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Explaining the performance gap in a French energy efficient building: persistent misalignment between building design, space occupancy and operation practices

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Abstract

Relying upon sociotechnical analysis of technology in organizations, space occupation studies, and the sociology of organizations, this paper investigates the dynamics of appropriation of space and equipment by the occupants of a high-performance tertiary building, the adaptation of equipment by the building operator, and the effects on energy performance. Through an ethnographic qualitative survey, we analyze the dependencies between occupants, operators and managers associated with the use and the adaptation of the building and its equipment. Our analysis shows that the dynamics of appropriation of technologies and occupied space have decisive effects on the functioning of the system, comfort experience and energy performance. The learning dynamics of users and operators can overcome some misfits between building design, space occupancy and operation practices, but the persistence of misalignments hinders energy optimization and comfort experience. Organizational structure and the subcontracting of building operations contribute to this misalignment, while organizational reconfigurations through informal cooperation remain limited.

Keywords

Energy efficiency – building uses – building management - sociotechnical interdependencies – constructivist studies of technology

Highlights

- The building automation that is supposed to help achieve energy performance is built on the basis of occupants' expected uses
- Comfort experiences of occupants and subversive practices in terms of appropriation of space affect the functioning of the building and its energy performance.
- Occupants and operator progress in understanding the uses and functioning of the building and coordinate informally to adapt.
- The rigid contractualization of building operations discourages adaptation to new practices and comfort expectations

1. Introduction

Energy performance objectives in new tertiary buildings have often resulted in the implementation of numerous automation systems that have replaced occupants in the management of energy equipment. Due to the sophistication of technical equipment, operators, who are responsible for maintaining and regulating the technical system, play an increasing role in optimizing energy consumption [1]. However, this does not mean that the occupants have completely disappeared from the scene; they participate by expressing their needs and claiming comfort, or do not always respect the planned operating modes and the expected uses of space [2]. Their behaviour cannot be understood without taking into consideration their activities and use of spaces [3], their experience of the technical system [4], and their relationship with operators and managers who can regulate the use of space or adapt the technical system. High-performance buildings will introduce specific constraints, often seeking the optimization of the energy system. The results of this optimization depend on the adaptation of the energy flow to the way spaces are occupied. As Day and Gunderson [5] point out, the success of a so-called “efficient” building depends not only on political regulations, market effects and technical progress, but also on the behaviour of the occupants.

Thus, to understand how energy performance can be improved, it becomes necessary to focus on how the members of the organization appropriate the building, its spaces and energy equipment, and how they defend their needs and comfort requirements, while supporting energy efficiency. Unlike the occupants of dwellings, the occupants of a tertiary building are governed by a certain number of rules specific to the organization, whether or not they are members thereof. Even in a tertiary building that receives the public, the latter must comply with occupation rules. The members of an organization share practices and occupancy rules that can influence the energy performance of the building [6].

In the literature on the energy performance gap, occupants and operators are often studied independently of each other. In the case of occupants, it explores their ability to understand and “efficiently” use spaces and energy systems [7, 8]; operators are often studied in the context of their ability to “convince” the occupants to change their behaviour, or even in their capacity to convey a political message of energy sobriety [9, 10] but the dynamics of relations between occupants and operators of the building, as well as the managers of the organization, are not studied in depth. For example, the satisfaction of occupants in terms of comfort presupposes technical adaptation by operators and managers.

Based on an in-depth ethnographic observation of the uses of a high energy performance tertiary building by its occupants, of the professional practices of operators, and of regular meetings between operators and managers, this article proposes to deepen the knowledge of the dynamics of appropriation of energy efficient buildings by the members of the organization, assuming that the different actors of this appropriation are dependent on each other in their search for comfort or energy performance.

Our analysis strives to embrace the dynamics of appropriation of the building, its spaces and its technologies in an evolving organizational context. According to the sociotechnical analysis of technology in organizations [11], the organization and technology interact in two different ways.

First, the organization sets social roles, with its own rationality, perception, issues, constraints and autonomy. Users and operators interpret technology according to their position in the organization, but their practices are not necessarily aligned with the script embedded in the technical system. This reasoning could be extended to relations with space: occupants often appropriate the built environment for activities other than those anticipated in the design phase [12]. This misalignment can lead to different immediate responses: users' adaptation to the technical system, dissatisfaction or unexpected uses that could affect the performance (perceived or calculated) of the building.

Second, the appropriation of the equipment can imply organizational change. According to Barley [13], the unexpected use of a piece of equipment can create tasks that were not anticipated and will affect *"the concrete, repetitive activities and interactions that characterize the daily routine of a social setting"*. Consequently, an organization should not be considered as a stabilized social order, with *"more or less stable patterns of action, interaction and interpretation"*. A new social order emerges from a negotiation of practices and tasks among the members of the organization.

This negotiation occurs in a dynamic system of relations: according to Crozier and Friedberg [14] each member possesses specific capacities of action derived from the control of resources, such as the setting and the modification of rules, the adaptation of the technical system, or practical skills. The dependencies between them stem from the distribution of capacities of action and the skills they can develop. Informal relations of cooperation help to manage interdependencies as each actor strategically adapts his or her behavior to obtain the cooperation of others [15, 14]. The process of realignment of the social organization and the technical system is thus mediated by informal political dynamics among members of the organization, integrating materiality as a flexible resource that can be adapted by some to "enroll" others [16].

This paper will firstly present the theoretical foundations of our analysis of the dynamic relations between material adaptation and organizational change. In the methodology section, we will explain how we conducted our observations and analysis. Then in the results section, the paper develops our observations on the use of space and technical system, organizational adaptations and their impact on energy performance. The conclusion will elucidate the potential contribution of this theory to energy studies, and more specifically to the understanding of the energy performance gap.

2. How dynamics of appropriation of technology and space question the organization

Constructivist studies of technology encourage a deep analysis of practices of occupancy and uses. Applied to energy technology and building occupancy, this approach helps to explain energy efficiency gaps by focusing on unexpected practices. We consider that such approaches oversimplify the analysis of an organization in a way that could be detrimental to understanding its relation to materiality and energy performance. Practices are related not only to the equipment, but also to the existing organization. This is firstly because the structure of the organization and the distribution of tasks, competencies and responsibilities affect the activities, interpretation and appropriation of the building

and technologies. The dynamics of appropriation by some actors can affect the properties and performance of the equipment. Secondly, these dynamics affect the tasks and the activities of other actors who are responsible for the performance of the organization, creating new relations of dependency. These new dependencies can be managed through cooperative strategies and contribute to the emergence of a new social order. By separating the local dynamics of appropriation of equipment from the social dynamics of negotiating the role of the organization, we risk failing to understand what Leonardi calls the “imbrication” [17] of the technology and organization.

2.1 Organizational position and the appropriation of buildings and technologies

The analysis of uses of space and equipment by each actor is the first stage of the analysis. Barley [13] considers that the uses of a technical object are not only imposed by the technical object itself but are part of a division of labour, a distribution of roles, and formal requirements. The formal structures and processes contribute to the framing of practices by designating responsibilities, incentives and sanctions for users, as well as authorizations and capacities of action that can be given to some users but not to others. These structures add their own constraints and also leeway. Each member of the organization, occupants, operators and managers has their own interpretation of the technical system. This meaning comes both from the object’s features and also from pre-established landmarks and references among users, related with competencies and social roles.

Existing literature on energy performance in buildings identifies the different stakeholders, their interests and their capacities of action, according to their organizational position [18]. Such papers focus on how occupants evaluate energy systems [19, 20] or deal with different forms of appropriating information systems on consumption practices in buildings [21]. During the use phase, users are oriented and guided partly by the possibilities and constraints of the technical object, but they also try to deal with the object according to their own objectives; in other words they reinterpret it and the scripts embedded therein.

While these papers analyze the dynamics of appropriation of energy technology, there is a lack of understanding of the occupant’s activities. Building and energy devices are designed according to expected activities, but occupants can carry out other activities that contradict initial expectations, leading to issues of comfort or energy performance [22]. That is why our approach also draws from Berker [12], who combines the theory of the domestication of inhabited spaces with the analysis of the adoption of technical systems to explore how the occupants appropriate the tertiary building in relation to their activities. Thus, the spatial variable is an element for understanding the practices involved in adopting technical devices.

Operators intervene as intermediaries in the domestication of built spaces and the technical system. Operators are confronted with the practices and social representations of the occupants, who “domesticate” their living spaces and alter the expected energy performance. They are part of the “building community”, i.e. the professionals who designed the building and the technical system according to criteria derived from their practices and professional training [18]. Building operators are

therefore in a "middle-out" category [23], positioned between ordinary occupants and energy performance measurement.

Thus, energy performance is the result of operators' reinterpretation of the relationship between occupants' practices and the materiality of the building. The design process anticipates uses and practices, and incorporates, in the technical equipment and building structure, the representations of users and their practices in the form of "scripts" [24]. For high-energy performance buildings, it can be assumed that designers are encouraged to develop fairly precise scenarios of occupancy and circulation because energy performance is closely linked to these patterns. The irreversibility of the design and the construction of a building makes initial assumptions on uses even more important and restrictive.

The identification of stakeholders could be extended by taking into account the distinction between three groups: the specialized team responsible for the operation (which could belong to an external company, linked to the one occupying the premises through a maintenance and energy optimization service contract); the manager, giving orders and representing the occupants; and of course, the occupant. Occupants, operators and managers do not have the same expectations regarding the operation of a building in terms of comfort or space occupation practices.

2.2 Dependencies between occupants, operators and managers: cooperation and alignment

The second stage of the analysis focuses on the capacity for action and relations of dependency created by any unexpected use of the building and the technology. The dynamics of appropriation of equipment is embedded in a dynamic social order, characterized by an evolving distribution of capacity of action and objectives. The sequential intervention of actors in the design and materialization of the building has an important effect in terms of the allocation of resources, capacities of action and constraints, although capacity of action is not stable. As technical devices are subject to dynamics of learning by the members of the organization, their use implies new skills and new activities, which are not necessarily taken into account by the initial formal organization. Actors explore new possibilities of transgression and circumvention. Unexpected activities and uses create misalignments with formal roles and formal objectives [13]. In the case of office buildings, many adjustments can be introduced in a comfort-seeking logic, along with many technical additions to the building to match different uses. Operators start with an expert knowledge of the building and the technical system: their fieldwork requires them to respond to the demands and needs of the occupants. They also try to address the inventive practices of occupants, intended to improve the functionality of the building and its equipment [3]. Unforeseen occupant practices can lead to deviations from the requirements and rules of the original organization, challenging the conditions under which it is managed by the operator and weakening the ability of the formal organization to control performance and responsibilities.

New dependency relationships emerge from a misalignment between the expected use of the equipment and actual practices. In their sociotechnical analysis of work in organizations, Trist and Bamforth [25] identified how variability in task accomplishment, associated with the constraints of the technical system and the formal division of work, can introduce relations of dependency, which could be

difficult for members of the organization to manage without cooperation. Barley [13] notes that *“since few tasks are truly independent, however, one’s work is likely to influence those with whom one interacts as well as how one relates to others. Altered tasks may narrow or expand the range of one’s role set, shift the nature of one’s dependencies, or affect the frequency and content of typical interactions”* (p. 68). Dependency relations are created by unexpected situations, or by new material constraints, introducing misalignments between capacities, competencies, and the organization’s roles and objectives.

In the case of building operations, the manner in which certain occupants use the building and the equipment can affect energy performance and the results of the operators and managers who are responsible for this equipment. The fact that such occupation practices are often recognized and legitimate increases occupants’ autonomy. However, occupants can also be dependent on maintainers or managers, who can initiate technical adaptations of the equipment.

Barley [13] supposes that new roles emerge naturally from dynamics of learning and mutual adaptation. While he considers rivalries in task appropriation, the principal mechanism for the emergence of a new division of work is the capacity to learn new tasks associated with the technology. It is possible to extend our analysis of the emergence of a new order by analysing the strategies of negotiation and social exchange between actors with regard to task distribution. According to Crozier and Friedberg [14], actors can activate their resources or develop their capacity of action in order to obtain behaviour favourable to their expectations from their counterpart. Drawing on Emerson [15], the authors consider that dependencies are managed by social exchange: through cooperative behaviour, some actors can obtain the cooperation of other actors on which they are dependent. Strategies of influence and social exchange can contribute to the stabilization of a new social order [14]. This social exchange is not always favourable to all parties: a lack of informal cooperation could lead to the persistence of misalignments between practices and expectations. Dependencies can also be strategically increased by some actors, exploiting the uncertainty and variability associated with the equipment, or ambiguity in the interpretation of rules [14].

Material changes are not ignored in the analysis of such dynamics of cooperation. As Michel Callon argues [16] with the concept of translation, strategies of influence can imply changes in the technology itself. The “translation” of the technology in the user’s material world can be a strategy of the technology promoter to enrol users and other interested parties. The gap between “expected uses” and “actual uses” of the building leads to a learning-by-doing manner of technical improvement and a renegotiation of energy performance. Thus, operators develop technical adaptation following the recognition of the users’ dynamic relationship between script and antiprogram [26]. Material adaptations contribute to the alignment of practices with expectations.

By analysing situations of comfort, social representations appropriations of technology and space, and learning dynamics, it is possible to analyze the misalignment between actual practices and initial script, and to understand the emergence of new interdependencies between occupants and professionals in charge of operations. Such analysis furthermore reveals the negotiation between professionals, operators and managers of the building on the adaptation of the organization and of the technical system, as well as the energy performance.

3. Materials and methods

3.1 Context

The case studied is the 23,000m² building of a French higher education institution. Its 1,450 students work daily with 550 permanent staff members in research, teaching and services. There are also a large number of occasional visitors, arriving for scientific and public events. The building has six floors and two interior courtyards. Its main architectural feature is the spatial organization around an agora, a large central space like a station hall, with collective services, such as a reception, catering or an amphitheatre, constituting a compulsory passage way for all visitors/occupants. On the upper floors are the classrooms as well as the administrative offices and research laboratories. While energy performance in collective spaces and offices is achieved by automating the energy system, in the agora the choice was made to have a "*temperate space*"¹, in other words, the temperature is regulated by air circulation and heat supplied from the data centre, located on the second floor.

The building was designed and built according to the Public-Private Partnership (PPP) economic model by which a company constructs a building and is in charge of its operations for 25 years, on behalf of the public actor, who pays an annual rent. After 25 years, the public actor becomes the owner of the building. A contract, drawn up prior to construction, defines the responsibilities of the builder-operator for the 25-year period. The operator carries out the maintenance and optimization of the building's operations under the control of a manager (representing the public actor), who applies contractual penalties if the objectives are not achieved.

In our case study, the building's energy performance is one of the contractual objectives. A consumption target was calculated according to pre-construction expectations of the building's uses and thermal performance specifications (with a temperature range in the offices). Under the PPP model, this objective must be readjusted according to the building's performance during the first two years, considered to be probationary.

The team in charge of site operations includes a chief engineer and three technicians. In addition to these in-situ resources, the hierarchy of the company manages the contract externally. The building's operation is governed by a technical system controlled by a Building Technical Management Software (BMS), which allows all temperature, lighting, ventilation and water settings to be controlled centrally. Only the operator has access to the software settings, which are negotiated in various instances, including the weekly operating review and the monthly Technical Committee (COTEC).

The architectural choices of the building meet performance requirements: materials, installation of air conditioning only in server rooms, automation of lights and outlets, window locking. The technical system has been designed and is managed on a daily basis according to a logic of "technical

¹ Interview with the architect who designed the building, 29/03/2018.

transparency" [27]: it must regulate the occupants' uses and guarantee their comfort while ensuring the building's energy performance without them noticing it. In addition to the architectural improvements, other adjustments related to the life of the building are managed from the BMS.

3.2 Data collection and analysis

Our interdisciplinary approach to the analysis of the energy performance gap in buildings requires the implementation of a methodology integrating several dimensions: organization, energy and space. In this sense, the method of organizational ethnography, embodied in space, seemed the most relevant to capture not only the dynamics of interaction between actors - over time and on different occasions - but also their relationship to the architecture and the technical system, in order to understand how to progress in terms of energy efficiency. According to Ybema et al, "*Organizational ethnographers do not describe the complexities of everyday organizational life in the abstract, but instead through reporting on their first-hand, field-based observations and experiences*" [28]; thus, our purpose is to avoid pre-established categories preventing us from grasping the complexity of the relationships experienced by the actors.

During the ten months of investigation, we attended operating meetings and followed the operator's work; we were also present at many events, demonstrations and informal occasions that allowed us to immerse ourselves in the area. We also conducted semi-directive interviews to supplement our observations. We attended three types of meeting: "management", "technical" and "information". During the management meetings, energy issues are presented in their relationship to economic and budgetary aspects. In technical meetings, technicians discuss the practical operations of the building, exchange skills and solve problems. During the information meetings, the decision-making actors collect the questions that staff and students have brought to the attention of their representatives and inform the latter of decisions concerning the operation of the building.

The ethnographic observation of users' space practices allows us to observe the practices being carried out and analyze the materiality of the architectural space. These observations revealed significant locations in the building where occupants deploy tactics and "arts of doing" [29] in order to appropriate a constrained environment. The sociological study of the occupants' practices led us to note and analyze the logic behind forms of adaptation/subversion of system constraints, and to update the modes of appropriation by which occupants interpret the script and its technical constraints. We linked the observation of practices in the building's spaces with interviews on its design and physical transformations: it was thus possible to reconstruct the design process, particularly with regard to the expected uses.

We monitored how operators develop the skills necessary to operate the building, in a continuous process of transformation and adaptation to occupants' uses. Monitoring the operators' work has provided access to the chief engineer's practices and his negotiations with other stakeholders. Several tours of the building allowed us to access parts dedicated to operations and not open to the public, such as the server room, machinery on the roof and in the basement, and the dangerous products room. We

assisted the chief engineer in several daily tasks, such as small maintenance work, preparing larger projects, or conducting tests to verify comfort issues in the offices.

4. Results

Our results show how actors appropriate the technical system and spaces, and how dependencies between the actors lead to a dynamic and “situated” [30] energy performance management. More specifically, the different parts of our results show how occupants intervene in a built environment limited by the materiality of the architecture and energy performance ambitions, and how the gap between “expected” and “actual” uses of energy and spaces creates room for negotiation and cooperation, or gives rise to rivalry between actors.

In the first part, blinds come to symbolize the gap in the perception of comfort between the operators' vision, linked to the technical system rationality, and the occupants' perception of the atmosphere. Occupants have comfort expectations that operators must recognize and take into account in their management of the building. When these expectations are not met, and more generally in a process of controlling one's own living space, occupants do not hesitate to tinker with the technical system to build comfortable spaces. To do this, they intervene in built spaces, especially in the offices. In relation to the energy system, their practices can be “constraining” or “subversive”, as proposed in the second part of the results. These practices result in unexpected uses of the building, which lead the operators, on the one hand, to reinvent their management of the technical system, and the occupants, on the other, to deal with the energy and spatial rigidities of the building. In the third part, the tensions between building rigidities and subversive practices lead operators and managers to intervene by adjusting the technical system and also by materially transforming the building. In this sense, the appropriation and management of energy performance cannot be successful without considering the materiality of the inhabited spaces. However, the last part of our results shows that this adoption process entails difficult negotiations and leads to a persistent misalignment, linked to the irreversibility of contractualization.

4.1 How occupants' expectations of building services are recognized by operators and managers

Actors tend to make sense of situations they face by using their prior knowledge. Occupants seek comfort through control of space in their daily experience of living in the building; the building's energy performance is often a secondary consideration. The definition of comfort is thus clearly “situated” and dependent on the position of the actors, between the immediate, situated experience of the occupant and the performance issues of the operator and manager. In this relationship between the actors and bearing in mind the limitations of the building, a first space for negotiation emerges: the occupant tries to make their own definition of comfort heard and this is relayed by the manager to the operator, who has control of the system.

In our case study operators interpret specific environmental situations, even discomfort, according to the theoretical scenarios for which they are prepared through their professional training and their calculations on the expected behaviour of the building. Thus, they often find themselves out of step with the real situation, where individuals perceive the building according to their own references in terms of their practices, their experience of the building and its materiality. Comfort specified as a level of temperature or degree of lighting implies an external, expert approach, while users can conceive comfort on a more personal basis, resulting from their ways of organizing their daily life in a familiar space².

The example of blinds illustrates how operators and users perceive comfort through different criteria. In order to keep the inside of the building warmer and thus reach thermal comfort, the blinds are automatically lowered at 5:30 p.m. when in winter mode. Around February, when the days get longer and there is still daylight at that time, managers inform operators that occupants would like to keep the blinds open longer.

During one of the operating meetings, the site manager in charge of technical issues asked for the setting to be programmed directly to 8 p.m. to avoid people asking for the blinds to be closed half an hour later every week, following the sunset time. The chief engineer, who controls the technical system settings, replied that the building would stay warmer inside if the blinds were closed earlier. Managers transmit a collective, informal request: “[The occupants say] *that this is like a signal. After that [blinds coming down], it's time [to leave]. It's a little depressing.*”³ The technical configuration (closing the blinds at a specific time) does not adapt to the gradual change in the seasons and the diversified practices of the users, some of whom may wish to stay late in the office. Thus, the energy-efficient setting of the device is interpreted as a limitation on personal freedom (invitation to leave the workplace), which also creates a “negative atmosphere”, as occupants say.

The chief engineer's argument against this request shows his confidence in technology: “[If the occupants want to keep the blinds open] *they have local switches.*”⁴ He insists on the ability of the technique to drive usage. Although the “depressing” feeling conveyed by the lowered blinds is not rational, it has an impact on individual workspace practices.

Moreover, the collective nature of the space in a tertiary building means that workers' practices have an impact on each other. When the chief engineer suggests, to those who want more light, raising the blinds in their offices, he does not consider the atmosphere generated by the closed blinds in other

² The same discrepancy can be observed in the perception of the satisfaction survey, sent by the managers to all permanent users at the beginning of 2018. While some chose not to answer (“*I have already answered several times*”), others collaborated, but deplored too strict and “technical” a vision of the questions (“*I am not always in the office: how do I evaluate my comfort in the other spaces of the building?*”; “*What about students' comfort?*”).

³ Observation of the technical meeting on 07/02/2018.

⁴ Ibid.

offices or in the corridors. Other observations from technical meetings show that the operator often trusts the software and its data, even when the latter are contradicted by the reality in the field⁵.

Situated interactions lead to comparing the divergent interpretations of operators and users, to come up with a specific, unprecedented solution. In the case of the blinds, the automatic lowering time has finally been set at 8 p.m. since the beginning of the year, which is a compromise between the actors. The operators would have lowered them at 5:30 p.m. with manual controls available to those who wish to raise them; the users would have preferred the blinds to be lowered a little later each day, at the rhythm of the seasons.

The approach to thermal comfort is more fragmented and subjective: a large number of occupants say they prefer to "put on an extra sweater" rather than break the rules (for example, by installing an auxiliary heater). The specificity of the office as a space for self-expression is visible in the very pronounced diversity of offices and among the feelings of the respective occupants. These singularities are related to the sharing of another part of the building, containing classrooms, meeting rooms and terraces - in short, all the collective spaces. While sharing in a collective space can lead to compromise in line with the impositions of the technical system, in a private space occupants are less hesitant to deploy subversive practices, giving priority to the construction of a comfortable habitat.

If occupants of dwellings often associate comfort with the perception of a certain temperature ("warmth", "coziness"), which can vary from one room to another according to the desired atmosphere [8], the collective dimension of the tertiary building leads the occupants to a perception of comfort more related to controlling a space "of one's own". The building's occupants experience comfort differently on the same premises and identify their comfort in the possibility of controlling their own living space.

In the private office space, the appropriation of the occupants is visible through wall decoration and the personalization of workstations, as well as through the many tinkered solutions that allow them to occupy their space in a comfortable way despite the restrictions of the technical system. For example, occupants disturbed by the ventilation did not hesitate to close the air vent to avoid the tedious flow of air. In such cases, space control plays a fundamental role: the negative consequences of containment (especially odours) are considered acceptable when they result from a decision on one's own workspace; yet when similar drawbacks come from the technical system (e.g. cooking odours in offices), they seem unbearable. Day and O'Brien [4] point out how the feeling of lack of control is a source of discomfort for users; hence, do-it-yourself practices in offices are a way not only to achieve visual or thermal comfort, but also to assert control over one's own living space.

The observation of how occupants organize their "private space" in the offices and collective spaces of the building reveals the gap between expected and real uses of space. While for operators the technical system abides by theoretical parameters and automation based on technical transparency, occupants, in

⁵ When the technician manager reported that the building's exterior lights were not turned off at night as they should be, the chief engineer asked for proof by viewing the surveillance cameras, before admitting that there was a problem with the software, since this "*said the lights were turned off*".

their declarations and practices, show eagerness for more diversified, flexible spaces. The search for comfort implies a capacity of action in the system, a source of rivalry with operators, who seek to retain control. The system becomes an arena of rivalry between the actors in the organization.

4.2 How occupants accept or subvert usage scripts

The rivalry and power relations between occupants, managers and operators revolve primarily around the technical equipment and the ability of each party to use or modify it in the direction of their own objectives, to the detriment of others. In this sense, the occupants' ability to implement practices of adaptation to or subversion of the technical system conditions the operators' management methods.

The field surveys of building users revealed two types of practices, which we categorized according to their relationship to the technical system. The first category includes practices that are subject to the constraints of the technical system and that fully respect the script. Since the technical system is designed to be passively accepted by users, constraint practices are often uses of space that allow the technical system to work instead of the human. Thus, the fact of never opening the window to allow the building to regulate itself properly is a deliberate choice made by the user. The latter can either judge that the building guarantees them a comfort that would be diminished by opening the window or may not wish to interfere with the regulation of the building. These practices may also be constrained by prohibitions or obligations to adapt. For example, the physical impossibility of fully opening a window leads to rethinking the use of the space around the window (in this case a calendar placed in front of the window). Similarly, the shut-off of the electric outlets at 8 p.m. forces employees to adapt their working hours accordingly. Other practices are not prohibited, but "strongly discouraged"; in such cases, their adoption is often the result of learning about space. The limit of these practices comes to represent the hierarchization of the occupants' priorities, particularly in the construction of a non-negotiable private space, where the system's impositions become secondary to personal comfort and self-expression.

For example, occupants most often work with their door closed to allow the office to regulate itself at a comfortable temperature. This condition is not necessarily natural because closing all the doors inhibits the conviviality of the shared professional space. Thus, when the technical system asks occupants to prioritize personal comfort and conviviality, they put the latter in second place, preferring alternative solutions (chatting in the corridors, coffee in the meeting room).

The second type of practice goes against the script, by forcing the technical system. These practices make it possible to actively distance oneself from the script, to challenge it and thus affirm one's own norms of space use. For example, the automatic door at the entrance of the building was forced several times because it was considered too slow; this practice in particular led to a redesign of the building's access. Forcing doors by means of wedges that keep them open is also part of these practices. Other "subversive practices" are less visible: some occupants know how to restart the electrical outlets after they have been switched off; others have keys to open their windows wide, while still others allow themselves an auxiliary radiator. The more obvious the prohibition is, the more subversive the circumvention. These practices prevent the technical system from operating "as it should", according to

the expected performance of the building. Other such practices may result not only from the deliberate choice of "subversion", but also from confusion about how the system works. For example, occupants are unaware that in some rooms the lighting is not automated, with the result that it is very common to see empty lit rooms.

Occupants can pay a high price, such as accepting deterioration in thermal comfort, for unanticipated space practices. The ways in which students use the agora and, more generally, the collective spaces significantly illustrate the divergence between expected and actual uses of the building and the technical system. When they are not in class, students say they often stop in the agora, sometimes to continue working or sometimes to meet and rest between two classes, because they do not have other spaces where they can meet without planning in advance. The agora was not designed as a workspace or a meeting/resting place, but was rather conceived as a space of "serendipity"⁶, in other words an indefinite space made as a passage way and for ephemeral encounters. Notwithstanding, it hosts a large range of hybrid uses that students require, such as working, meeting for coffee or resting on sofas.

The rigidity of the architecture and the technical system makes the agora an uncomfortable space, but strongly appropriated by students through the above-mentioned hybrid uses. Thus, occupants have to pay the price of their unanticipated uses in terms of choice of space or thermal comfort. A similar analysis can be made for the outdoor spaces adjacent to the student restaurant; as soon as spring arrives, the few outdoor tables are not enough to accommodate all the students, who have to sit on the ground if they want to be outside. The discomfort of the agora is confirmed by the frequent choice of students to move their activities to the mezzanine just above it, an open but warmer space.

These examples of real use and fluidity in space occupancy patterns reveal the dynamics of appropriation of the technical system by occupants, who do not hesitate to break away from the script to adapt the spaces to their needs. Occupants develop "situated" skills and knowledge [30] from their appropriation of spaces that overlap and sometimes replace the operator's technical skills. However, these appropriations remain in permanent conflict with a rigid technical system that leaves little room for flexible occupant practices. Thus, all subversions have costs, whether in user-friendliness, comfort or anticipation of uses. These limitations are mainly due to the material constraints introduced into the building at the design phase, but the irreversibility of these constraints is only partial and any change implies on-the-ground learning for operators.

4.3 How operators face unexpected occupants' behaviour and use of the building

Faced with unexpected behaviour in space use or comfort requests, operators learn, redesign and modify the technical system. Despite the centralized management, which makes the operator the only party capable of fully knowing and mastering this system, appropriating the latter seems rife with difficulty and negotiation. Malfunctions and discrepancies with daily use are increasing, leading to

⁶ Interview with the architect who designed the building, 29/03/2018

changes in system settings and even physical changes in the building. In our case study, this is particularly true of the agora: conceived as a temporary area for visitors, it is rather an ephemeral meeting space for students and a permanent workspace for reception staff.

The daily work of the chief engineer requires a diversified presence in the field adapted to the fragmentation of space usage. Many problems cannot be solved without a physical presence on site and long-term technical and relational work, as well as mutual acculturation with users. Operators thus gain a better understanding of users and their ways of living in the building, and thereby modify the settings of the technical system and the performance management. In this sense, interactions with occupants trigger a process of enactment [11] of the initially planned operating system, with space playing a fundamental role in this process. Thus, the technical system in the building is not a finite object but a process in the making, set up and modified by the interaction between operators and users. Energy performance cannot be an objective set in stone on the basis of theoretical calculations but must be conceived and managed as a process in constant redefinition through the interaction between the actors [27].

Operators arrive in the building with a theoretical background of expertise but this does not enable them to operate in a way that meets the needs of all occupants. To adjust their action, they develop skills "by-doing": they learn to deal with specific problems through interaction and "improvised learning" dynamics [31].

The fragmentation of the operating chief engineer's action is also visible in the diversity of tasks he must perform within the same day: external orders, administrative questions, technical adjustments and management of the relationship with his hierarchy. The systematic use of subcontractors, which depends only on the operating company, makes the job more complex when the engineer must report on his work progress to the managers. The operator managers present during the monthly and quarterly meetings are hardly ever in contact with the field, and the turnover of people in the Operating Department does not facilitate knowledge of the building over time. The flexibility of occupants' practices imposes alternative uses of the building, which, on the one hand, are often considered dysfunctions - in terms of operation and performance ambitions - and, on the other, impose unavoidable constraints on operations. Decision makers are gradually being forced to take this into account and adapt the technical settings accordingly, or even make physical changes to the building. The most significant example of "subversive practices" that have led to modifying the building is the entrance door: the thermal and practical discomfort due to the automatic operation of the door has led users to adopt "subversive" practices and decision-makers to rethink the entrance space to the building.

The construction of the entrance doors complies with regulatory requirements. People enter the building by crossing two automatic doors in an L-shape, designed to operate in summer or winter mode. In the former season, both doors open at the same time to allow passage; in the latter, it is necessary to wait until the first door closes for the second to open. The winter mode was designed to prevent the cold from deregulating the internal temperature. If the agora is not heated, the internal temperature benefits from the circulation of hot air from the data centre. However, the door seems inadequate to absorb the large flow of students arriving between 7:55 and 8:05 a.m. for the beginning of classes. A very large number of students arrive within ten minutes, causing great difficulty in entering, according to accounts

collected during our investigations. Sometimes, having too many people in the space between the two doors prevents the first door from closing, and therefore the second door from opening. At other times, the wait seems too long for people in a hurry to enter. On several occasions, the inner door was forced and had to be repaired to restart the engine. Faced with this deterioration, the building managers decided to leave the door permanently in summer mode, in other words with both doors opening at the same time, which allows very cold air to enter the agora, especially in winter. Those most affected are the service staff members occupying the offices adjacent to the entrance, especially the two secretaries, who are obliged to permanently keep their office doors wide open as they work both on the computer and at the reception desk.

After the third uncomfortable winter, windows were installed at the reception desk to prevent air from entering the back offices. While the feeling of thermal comfort has improved considerably, the glazing has changed the initially designed relationship between the reception and the agora, and has modified the visual perception of the reception space.

Following incidents and complaints about comfort, the managers decided to also intervene in the entrance itself and installed a large revolving door which would absorb the flows of students in the morning, and guarantee that the existing door would remain in winter mode all the time. While decisions on the design of the revolving door did not directly involve users, the solutions adopted resulted from learning about their "subversive" practices and listening to the needs of the reception staff. By adopting these solutions, decision-makers reconfigure their knowledge of the building and its expected uses, and develop skills that complement or even challenge their theoretical expertise. However, these reconfigurations of their professional activity do not go as far as questioning the organizational structure governing operations, as this is constrained by the PPP contract.

4.4 How issues raised by occupation threaten the formal organization of responsibilities

The process of adapting the technical system does not happen in a space free of constraints; on the contrary, it is part of an organization where roles, issues and competencies are distributed among the actors, producing an impact on them. Unexpected occupant behaviours can hinder the work of operators and therefore the performance measured by management indicators. When operating activities are subcontracted, lower performance can affect the contractual relation. Managers of the building are also concerned about occupant satisfaction. All these adaptations are restricted by contracts and a limited budget. The variability and uncertainty of occupations, along with ambiguity in the evaluation of comfort, lead to a complex set of interdependencies that can be partially managed by cooperation and negotiation.

As mentioned above, the operations team belongs to an external subcontractor and is limited by a budget, initially based on the specifications of the service. The team is encouraged to reduce energy consumption and cut costs as soon as it reaches the initially defined level of performance. The appropriation processes we have described reflect the significant gap between upstream contractual specifications and an expression of needs resulting from usage and the experience of uncomfortable situations.

Thus, those representing the subcontractor frequently return to "*what was set out in the contract*"⁷ to show that their company is complying with the "original" commitments and therefore cannot be held liable for any breaches. It warns managers that if the operation of the technical system changes, the thermal behaviour of the building will also change and therefore the company can no longer be held responsible for the performance objective. Instead of guaranteeing simpler operations, the contract binds the parties to their initial commitments and does not allow for any deviation, except at the cost of very long negotiations.

Building managers relay the requests and dissatisfactions of the occupants to the operators who provide the service, putting themselves in an intermediary position. Managers are dependent on operators to implement occupants' requests. They are responsible for financing all the activities not provided for in the initial contract, such as modifications to the building or the technical system, arising from new needs. Their objective is to satisfy the occupants but, since their budget is limited, they must arbitrate between the needs expressed. As far as possible, they seek to demonstrate that responses to the occupants' requests are indeed part of the operator's contractual obligations and therefore should not incur payments in addition to the agreed rent.

One illustration of such negotiation is that arising from the problems of thermal discomfort. It is a contractual grey area: operators are required to respect minimum and maximum temperatures in each office but they are also subject to overall consumption requirements. To meet these expectations, they are required to optimize regulation, even at the office scale. According to the specifications, they must meet target temperatures, but not necessarily comfort expectations. However, the manager, who acts as the occupants' spokesperson, argues that this optimization should take into account perceived comfort and not simply contractual requirements: "*I do not think that [the reference to the contract] is an answer that can satisfy the immediacy of the question. Whatever the factual data, a response to a perception must be provided. And the perception is that there is discomfort.*"⁸

The informal process by which occupants report their dissatisfaction exacerbates this grey area and plays a strategic role in interpreting gaps and assigning responsibilities. Thus, managers quickly understand that anyone who takes control of the expression of occupants' needs or analyzes their practices will be able to guide their interpretation and the distribution of responsibilities, and use this power as a resource during negotiations.

The formal procedure for any issue in the building is to report it on a centralized online platform, managed by the technician manager. It is then forwarded by the latter to the operator, who addresses the problem in the field. Around this formal practice, there are various informal practices. When an occupant reports some dissatisfaction, even if the general rule is to go through the online platform, it is not uncommon for the problem to be resolved by the technician manager, met in the corridor and stopped in person. Similarly, the technician manager may invoke his own skills and resources ("*my*

⁷ Observation of the COTEC on 06/12/2017.

⁸ Ibid.

plumber") to compensate for delays or deficiencies in the operator's official interventions. This ambiguity leads some occupants to consider their interlocutor to be the operating team while others believe it to be the technician manager.

Due to their dependence on the technical system, requests for repairs and adjustments by occupants are more easily expressed through direct interaction with maintenance operators, which contradicts the formal nature of computerized requests. The official procedure is subject to widespread hijacking, bypasses and do-it-yourself operations. The occupant can call on a member of the operating team in the corridor; this person then goes and solves the problem without a computer report. In order to manage the interventions of the operating team, the chief engineer tries as far as possible to limit the requests to those formally entered in the online platform so as to preserve a certain traceability of his interventions and a visibility of this expression of needs. However, the fact that managers must filter every problem report slows down the process and hinders the creation of trust between operators and users.

More generally, operator and managers have interest in addressing the responsibility of occupants' discomfort or dissatisfaction. Depending on how occupants' practices and needs are interpreted, the costs must be borne by one of the two structures. In this process of interpretation, everyone is tempted to minimize the importance of gaps falling within their own responsibility and conversely to maximize the importance of gaps whose management falls within the partner's responsibility.

4.5 Persistent misalignment linked to the irreversibility of contractualization

These rivalries over the optimization of energy performance and the management of occupant demands reflect a low level of trust between managers and operators. While lack of trust and the systematic reference to the contract are part of the culture of building construction and operation, it is particularly strong here. It can be assumed that the contractual framework, a 25-year PPP, causes suspicion on both sides.

Indeed, during the period of our observations, managers and operators undertook a renegotiation of the building's performance objectives and the rent for more than twenty years. In these negotiations, managers were not in a favourable position because they were strongly bound by an initial contract that is largely unsuited to the reality of their uses and needs. Managers cannot change operators nor impose resource requirements, for example to increase the number of technicians of the operator team. They may therefore fear a loss of control over the relationship.

In this unfavourable context, managers nevertheless try to demonstrate that the resources put in place by the operating company are clearly insufficient. Thus, managers are particularly vigilant about the human resources allocated by the operators, such as the replacement of technicians or engineers on departure, and the level of competence within the team. For example, when one of the technicians left the operating team, managers asked to see the profiles of the new recruits and complained about the two remaining technicians, according to information gathered by users. Managers also systematically contest the attendance schedule, considering that it does not reflect the reality of the operating team's investment.

During the many negotiations related to the operation of the building, the exchanges have followed repeated patterns that distort the management of the building by refocusing on topics such as assignment of responsibilities; communication of information; deadlines for solving problems; and gaps with the contract. Meeting discussions move away from the content of problems and lengthen resolution times. This deviation leads managers to perceive that operators are more interested in compliance with the contract rather than the performance of the building. By exercising detailed control and expressing ongoing dissatisfaction, the managers' main objective is to put pressure on the operator hierarchy to obtain more resources in the building operating team.

The building managers seemed to clinch some changes when a new PPP manager arrived in the operating team. By participating in expert assessments and organizing additional meetings with managers to discuss specific urgent issues, he demonstrated a strong commitment to addressing problems. From the managers' reactions, this strategy seemed to be bearing fruit: technical procedures were moving forward and relations between the two parties became more relaxed. However, the pressure exerted by the managers during the technical committee meeting contributed to the operating team's feeling of being overloaded and under-recognized. This dissatisfaction of the operators' team was reflected in the resignation of the chief engineer, which has become a problem for their employer; staff turnover has a cost and contributes to the deterioration of performance.

This analysis of the relationship of dependency between manager and operator has brought into question their ability to adapt the functioning of the building to the needs, perception and practices of users. The formal contract, establishing a long-term relationship and made before occupation, is not flexible enough to encourage negotiation on new needs. This gap can create a vicious circle: the conflictive relation leads to a rigid interpretation of the contract by both parties, and this rigid interpretation in turn prompts conflict. The new PPP manager assigned to the building is trying to break this vicious circle by adopting a new attitude in negotiations, without any guarantee of success.

5. Discussion

Our research advocates the adoption of a relational approach in the analysis of the energy performance gap, i.e. not focusing solely on the professional practices of operators, the space occupation practices of users, or the decision making by managers, but rather analysing their interdependencies and the dynamics of cooperation between them.

The automation of the technical system, which is based on the principles of "technical transparency" and "user passivation" [27], has been designed to guarantee energy performance through minimal interaction with the occupants, in other words minimum control on their part. Behind this decision, there is a social construction of experts guaranteeing technical performance by orienting practices. On the other hand, occupants' appropriation reveals a social construction of the building as a living area, where control of space is fundamental in achieving comfortable living. Thus, occupants take to "subversive" practices when the constraints of the technical system or the materiality of the building restrict usage. These appropriation dynamics create spaces for a fluidity of uses and needs that cannot

be facilitated by a purely expert approach to the technical system or by an injunction from the operator and manager to adopt energy-efficient behaviour in line with the scenarios envisaged in the building design [32]. Thus, operators engage in a process of learning in the field, progressively diversifying their approaches to problems raised by occupants.

The first difficulties experienced by occupants, operators and managers are the different perceptions of ambient situations, in other words the material and even emotional possibilities of spaces. In the offices, the question of controlling space becomes central to the organization of usage and has a significant impact on energy performance. The link between architectural materiality and energy performance is interpreted differently according to the position of the actors in the organization [33]: for the occupants, it calls for architectural and technical flexibility allowing for a significant hybridity of uses, while ensuring comfort. For operators, an energy performance embodied in the architecture is necessarily governed by strict automation rules, guaranteeing efficient consumption through constraints on use.

However, in the face of user interpretations and appropriations, which develop in a "subversive" way when limited by space and device, operators are forced to diversify their approach to implementation. New competencies emerge from the interaction between actors and devices. While appropriation can be an individual process, by which an occupant adopts or diverts the technical system, the joint adaptation of practices and technology is a collective process by which a "community" builds a shared energy performance. The adaptation process thus takes the form of an institutionalization of operating practices, which guarantees dynamic energy performance. Energy performance is thus a process collectively constructed by interactions between actors [34].

The sociotechnical dynamics of adaptation have similarities with participatory approaches [35]. Although the participation arrangements we have observed are often limited to a few occupant representatives, we have shown that occupant behaviours are highly dependent on the organization's ability to engage in a communicative relationship with them. Our study confirms that informal interactions contribute significantly to information, persuasion and practice directed in favour of energy efficiency [36]. Nevertheless, our analysis refines the conditions of this cooperation in the case of building operations, by specifying the relationships of dependency between occupants, operators and managers. Energy efficiency is conditioned here by an alignment of occupancy practices with the script incorporated in the building and its technical equipment. Operators and managers have a high responsibility to adapt the script of the equipment to occupants' practices, but organizational rigidities and technical irreversibility slow down this learning process.

That is why the flexibility of the organization, in other words its ability to accept new tasks and new roles, seems to be a prerequisite for adaptation to occupation practices and technical appropriation. The contractualization between managers and operators in the context of the outsourcing of maintenance and energy optimization is a major organizational constraint that limits negotiation, social exchange and ultimately flexibility [37]. Our observations highlight the limits of long term performance contracts in the face of uncertainties in space occupation practices, the experience of comfort, and transgressions in the use of technical equipment. The reality of exploitation leads to new energy performance scenarios, which must however be put in perspective with the contractual rules. This leads to lengthy negotiations, where the assignment of responsibilities takes precedence over decisions. Even if contracts are also a

resource in the negotiation and can be used strategically with some degree of flexibility on the basis of cooperation the financial issues of the long-term contract prevent the alignment of responsibilities and lead to tensions and mistrust.

On a larger scale, this case questions the financial strategies currently in use in the tertiary building sector. These contribute to the fragmentation of roles and responsibilities and the sophistication of contracts, but their lack of flexibility does not allow the observed appropriation processes to be tackled, running the risk of persistent misalignment, which is inconsistent with the challenge of optimizing comfort and energy performance [38].

6. Conclusion

The search for energy performance in office buildings has been accompanied by a major technological investment with the implementation of automated temperature and light control systems, which has often led to the outsourcing of maintenance and optimization skills to specialized service contractors. We questioned the consequences of these technological and managerial choices in the context of the use and operation of the building. We tried to understand how the strategies of the occupants, in terms of space occupation, comfort and the appropriation of technical systems, were compatible with said technological and managerial choices.

To do this, we relied on an organizational ethnography method that favours an all-round approach to the practices of the members of the organization with regard to the building and technical equipment. This ethnographic approach and the interpretative work permitted us to gain an integrated understanding of both the uses and their consequences on the organization, taking into consideration dependency relationships between occupants, operators and managers.

A first result is that divergences between anticipated and actual uses are inevitable: unplanned activities and comfort issues lead to different appropriations of the scenario of use, in which the building and equipment are inappropriate. Occupants carrying out local adaptations and operators modifying the system settings in order to respond to them, are in fact dependent on each other. Thus, each adaptation has consequences in terms of cost or energy performance because of the technical and contractual sophistication of this highly automated high-performance building.

A second result is that the quality of cooperation relations (partly determined by formal and contractual parameters) appears to be a determining issue. We detailed three characteristic roles with different stakes: occupants, operators and managers. We observed coalition strategies that allow certain stakeholders to make progress with their issues to the detriment of opposing stakeholders. The operators can agree with the occupants by developing informal relations with them concerning modifications that the manager would not have accepted because they are too costly or lead to a deterioration in energy performance. Conversely, managers, in their conflictual relationship with the operators, mobilize the dissatisfaction of the occupants to highlight incompetence or the insufficient involvement of the operator. Alternatively, operators and managers may agree to prioritize energy performance and cost control to the detriment of the occupants' demands for comfort and adaptation.

Thus, this study invites us to place the uses of technical systems and built spaces within the framework of an understanding of the relations between the actors (both users and professionals) without simplifying the technical and economic stakes and the distribution of capacities of action. The increasing technical sophistication of high-performance buildings, accompanied by ignorance of the needs of the occupants for flexibility of use, leads to misalignments that are particularly difficult to remedy and consequently produces a gap between the energy performance announced at the construction stage and that finally obtained in operation.

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