provide complete data for their products. For public clients, it is essential to present or offer product equivalences. Private clients also appreciate this practice. For contractors and subcontractors, availability is a crucial factor. For projects aiming at environmental certifications, it is important to obtain thorough information on the provenance of the material.

Manufacturing representatives are specialists. They can aptly deepen architects' knowledge on cladding assemblies. However, when architects seek information from manufacturers' representatives, they often feel like they are dealing with sellers instead of technical advisors. They look for manufacturing representatives who are organised and knowledgeable about the proposed

system. They seek to establish a trust-based relationship with a transparent representative. They expect representatives to educate them by identifying beneficial typologies as well as providing information on interaction with the envelope (i.e.: air barrier, vapour barrier, thermal bridges, moisture movement). During the interviews, common complaints concerned insistent representatives, too much information documents, and too many samples.

4.2.5 Delivery

Delivery schedules must be respected as they have a direct impact on the final delivery of the building. Contractors and subcontractors expect honesty and rigour in the delivery schedules. They require actual costs and delivery times to be able to make an effective plan of the budget and work sequence. Contractors and subcontractors noted many delivery problems in the cladding industry. The delivery delay is important. Respondents identified fewer than three weeks as a reasonable delay.

The non-residential construction segment differs from the residential segment in the distribution of materials. Non-residential construction uses more custom and overseas products. Interviews indicated that customised products require longer delivery delay because of the length of the process: measurements at the site, sending data to the manufacturer, validations of drawings, approval, manufacture, painting, delivery. Delivery times of over 14 weeks should be avoided. For overseas products, having to pay prior to delivery is a major irritant for subcontractors.

4.2.6 Installation

The installation stage mainly involves contractors and subcontractors. Contractor #1 summarised the situation well by mentioning that at this stage, preoccupations are mainly on cost reduction and constructability. The results of the interviews have highlighted four requirements to define an easy installation: the speed of installation, the simplicity of the system, the coordination effort, and the possibility to modulate product on-site.

First, the speed of installation is an important element. Architects associate this notion with the price/surface covered ($/pi2). Products with low installation tolerance are cited as an example of product with a low speed of installation. Second, stakeholders are also looking for fastening systems that are simple, proven and familiar to installers. They try to avoid unique concepts or systems from a single company. They do not want installers to have to learn on the job in order to limit the errors, the time, and consequently, the construction cost. Third, there is a need to minimise coordination efforts. There is a problem of communication between the different subcontractors involved in the construction of the envelope. Products requiring few workers and few materials resources are preferred. Subcontractor #2 mentioned a major problem with the envelope/cladding interaction. The cladding companies are not the same entities that deal with membranes installation. Subcontractors do not handle envelope problems. The uniformity of the envelope depends on different trades and companies. For example, a subcontractor says that his workers always need to perforate the membrane for installing cladding, but that the membrane never gets repaired since they are never asked to do so. Finally, according to the contractors and subcontractors, the best products can be modulated on-site (i.e.: cutting, joints lost, molding). These products minimise the loss rate and offer modularity in case of breakage. Subcontractors appreciate being able to work and

modify the products while trade workers are aboard the lifting equipment. Errors are expensive on construction sites and product modularity reduces this impact. Paradoxically, interviews with the subcontractors demonstrated an increased use of panel systems that are impossible to modulate on-site. These systems seem to be highly appreciated by architects, but not so much by subcontractors.

4.3 ISSUES

Issues are problems that have been expressed by different stakeholders. Issues have an impact on several stages of the construction process. Regarding the cladding, the main issues discussed by stakeholders concerned product novelty, lack of construction details, lowest bidder rule, and maintenance.

4.3.1 Product novelty

New products and systems are perceived as problematic during the concept development phase as well as during the installation. Stakeholders do not want to play the role of product testers since potential problems may have significant monetary consequences. When new products are specified, they search for projects that used those products before. Architects seek more information and proceed to deep risk management analysis. There are informal communications with contractors and clients who previously used a product to get insight on installation, weathering, and potential future problems. Contractors and subcontractors mentioned that it is common to verify the cladding installation on other buildings. When using a new product, architects want to transfer the responsibility to the manufacturer. They prefer to go with proven systems. In the end, a bold cladding choice remains the client's and the architect's responsibility.

4.3.2 Lack of construction detail

Architects demand control over the process because it is their professional responsibility. They are primarily responsible for plans and specifications. Moreover, architectural details are fundamental for adequate estimations. Subcontractors will generally rely on the plans and specifications. As identified during the interviews, when subcontractors ask to modify the cladding choice, they do so primarily for three reasons: 1) anomalies in the specifications (e.g. molding, jointing, length, pledge, etc.); 2) identical product at lower costs; and 3) the product is not seen as a good product.

Contractors and subcontractors agreed on the general lack of details in plans and specifications. However, the lack of detail offers more freedom to the contractor. The downside is that contractors do not always have the knowledge to design good material junction details. Subcontractors explain the lack of details in an architect's plans by a lack of experience, a lack of knowledge of constructability, the copy of an old plan, and a lack of time or budget. It was noted that it is not the manufacturer's responsibility to provide and ensure the material junction details.

4.3.3 Lowest bidder rules

All stakeholders agreed that the way contracts are awarded is outdated. The rule of the lowest tenderer engenders a real price war. The focus is not on quality, but on price. Different strategies take place to reduce the cost: cladding thickness reducing, fewer construction details, faster surface coverage, prefabrication, products substitution, use of established products. Contractors and subcontractors want to have the choice of material supplier. They do not want to be tied to one cladding manufacturer. Mainly for price reasons, they seek diversity of manufacturers for a type of material.

Another consequence of the lowest bidder rule is the silo effect. As Architect #4 noticed, involving the manufacturer in the early stages of concept or technical design is sometimes more complicated because of the rule of the lowest bidder. This contravenes the tendering process.

4.3.4 Maintenance

Lack of knowledge transfer has been pointed out during the interviews. There is a knowledge gap on how to use management tools and maintaining adequate documentation and « as built » plans. Transmitted documents are often consulted or lost. Thus, stakeholders mentioned that they prefer to use materials that do not require maintenance. Architects, contractors, and subcontractors do not want to return to a site to perform maintenance because it costs time and money to the company.

Maintenance culture has to be developed. Maintenance plans are required to increase building envelope life. Leadership in Energy and Environmental Design (LEED®) projects are good examples that represent the implementation of maintenance and short, medium, and long-term investment plans.

4.4 INNOVATION

When asked if the cladding industry was innovative, most stakeholders argued that they see a lot of small products and/or process innovations. Improvements mostly focus on performance, personalisation, productivity increase, and costs reduction. In terms of technologies, stakeholders mentioned some promising product examples: self-cleaning products, energy collectors, reactive glazing, integrated lighting, and dynamic façades.

Some stakeholders also addressed the issue of innovation in terms of how to design the building envelope. According to one contractor, in recent years, there has been a lot of development focused on mechanical systems, coordination, commissioning, and building structural elements. The importance of the envelope is often underestimated while having a critical impact on a building's long-term durability. For stakeholders, innovation requires a more comprehensive understanding of the envelope, that is, thermal bridges, vapour barriers, air barriers, and moisture. Manufacturers of cladding material have a role to play: they have to better understand the envelope as a whole. This is a general weakness of the industry. Another contractor mentioned that plan details are too complex. Professionals misunderstand the stakes of constructability on-site and make construction details too difficult to realise. Better envelope understanding and design are essential to build more efficiently. Manufacturers need to know how products are used in order to identify the best typologies.

5 LIMITATIONS OF STUDY

Given the exploratory nature of this research project, many limitations deserve to be emphasised. First, the regional nature of the study limits the scope of the results. It is difficult to extend the results to similar weather region since all stakeholders were from the same region: Province of Quebec, Canada. Secondly, the low response rate of participants is a limitation factor to consider for the online survey and the interviews. Participation throughout the study was based on willingness, hence possibly introducing self-selection biases. In addition, sampling was not made at random. While these potential biases would hamper statistical representation of the population, they are acceptable within an exploratory study. However, it must be noted that results might have been different under different survey or investigation conditions.

6 CONCLUSION

In order to enhance the product development and marketing campaigns of cladding manufacturers, this paper highlighted stakeholder's choice criteria in the selection of a cladding material for non-residential use in the context of Quebec, Canada. The results could also be used in contexts where construction procurement strategies are similar. Surveyed stakeholders included clients, architects, contractors, and subcontractors. This article pointed out that the processes of selecting cladding material in non-residential construction is complex and mainly driven by influence criteria, requirements, and issues relative to the choice of a cladding material. The first objective was to identify which criteria influence the choice of a cladding material. Results indicate that client type, building type, project context, and personal experience are factors that have the most impact influence on the material choice. The second goal was to determine the requirements regarding exterior cladding. Performance was the most important criterion for the selection of cladding. Performance is a broad concept and there is no definition for the minimum performance. However, stakeholders prefer a minimum maintenance-free period of 25-year or half the expected lifetime of the building. Appearance was the second most important need for architects. Architects are looking for modular products that keep their aesthetic condition over time. They want to be able to understand all the possible applications of a product as quickly as possible. Warranties were the third most important requirement criterion for the architects. A warranty of less than 10 years is not desired as stakeholders are limited in the maintenance effort that they can transfer to the clients. The most important factor is to understand the warranty's clauses and ensure good design details to make sure warranties apply. As for delivery, contractors and subcontractors are looking for delivery delays of fewer than three weeks. Meeting deadlines is crucial because it has serious repercussions for a building's delivery schedule. Requirements for installation are the speed of execution, the simplicity of assembly, coordination, and possibility of modifying the product on-site. The results highlighted a maintenance problem in most buildings. Finally, this paper examined the potential of innovation within the cladding industry. The most interesting innovation in the cladding industry would be a better understanding of the cladding's interaction with the envelope and its position in the building. Such progress by the manufacturers would ensure a building's long-term durability. The findings of this exploratory project will enable the manufacturer to understand how stakeholders select materials in a non-residential market. It provides information on the desired attributes of a good exterior cladding product. Ultimately, this study will serve as a point of dialogue between the stakeholders to ensure the construction of more efficient building envelopes.

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