Design, decision-making and trade-offs in the Centre for Sustainable Development (La Maison du développement durable) in Canada

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Abstract. In order to fight climate change and reduce carbon emissions, professionals in the construction sector often strive for optimal mechanical/technical solutions and assume that a “best” solution exists at a given time and in a given place. But what happens in sustainable building projects when different sustainability or project objectives run at odds with one another? The Maison du développement durable or Centre for Sustainable Development (CSD) – a LEED platinum certified building — is recognized as one of the most sustainable buildings in Canada. This mixed-use building, conceived to be a social and environmental hub in downtown Montreal, houses 3000 m² of office space and conference rooms. The design included a series of innovations, such as a five-storey biofiltering wall and an under-floor air delivery system. In 2018, the Fayolle-Magil Construction Research Chair in Architecture, the Building Sector and Sustainability from Université de Montréal and the Canadian NGO Equiterre partnered to conduct a post-occupancy evaluation (POE) of the MDD. The study focused on six functional and architectural aspects of the MDD and involved analyzing 12 integrated design workshops, dozens of project documents, and specifically gathering new data. The results show that finding what is “best” is not what happened in reality. Instead, professionals were required to make a series of trade-offs in decision-making. Some examples of these trade-offs include: adaptability vs. cost, air quality vs. energy performance, shared spaces vs. building floorplate efficiency, and innovation in the design phase vs. long-term operations. This paper shows that tradeoffs adopted during the design phase impacted the MDD’s performance. The results of this study are not only valuable to the project’s partners, but also to the construction industry in general, offering insight into design compromises in sustainable office buildings.

1. Introduction

The environmental impact of building is enormous. About 40% of total energy consumption and 30% of greenhouse gas emissions are a result of the construction sector [1]. Architects, engineers, project owners, and other decision-makers seek to reduce these impacts by constructing more efficient buildings. In order to fight climate change and reduce carbon emissions, professionals in the construction sector often strive...
for optimal mechanical/technical solutions and assume that a “best” solution exists at a given time and in a given place. However, there is often a significant gap between the expected performance of sustainable buildings and their actual performance (post construction), especially in terms of energy and technical systems. In addition to these very common performance gaps, sustainability-related choices need to be made that may sometimes result in diminished performance in another area of the building design and operations, what we refer to in this paper as sustainability tradeoffs. In other words, it is difficult to attain high levels of sustainability in all areas, such as energy performance, air quality, human comfort, and so forth. This was the case in the authors’ study of the Centre for Sustainable Development in Montreal, Canada.

The Maison du développement durable or Centre for Sustainable Development (CSD) – a LEED platinum certified building — is recognized as one of the most sustainable buildings in Canada. This mixed-use building, conceived to be a social and environmental hub in downtown Montreal, houses 3000 m2 of office space and conference rooms. The design includes a series of innovations, such as a five-storey biofiltering wall and an under-floor air delivery system. Its primary mission as described in the concept document prepared by the project architects was to create “an ecological building designed to promote and stimulate the exchange of ideas” [2] and is a building that places human comfort and well-being at the heart of sustainable construction1 (although it evidently also innovates in terms of environmental performance). This paper, however, will elaborate on how the “ecological building” aims sometimes came at odds with the “promoting and stimulating exchange of ideas” aims of the project.

In 2018, the Fayolle-Magil Construction Research Chair in Architecture, the Building Sector and Sustainability from Université de Montréal and the Canadian NGO Équiterre partnered to conduct a post-occupation evaluation (POE) of the MDD [4]. The study focused on six functional and architectural aspects of the MDD and involved analyzing 12 integrated design workshops, dozens of project documents, and specifically gathering new data. Four aspects were analyzed in depth: the adaptability of spaces; the efficiency of the raised floor system with integrated ventilation; the comfort, wellbeing and productivity of employees; and the rental/usable factor (R/U) of the CSD building. In conducting the post-occupation evaluation, the authors found that there was not always a clear direction for defining performance; the results show that finding what is “best” is not what happened in reality. Instead, professionals on the design team were required to make a series of trade-offs in decision-making. Some examples of these tradeoffs include: adaptability/flexibility vs. cost, air quality vs. energy performance, shared spaces vs. building floorplate efficiency, and innovation in the design phase vs. long-term operations. This paper shows that tradeoffs adopted during the design phase impacted the MDD’s performance in different ways, and argues that rather than always achieving “optimal” solutions, the CSD creates opportunities for encounters and sharing and therefore pushes the boundaries of social sustainability and ethical construction. This paper seeks to help professionals, contractors, and decision-makers focus on the essential elements of office building design, inviting a reflection above and beyond responsibility towards occupants in the creation of sustainable buildings.

2. Innovation in the construction sector
Before describing the methods and results of our study, it is important first to frame these within a larger discussion on innovation in the construction sector. Professionals who work on very sustainable buildings

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1 For instance, results of a post-occupation study on the CSD that focused on social and environmental impacts revealed that 87% of survey respondents participate in at least one programmed activity inside the CSD per year, and 69% say they have improved their knowledge or skills on certain topics [3]. Moreover, 30% of respondents, or 40 sustainable development professionals, mentioned having developed informal relationships with other residents leading to new projects.
take risks in order to innovate and in doing so they, take arguably take on a higher degree of risk than in traditional projects.

The construction industry in general is considered one that is very slow to innovate, especially in comparison to other industries such as the automotive industry or aeronautical industry. However, some authors argue that the construction industry needs to innovate in order to deal with the increasing constraints introduced by ‘sustainability’ [5, 6]. Other authors stress the need for a more collaborative and integrated approach in order to address the increasing complexity of design problems [7, 8]. Innovation does not necessarily imply the implementation of radically new ideas. It also can reframe old practices in new ways [9]. In fact, it is quite difficult, if not impossible, to talk about innovation in the construction industry without referring to collaboration as a mechanism for facilitating the sharing of information, resources, and knowledge in both radical and incremental innovation processes [10]. Confronted with environmental challenges, several authors have argued that today’s professionals need to collaborate to innovate and to innovate by way of collaboration [11-14].

At the same time, it is important to acknowledge the relationship between innovation and risk. According to Kulatunga [15], the willingness of clients to share risks and their commitment and leadership in project planning and execution are critical for innovation achievement. Determining innovative goals for all team members early in the process can also “bridge the gap between the client, designers, and builder in recognition of those goals despite (sometimes) misaligned agendas.” [16] In this way, despite risks, both clients and professionals benefit from innovation. The client benefits from an innovative solution and improved project performance, and the builders and professionals benefit from innovation through potential application in subsequent projects [16]. However, as will be discussed further on in this paper, innovation in sustainable buildings also has an impact on long-term operations, and this is something seldom discussed with clients, who bear a fair share of the risks.

The CSD was conceived as a demonstrative building, where important innovations in sustainable construction could be developed and incorporated. It includes several important ‘innovations’ such as a five-storey biofiltering wall, a green roof, recycled rainwater system, geothermal energy for heating and cooling needs, use of salvaged river wood, a number of shared spaces, a rotating exhibit space in the main lobby, a raised floor system, and an overall very mixed-use typology for an office building. Particularly with respect to the mechanical and ventilation system, the design team sought to innovate at many levels. The mechanical system consists of 28 geothermal wells for heating and cooling needs, the raised-floor system designed to passively ventilate the office spaces, the biofiltering wall, and high efficiency ventilation equipment located in the 5th floor mechanical room. The air from the system comes from several sources: fresh air from outside, stale air from office spaces and atrium naturally treated by the green wall, and return air from floors 2 to 5. These choices for the HVAC system were taken to optimize human comfort and well-being, ensure superior air quality (the raised flooring system allowing contaminants to rise above the level of occupied space), and better energy efficiency than conventional ceiling systems thanks to a less pre-conditioned air supply and a lower driving force. CSD floors three through five (the floors with offices) have raised floors with integrated ventilation.

The Centre for Sustainable Development and the sustainability trade-offs encountered in its performance must therefore be understood in relationship to this wider discussion of innovation and risk in the construction sector.

3. Methods and procedure
This paper draws on both qualitative methods (interviews, analyses of spaces, on site observations) and quantitative methods (tests, occupant surveys, analyses of plans and standards, and others) from the post-occupancy study in order to dissect different trade-offs in decision-making. These methods also allow us to explain the consequences of decisions made by project stakeholders on aspects pertaining to social and
organizational order. This paper adopts what researchers call a "constructivist perspective." This is not about studying and "discovering" reality in a research laboratory, nor is it intended to demonstrate the empirical application of a pre-established theory or hypothesis. On the contrary, reality in this context is constructed and revealed by many different on-the-ground actors, using an iterative process where contextual and temporal dimensions are imperatively taken into account. In this study, we co-generated knowledge with CSD managers and employees. We (researchers and occupants) have thus chosen a partnership and continuous dialogue approach throughout the editing and development of the study.

The post-occupancy study, which serves as the basis for a discussion of sustainability trade-offs in this paper, was carried out in five main stages. First, we analyzed a large number of documents, including: dozens of theoretical references specific to office buildings and POEs, ten publications on the real estate market in Canada, about 20 building construction documents from the CSD building (plans and estimates, budgets, timelines and documents related to renovations), as well as norms and standards such as building codes, LEED certification, WELL certification, and guides from the International Building Owners and Managers Association (BOMA). Second, we specified the issues to be examined. In order to choose the criteria to be evaluated, we conducted a first exploratory survey of seven key people working in the CSD building (men and women in various roles). Third, we identified gaps in the existing quantitative data. We then generated new data using specialized tests (specifically on air quality). We also produced building analysis diagrams and plans. In addition, we performed new calculations for certain indicators such as the rental/usable factor (R/U) of the building and the environmental impacts of certain components. We analyzed previously completed studies at the CSD (in 2012 and 2014), and performed a building code analysis to estimate the densification potential of the building. Fourth, we collected additional qualitative data through interviews with thirteen experts and industry professionals. We also analyzed more than fifty hours of video recordings from the CSD building's integrated design sessions. During this stage, we also analyzed a detailed survey conducted by the client with all CSD employees. The survey focused on the comfort, wellbeing, and functionality of the CSD's spaces. In the final stage, and the most relevant for this paper, we conducted the data analysis, accompanied by a series of validations from research participants, including three green building experts, two professionals, and a researcher employed by CSD. The objective was to finalize the analyses, adjust the results, and validate specific arguments. In analyzing our data from all these sources – documents analysis, exploratory survey, new data generation, interviews and occupants’ survey – we were able to highlight important tensions and sustainability tradeoffs that occurred in the four components of our study (refer to Table 1 below). It is important to note that that many of these trade-offs are between technical criteria and social criteria.

### Table 1: Summary of components of the study and sustainability trade-offs.

| Component of the study | Sustainability trade-off |
|------------------------|--------------------------|
| 1. Adaptability to future uses | Cost vs. adaptability/flexibility |
| 2. Raised floor system | Air quality vs. energy performance |
| 3. Building floorplate efficiency (R/U ratio) | Shared spaces vs. building floorplate efficiency |
| | Innovation vs. long-term operations |

This paper’s primarily goal is not to summarize the overall findings of the six-part post-occupancy study, which is available online from Equiterre’s website, but rather to engage in a higher-level discussion of sustainability trade-offs.

### 4. Results
The decision of the client-occupant to prioritize human comfort and well-being over all other sustainability objectives led to four main sustainability trade-offs discussed in sections 4.1 to 4.4 below. These are each explained, followed by a discussion/conclusion section that puts these sustainability trade-offs into perspective and offers advice to sustainable construction professionals.

4.1. Adaptability/flexibility and cost

In the first component of our POE, we found that there was a tradeoff between adaptability to future uses and the willingness of clients and developers to invest in future adaptability. The CSD’s adaptability to future needs and uses was an important performance criterion for the client (also occupant and manager) of the CSD since the inauguration of the CSD in 2011, four interior renovations totaling approximately $1 million have been undertaken. Adaptability is also an important aspect of sustainability, given the contribution of renovations to waste and carbon emissions. The non-residential building renovation sector plays a fundamental role in Quebec’s construction industry. This sector is gaining importance, particularly in the context of the environmental impact of the construction industry, which contributes to billions of tons of waste per year. It is estimated that in the United States, every year, five billion pounds of carpets are sent to the landfill. Adding to these drywall, cabling and other coatings, every time a company changes its office space, it produces a heavy impact on the environment. In Denmark, for example, it is estimated that 75% of construction waste comes from renovation projects [17]. The impact of the renovations is doubly important because we must take into account not only the waste associated with the demolition, but also the intrinsic energy, and other factors such as the lack of efficiency of the occupants during the activities of the building, construction and the effects of renovations on their health. All of this adds to the impacts caused by the production of new components that will be added to the building. Thus, an increasingly important dimension of a building’s sustainability is its adaptability to the future needs of its occupants.

Overall, our research into the adaptability of the CSD to future changes was not exceptional; on the contrary, it is rather typical. Its floorplate and structural design allow for interior alterations and easy use changes. The raised flooring system allows for easy office space reconfigurations within a same office space, but does not necessarily allow for easy renovations involving building or removing fire-walls. But while the building does have a configuration suitable to adapting spaces; it cannot easily support future density in terms of occupants.

To explain this last point further, our research found that since much of the Canadian housing stock that is already built will need to be renovated, the advantages and disadvantages of new corporate development market trends will be worth considering. One of these is the densification of office space. This strategy of optimizing square footage has important implications for employers, employees, developers, and property managers. Our study proposed a reflection on whether the real estate sector in Quebec is capable of taking advantage of this new trend, particularly in downtown Montreal. In a building, the dimensions and quantities of many components depend on the occupant load being in accordance with the building code, such as with regard to the exits and their accessibility, the ventilation system, the vertical transport system, and the toilets. However, it is possible that existing buildings are already saturated with components unable to absorb an additional load of occupants. Market pressure toward the densification of spaces could result in costly operations for existing building owners, some of whose components are already at full capacity.

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2 It should be noted that the adaptability of the building was brought up by the client and the consultants during the design process, but having not been identified as a priority objective, it was not included in the project charter. This dimension and its implications should have been the subject of further discussion and offered more support from the start of the project.

3 In the case of new buildings, the challenges of potential future densification are equally important. In an office construction context that favors the densification of spaces and the availability of unassigned work areas, traditional standards for calculating the number of elevators and the size of certain components are no longer appropriate. In addition, planning ahead for an additional occupant load means oversizing components and systems whose size and optimal performance are indeed dependent upon the number of occupants. Spatial oversizing can have a significant impact in the case of a tall building, since there is a need to multiply
In the case of the CSD, our study found that it is already at capacity and cannot easily accommodate future density of employees. The main reason for this is the evacuation capacity of the exits, which we have already estimated are at their limit. A major barrier for designing for future density is cost. Few developers want to pay for larger elevators, staircases, wider corridors, or more washrooms than the bare minimum as each of these elements results in fewer rentable square feet. In conclusion, both in cases of redevelopments and new construction, developers and property managers will have to take into account the opportunities but also the limitations that the dimension of building adaptability presents, without neglecting economic and environmental impacts. This is a subject that deserves further attention.

4.2. Air quality vs. energy performance

One of the four components of our CSD post-occupancy study was the building’s raised flooring system, which represented an important financial investment for the client-occupant. The results of this study (which were that the raised flooring system only partially responded to the client-occupant’s expectations) highlighted an important tension (not uncommon in the construction industry!) between air quality and energy performance. In the case of the CSD, the client made a clear choice to prioritize the air quality of occupants, which came at the expense of energy performance.

As section 2 of this paper noted, the raised floor system was an important innovation for the CSD project. However, rather than single-duct air supply at a single temperature—more common and supposedly less energy-consuming—the designers opted for a dual-duct ventilation system at the CSD. This is again because of the client’s priority being placed on occupant comfort and well-being. Powered by geothermal energy, this system maintains a cold air duct and a hot air duct at all times, which combine in mixing dampers to provide occupants with an optimal temperature. This is a system that maximizes user comfort. The designers adopted this system due to three advantages: better air quality, better user comfort, and possible energy savings.

![Installation of the CSD’s raised flooring system. Source: lamddvirtuelle.org.](image)

The choice of the client-occupant to prioritize human comfort and well-being over other sustainability criteria led to compromises on three levels with respect to the raised flooring system. First, cost-wise,
because raised floors and the double duct ventilation system are more expensive than other more conventional systems for office buildings. Second, in terms of intrinsic energy, because raised floors mean the addition of building materials that incidentally increase CO2 emissions (although this system avoids the need for suspended ceilings in some areas), even if relatively small considering the entire life cycle of the building. And finally, in terms of energy performance, because it likely achieved less here than could have been achieved with another solution.

In terms of air quality, recent tests (2018) reveal that the quality is very high at the CSD. However, the stratification of contaminants collected by the system is hardly perceptible (it should be noted that the stratification of contaminants—unlike that of air temperature—is desirable). Thus, significant differences in the CO2 and contaminant concentrations at the floor and ceiling levels are not captured. It would have been more desirable for fewer of the ducts to be located in the rooms’ occupied zones. Nevertheless, users are largely satisfied with the air quality, thanks to a first intake of fresh air which comes from the outdoor raised level, and quality filtration. As for thermal comfort, while it would have been considered good in the case of a building with a more conventional mechanical system, the CSD is not optimal considering the type of system adopted, which would normally have had better performance to this end. Nevertheless, 57% of the occupants are satisfied or very satisfied.

The results of study reveal the importance of understanding compatibility between different building components. If human comfort was the number one priority, the CSD likely could have arrived at the same air quality without the raised flooring system through a mix of the biofiltering wall, very good air filters, large quantity of fresh air intake, etc. The combination of the raised flooring system with dual-duct ventilation in some ways poorly affected performance and arguably added unnecessary construction costs and embodied energy costs to the project.

4.3. Shared spaces vs. building floorplate efficiency

The fourth component of our post-occupancy study was the efficiency of the CSD in terms of its R/U factor. The R/U factor (or rental/usable space) is used internationally by property managers to calculate the amount of fees each tenant must pay in an office building and is calculated using a method developed by BOMA. BOMA (2010) defines the R/U factor as “a ratio, the numerator of which is the preliminary floor area of a floor, and the denominator of which is the usable area of that floor, that distributes floor service areas to the occupants on a floor on a proportional basis.” Tenants often pay not per square foot they occupy, but also for some of the common areas they enjoy, such as corridors, mechanical rooms, vestibules, and others. This factor is, for owners, among the criteria of efficiency with regard to office building occupancy. As the architects in 2012 had originally estimated the CSD’s R/U factor at 1.486, which is significantly higher than today’s industry standards of 1.10–1.20, the client-occupant had asked us to look into this issue further. Our study focused on the following questions: Is the real R/U factor of the building consistent with client-occupant expectations of the CSD? Is the CSD building inefficient in terms of rental space usage? Why is its R/U factor high? In conducting this study, we found an important sustainability tradeoff between shared spaces (to spark innovative exchanges) and building floorplate efficiency.

4 In terms of energy efficiency, CSD operators do not yet have a way to measure the energy savings of raised floors with integrated ventilation. This study cannot therefore be quantitatively expressed. However, there is good reason to believe that the potential energy savings promised by floor ventilation are partially or completely overshadowed by the "energy-intensive" dual duct ventilation system. Several mechanical engineers interviewed for the post-occupancy study, although acknowledging the complexity and high costs involved in precisely measuring, expressed the probability of the energy intensive dual-duct ventilation system overshadowing other energy savings.
Our study revealed several reasons why the CSD’s ratio is still higher than the industry standard of 1.10 to 1.20. We found that several of these reasons are related to different aspects of its sustainability, either in terms of LEED certification requirements or occupancy well-being (inclusion of many common and social spaces). To illustrate, the fact that the CSD is a green building, and LEED certified, reduces its effectiveness in terms of occupancy by up to six percent due to the fact that the building was required to have interior bike storage, bike showers and a larger mechanical room for geothermal equipment. These results open the door to questioning whether the over-mechanized approach of so-called "sustainable" buildings diminishes their efficiency in terms of occupancy (rentable space), the reason being that the mechanical equipment currently deployed to achieve eco-friendly performance requires more built space that is not dedicated to renting. Please refer to Figure 3 for a summary of building social and common spaces as well as spaces related to sustainability that reduce the CSD’s efficiency in terms of occupancy.

Following our analyses however, we concluded that it is important to put the CSD’s R/U factor into perspective. Its R/U factor is higher because the building was built on a small lot, where a building height was chosen below what regulation allowed. It is also an ecologically efficient building that dedicates a lot of space to mechanical equipment. In addition, the building has common spaces that are rented and generate significant income for the CSD. The MDD offers the following communal spaces for its members and tenants: 7 meeting / conference spaces, a kitchenette rented and shared by smaller organizations, as well as a rooftop terrace and an atrium accessible to all. The bistro on the ground floor and the park adjacent to the building also provide synergy for occupants. The CSD is not a conventional office building and can hardly be compared to a building constructed by a real estate developer with objectives of maximum profitability. The offices open onto a majestic atrium with a green wall, and the view overlooks Hydro Quebec Park. This is an architectural space with great added value. But the vacancy rate of the CSD is almost nil. It also achieves energy savings of about 17% compared to its reference building. The operating costs of this single building are therefore hardly comparable to those of the standard office building on which the concept of
Figure 3: Simulation of the CSD’s R/U ratio eliminating spaces related to LEED certification and taking into account retable common spaces. BOMA 1996 method. Source: authors.
the R/U factor was based. So even though the CSD is less efficient than a standard building in R/U factor terms (i.e. 1.356 rather than 1.20), our research led us to conclude that this factor is of less importance here than in the case of a conventional office building.

We therefore argue that the R/U factor does not sufficiently take into account the human factor. Returning to the client's vision for the CSD and the strategies developed in the charter, it appears that the CSD’s design meets its initial vision (for example, to provide a high-quality workplace, create an innovation hub, generate savings for its partners, and inspire the construction sector). In the context of non-profit management, the CSD meets its financial goals while providing high quality spaces for employees. These findings make relevant contributions to knowledge about the R/U factor of green buildings and of those that value the "sharing economy.” They highlight the importance of the human factor in the analysis of spatial efficiency in sustainable buildings and provoke developers and investors to look beyond pure numbers. Green building professionals working on sustainable buildings may want to be aware of this trade-off between the R/U ratio and shared spaces in a building and understand the limits of relying too much on R/U numbers when the sharing economy can both be profitable and provide important social benefits to inhabitants.

4.4 Innovation in the design phase vs. Long-term maintenance

Another important finding from our post-occupancy study was that there is a tension between innovation in the design phase and long-term maintenance. The client-occupant of the Centre for Sustainable Development brought together a dozen professionals from different disciplines to partake in an integrated design process and innovate. And the client and design team did manage to innovate in a number of ways. However, the client-occupant did not realize that there are consequences to innovation, and often innovative building solutions require more hands-on and specialized operations and maintenance. As a result, the CSD’s energy performance was significantly lower than was anticipated. In fact, it consumes 2.3 times more energy than was anticipated and modelled during the design phase [18]. Over the first six or seven years of building operations, the client-occupant had to make many adjustments to the building in order to try and improve its performance. The client-occupant had to consult again with the mechanical engineers to, for example, pre-cool less the air that is fed into the raised-floor system (displacement ventilation system). In doing so, the CSD is now approaching the energy performance it expected during the design phase. However, this took a long time to resolve and very specialized knowledge and technical expertise. This tension between innovation and long-term maintenance may be poorly understood in the construction sector and deserves further attention so that professionals and clients can understand the type of ongoing maintenance and expertise that will be required after construction during the operations phase.

5. Study limitations

This study has certain limitations. First, while the client-occupant provided access to dozens of documents from the CSD building project, it was not possible to access all the data and key people required for the four components of the project study (including in-house technical studies of architects or engineers, detailed reports for LEED credits, a study on the architect’s code, and data on the ventilation system’s cooling and heating modes). In some cases, the research team had to generate data or make extrapolations that merit additional empirical validation. Second, the CSD's survey on spatial comfort, wellbeing and functionality was not designed to easily perform statistical correlations. Some correlations may therefore have a low quantitative strength (see section 3 for the statistical limits of the survey). Third, the study faced technical limitations, particularly with respect to simulation tools for some aspects of the components, including the energy savings resulting from raised, integrated ventilation floors. Fourth, the study is limited by time and budget constraints. Finally, the study is limited by its results, which are not generalizable, as they are very specific to the CSD building. Thus, the study does not provide solutions even though it
provides the client-occupant with recommendations. Finally, the results do not therefore apply to all green buildings or office buildings more generally.

6. Conclusion: an ethical approach to office building construction

In green building projects, clients and design teams often take risks. They integrate constructive, mechanical systems and materials whose actual performance in a complex system are unknown. There is therefore a higher level of risk than in a conventional project. But in the building sector, there are no "optimal" solutions applicable to all projects. Solutions can only satisfy certain people at certain times. They are also highly contextual, responding to constraints specific to geographic location, built environment, the immediate site, occupant characteristics, and the availability of resources. Designers sometimes underestimate these factors and attempt to measure up to industry standards at any cost, calling on certifications and construction sector general standards.

Our study confirms the importance of design compromises and their impact on the performance of green buildings. Very often, the differing objectives of sustainable development and performance come into conflict. Tensions emerge between several performance objectives. In these cases, it is imperative that the project stakeholders agree on a clear definition of priorities and reach a consensus on the values that should guide the final solution. Any design decision (even those underlying the quest for "greener" answers) has positive and negative consequences for the building’s overall system. Understanding these consequences is fundamental to responsible decision-making. And these are not absolute, but depend on one’s priorities and perspective.

Our study also confirms that the technical performance of a building is not cumulative. In reality, the different types of performance interact in a complex way and thus, a subsystem that is highly efficient on its own may not always be when interacting with other components and systems. In a sector that increasingly favors "checklist" type certifications, understanding these interactions becomes fundamental.

An important transversal lesson is the importance of properly transferring the building to the operator once it is built. With the growing complexity of mechanical systems, it is becoming more and more difficult for operators to maintain the functional and technical performance of their building, not to mention its ecological performance objectives. If building industry professionals do not properly pass on the torch to the operator, the operator can render the building less efficient, simply due to lack of knowledge about the performance thresholds defined at the design stage. The lack of continuity between design, construction and operation phases represents a significant gap in the field of architecture and sustainable architecture in particular, and which can also determine the eventual impacts of the sustainability trade-offs, some of which were outlined in this paper.

This paper also opens the door to future research on social objectives and how they might come at odds with environmental objectives in sustainable construction projects. In contexts such as Montreal, Canada, where we have access to affordable renewable energy via hydroelectricity, the priority of ecological buildings simply isn’t energy performance or carbon, but promoting a sustainable lifestyle via sustainable alternative transportation, local food, and also social sustainability. We hope that this paper can help fuel much-needed reflection on the social responsibility of project actors in the increasingly frenetic race for performance in the fields of construction and architecture.

The CSD project put human beings first and foremost. This is an appropriate decision, not only due to its ethical nature, but also because of its positive impact on the performance of the organizations that make up the CSD. The CSD's experience shows that the human factor should not be underestimated in the design of eco-responsible buildings. Finally, a person spends an average of 90,000 hours of their life at work. The design of quality spaces for employees today is a fundamental in the pursuit of social and environmental responsibility for customers, employers, developers, and property managers.

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