A Comprehensive Smart System for the Social Housing Sector

Isam Shahrour

Abstract This chapter presents a comprehensive smart system for the social housing sector which considers technical, social, and environmental issues. The chapter is composed of four sections. The first section discusses the challenges of the social housing sector with an emphasis on the social and environmental dimensions. The second section presents the research methodology, including an analysis of the expectations of the tenants and the social housing manager and the specifications for the design of the comprehensive smart system. The third section describes the architecture of the smart system, including the stakeholders' communication channels, the monitoring system, and the smart services. The last section shows an application of smart system to a renovated social housing residence. The chapter shows that the comprehensive smart system should go beyond the smart building concept by extending this concept to the construction of a smart community and the involvement of this community in the improvement of the social housing environment.

Keywords Social housing · Tenants · Smart · Community · Energy performance · Sensors · Platform · Comprehensive

1 Introduction

The social housing sector constitutes a significant issue for several European countries. It accounts for 30% of the rental housing in the Netherlands, 18% in the United Kingdom, and 17% in France. The importance of this sector goes beyond the high housing sharing ratio because it generally combines a challenging social context and poor construction performance. Since this sector concerns mainly low-income families, tenants are exposed to social and economic difficulties such as low income,

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unemployment, and lower access, compared to other populations, to essential services such as education, health, culture, and sports.

Some scholars have focused on analyzing the poor energy performance of the social housing sector and its consequences for tenants' quality of life and housing precarity (Esmaeilimoakher et al., 2017; Filippidou et al., 2016; Elsharkawy & Rutherford, 2015; Juan et al., 2018). They showed an urgent need for the renovation of the aged social housing sector for both energy savings and occupants' quality of life. Other scholars have analyzed the impact of social building renovation on energy savings (Elsharkawy & Rutherford, 2015; Enertech, 2018; Kavgic et al., 2012). The results showed that the renovation program did not result in the expected energy savings. They attributed this disappointing result to an insufficiency in the monitoring program and occupants' involvement in energy management. Kavgic et al. (2012) showed that building characteristics are not the most relevant factors in energy savings because of the dominant role of resident behavior in energy consumption. Belaïd and Garcia (2016) explored the main factors influencing residential energy-saving behaviors in France. They highlight the impact of five main attributes incentivizing energy-saving behaviors: energy price, household income, education level, age of head of household, and dwelling energy performance. A questionnaire to the residents of an energy-saving program in Nottingham showed that the achievement of high energy performance requires occupants' involvement and policy interventions (Elsharkawy & Rutherford, 2015).

A recent report about the portrait of social housing tenants in France indicated the following features (USH, 2019): approximately 40% of tenants live alone, 20% are single-parent families, 30% are over 60 years old, and 30% live below the poverty line. In addition, approximately 70% of the social housing buildings in France were built before 1990, which means that most of this sector does not respect today's building standards. Approximately 66% of these buildings are energy intensive, which means high energy consumption and too many expenses for low-income tenants.

In a recent study, Freund et al. (2022) showed the following well-being needs of social housing tenants in Australia: paying unexpected bills, feeling sad or anxious, feelings of anger or frustration, and memory or concentration problems.

The portrait of the social housing sector shows that this sector is facing significant and explosive challenges because of the critical social and construction contexts. To address these challenges, national and local governments launched several initiatives and strategies to renovate the social housing stock. These strategies are, of course, necessary (Jensen et al., 2022; Bal et al., 2021). Nevertheless, considering the social context, they should be carried out within a comprehensive strategy that combines social development, tenants' participation, and innovative services with guarantees that tenants can have easy access to these services (Shahrour & Xie, 2021; Jnat et al., 2020; Duvier et al., 2018). This chapter presents how the smart city concept could help create this environment. The chapter first presents the research methodology, including establishing the specifications for the smart system. Then, it describes the architecture of this system and, finally, its application to a renovated social housing residence. The main contribution of this chapter consists of the

design of a comprehensive smart system for the social housing sector, which goes beyond the smart building concept. The design is based on analyzing the expectations of the tenants and managers of social housing. The capacity of the system is illustrated through its application to a renovated social housing residence.

2 Research Methodology

2.1 Overview

This research was conducted through cooperation with social housing managers with the objective of designing a comprehensive smart system for social housing management that considers technical, social, and environmental issues at both the apartment and complex levels. The research started by analyzing the process of managing the social housing complex and identifying the responsibility of the social housing manager. Concertation was then conducted with tenants to understand their expectations from the smart transformation of social housing. The combination of the manager's and tenants' expectations allowed us to determine the specifications for designing the comprehensive smart social housing system. Since this system is expected to offer a wide range of services, its construction requires time, resources, testing, and readjustment. For this reason, the first phase of its implementation concerned the evaluation of the impact of renovation on tenants' quality of life and energy consumption.

2.2 Manger's Expectation of the Smart Transformation of the Social Housing Complex

The responsibility of the social housing managers concerns providing services related to the maintenance of buildings and infrastructures, supply of drinking water and heating, lighting and cleaning of common areas, local waste collection, and access security. The manager is also responsible for tenants' information about maintenance works, water, energy consumption, and current shared expenses.

Generally, social housing managers work with many companies and service providers. Since each company has its communication channel and management system, the social housing manager has to deal with a multitude of unconnected systems that cause frequent manual interventions.

Maintenance work, particularly that requiring emergent interventions, seems to be the most critical. The challenge is how to capture, transmit, and efficiently organize urgent interventions. This challenge could be addressed through the development of a smart monitoring system that (i) ensures a real-time survey of the critical equipment and spaces, (ii) transmits the collected data to concerned people,

Table 1 Tenants' expectations from the smart transformation of social housing

Expectation	Concerned stakeholders
Report complaints and follow up responding measures and actions	Social housing manager, tenants' community, services providers
Access to information about maintenance works, disorders, new services, etc.	Social housing managers, services providers, maintenance companies
Access to data about energy and water consumption, indoor comfort, and air quality	Social housing manager, services providers, occupants
Security and safety	Social housing managers, security companies, emergency services, police departments
Delivering services for occupants with specific needs (people with disabilities and older people)	Social housing manager, services providers, medical services, social services, tenants' community
Addressing energy precarity	Social housing manager, services providers, social services, tenants' community
Build a smart community	Social housing manager, tenants'community

including the local building manager, the maintenance companies, and the tenants, (iii) tracks the technical interventions, (iv) informs concerned people about the intervention progress, and (v) establishes automatic reports about the technical interventions. In a large social housing complex, urgent interventions could be delayed by difficulties related to localizing and accessing the intervention area or requirement. Rapid localization could be provided by a smart indoor navigation system based on digital tags displayed in the main indoor sections and equipment. Building information modeling (BIM) offers extensive 3D graphic facilities to digitally identify buildings' components and equipment, including their properties and spatial localization and indoor navigation.

The manager is also concerned with establishing an efficient communication channel with the occupants to receive their complaints and observations and to follow up on the measures and responding actions.

Table 1 summarizes the expectations of the social housing manager from the smart transformation of the social housing sector.

2.3 Tenants' Expectations

Discussion with the social housing tenants showed several expectations, which could be classified into seven categories. The first concerns the communication channel. It is about how the occupants can easily report complaints and observations and follow up on the responding actions. The second concerns receiving information about the maintenance works, service interruption, and new services. The third category concerns access to real-time and historical data about indoor comfort, air quality, and energy and water consumption. The fourth category is related to

Table 2 Tenants' expectations from the smart transformation of social housing (Jnat, 2018)

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security, emphasizing secure access to the building and external common areas such as parking, green spaces, and children's playing areas.

The fifth category concerns delivering customized services to occupants with specific needs, such as persons with disabilities and older people. The question is, how could the manager help provide specific services? The sixth category concerns energy precarity, which harms low-income families. The tenants expect to benefit from measures to reduce energy consumption through construction renovation and replacing energy-intensive appliances. The last category concerns building a smart community to create a friendly social environment to enhance mutual aid, cultural and collective activities, services and products exchange, and break individual isolation and loneliness.

Table 2 summarizes the tenants' expectations from the smart transformation of social housing.

3 Design of the Comprehensive Smart System

3.1 Communication Channels

The architecture of the comprehensive smart system is illustrated in Fig. 1 (Shahrour & Xie, 2021). A smart platform ensures communication with social housing stakeholders, including social housing managers, tenants, maintenance companies, service providers, social services, and emergency services. Each stakeholder can communicate with the platform using a mobile application or a web service. Stakeholders receive information on the mobile application or through email or messages. Each stakeholder has secure identification access. Tenants have a personal profile.

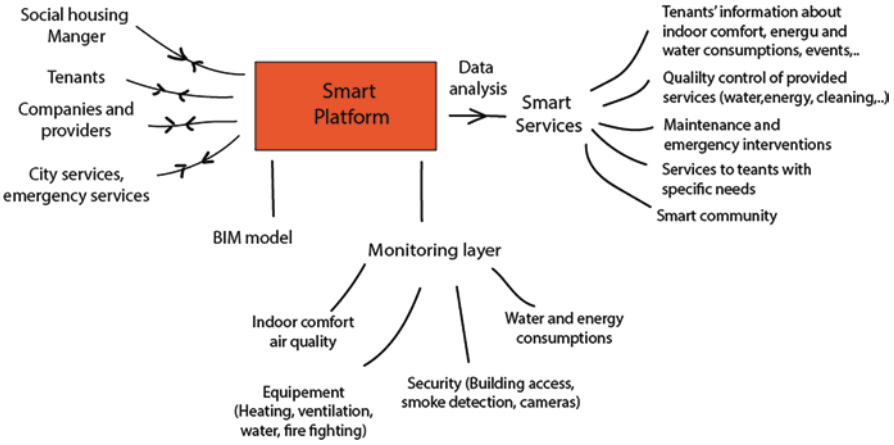

Fig. 1 Architecture of the comprehensive smart platform for social housing (Lagsaiar et al., 2021)

The platform is connected to a BIM model of the social housing complex, which includes a spatial description of the complex and the properties of its components. It provides tools for the 3D visualization of the complex and its components. It also provides graphics for dynamic data such as indoor comfort, air quality, and energy consumption.

3.2 Data Collection

The social housing complex is monitored by smart sensors that measure and transmit real-time data to the platform (Lagsaiar et al., 2021). Smart monitoring covers a multitude of parameters, such as indoor comfort, air quality, energy and water consumption, and security parameters, including building access, smoke detection, movement detection, and survey cameras. In addition, some equipment, such as heating and ventilation systems, are monitored to track their functioning. They are also equipped with actuators that permit their online or automatic control.

Social housing stakeholders, particularly tenants, can transmit their observations through mobile applications. For example, when they observe an anomaly, they can take a photo, record a voice message, and send their comments via the mobile application.

For maintenance work or emergency interventions, professionals can access information and data about the equipment through the mobile application. They use the mobile application to upload the intervention reports, which are then automatically transferred to concerned people.

3.3 Data Analysis: From Data to Smart Services

The platform operates data analysis to turn the collected data into smart services. Figure 1 shows the smart services provided by the system. They include (i) information of tenants about indoor comfort and energy and water consumption; (ii) control of the quality of provided services such as water and energy supply, cleaning, indoor and outdoor lighting, and waste collection; (iii) maintenance of buildings and emergency interventions; (iv) services for people with specific needs, particularly people with disabilities and older people; and (v) building a smart community with an emphasis on mutual aid, cultural activity, services exchange, and breaking individual isolation and loneliness.

4 Application to a Renovated Social Housing Residence

4.1 Objectives

This section presents the application of the proposed system to renovated social housing residents in northern France. This application concerned the first stage of implementing the comprehensive smart system with emphasis on the impact of the renovation on tenants' quality of life and energy consumption.

4.2 Description of the Social Housing Residence and the Monitoring System

The social housing residence is approximately 50 years old. It was completely renovated (Jnat et al., 2020). It uses a central heating system with a manual regulation system. Despite the recent renovation, occupants complained about the high energy expenses. To understand the causes of these increased expenses, some apartments were monitored by indoor comfort sensors, including temperature and humidity. Data were recorded at 30-minute time intervals. The outdoor temperature and humidity were obtained from the nearby weather station. The monitoring program covered the heating period from October to April.

4.3 Results of the Monitoring Program

Figure 2 illustrates the variations in indoor and outdoor temperatures. The outdoor temperature varied between −5 and 23 °C with an average value of 5.1 °C, while the indoor temperature varied between 19 and 29 °C with an average value of

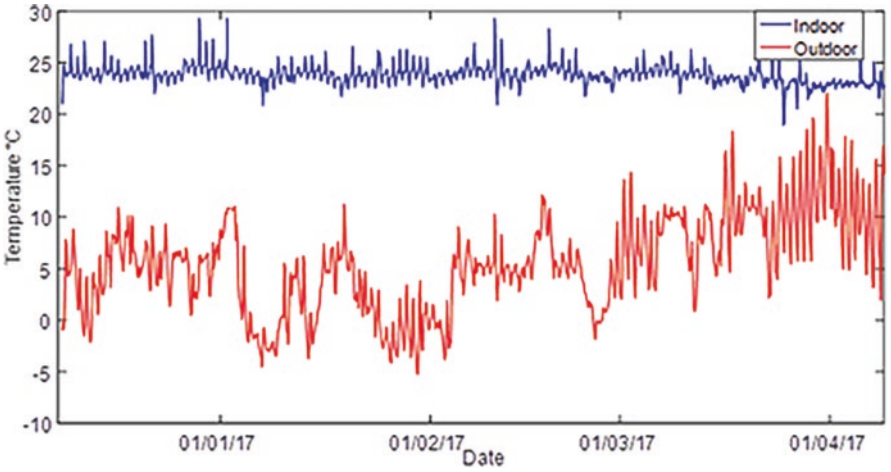

Fig. 2 Variation in the indoor and outdoor temperatures (Jnat et al., 2020)

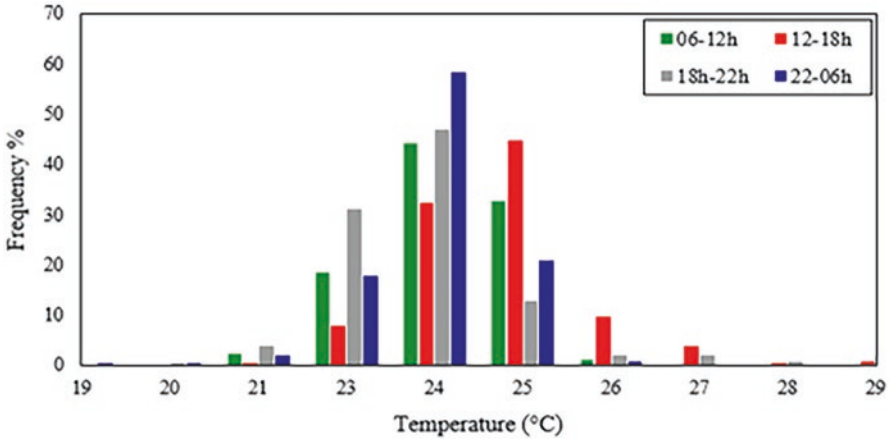

Fig. 3 Temperature distribution according to time slots during the heating period (A) (Jnat et al., 2020)

23.8 °C. This average exceeded the French regulation heating temperature by approximately 4.8 °C.

Figure 3 compares the distributions of the indoor temperature during four daily periods. The temperature distributions over the four periods are very close. The high-temperature values in the afternoon and the evening are related to tenant activity. According to French thermal regulations, the maximum indoor temperature during this time should not exceed 19 °C. During sleeping time, it should be limited to 16 °C. As shown in Fig. 4, indoor temperature highly exceeds the French thermal regulations values all over the day.

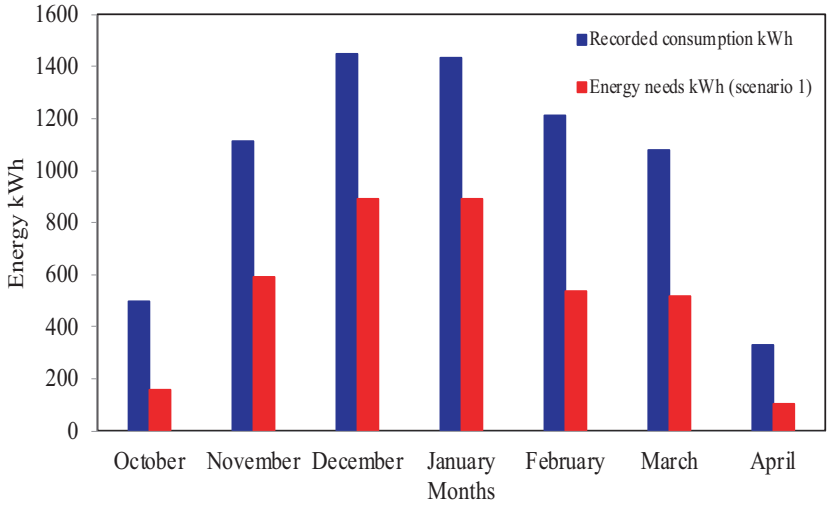

Fig. 4 Comparison between recorded consumption and estimated energy needs according to the French thermal regulations RT 2012 (Jnat et al., 2020)

Discussion with tenants showed that they were not aware of the excess indoor temperature and its consequences on their energy expenses. They attributed the high indoor temperature level to the manual regulation of the heating system and to the absence of a monitoring system that alerts them about the indoor temperature excess and its consequences on their expanses. Therefore, they were interested in estimating the impact of a friendly heating system on energy expenses.

To respond to the tenants' demand, the thermal software ArchiWIZARD (Jnat, 2018) was used to estimate the energy expanses according to the French thermal regulations RT 2012: an indoor temperature of 19 °C during the occupancy period, 16 °C in the case of a vacancy for a period less than 48 hours, and 8 °C for a vacancy exceeding 48 hours.

Figure 4 compares the recorded heating consumption and the estimated heating energy consumption according to the French thermal regulation RT2012. The monthly energy savings vary between 229 kWh in April and 675 kWh in February. Over the heating period, the overall heating energy savings equal 3420, which is approximately 45% of the heating consumption.

This example shows how the smart monitoring program could help identify the causes of high energy consumption in renovated social housing buildings, which combines poor monitoring and regulation of the energy system and the lack of information and awareness of tenants. The use of the proposed concept could help address these two issues.

5 Conclusion

This chapter presented the design of a comprehensive smart system for the social housing sector. The design is based on analyzing the expectations of the tenants and managers of social housing. This analysis showed that the comprehensive smart system should go beyond the smart building system. It should extend the conventional services of the smart building to social issues, including assistance to tenants with specific needs, cultural and sports activity, services exchange, and building a smart community. It also requires the establishment of an efficient communication channel between the tenants and the social housing manager.

The first phase of this approach was applied to a renovated social housing residence to understand the low impact of building renovation on energy expenses. The smart monitoring of the residence and exchange with tenants showed global indoor overheating due to poor management of the heating system and to the absence of a monitoring system and an efficient communication channel between tenants and the social housing manager. This example shows the importance of implementing the proposed comprehensive smart system in the social housing sector.

The concept proposed in this chapter could help policymakers improve the performance of both new and renovation social housing programs because it takes into consideration both technical and social issues. In addition, it reduces the current expenses of low-income tenants and facilitates their integration into the community as well as their access to cultural, sportive, and education services.

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