A methodology for the Energy Retrofit of 20th Century Architecture: the *Modèle Innovation* La Salamandre

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Abstract

Since the 1970s, in response to critiques of the *Grands Ensembles*, French housing policy shifted toward innovative, small-scale projects. The Plan Construction (1971) supported residential research through the Innovation Models (1973-75). Among them, the Salamandre residence in Villeneuve d'Ascq (1979), by André Wogenscky and Sud Atelier, applied Modernist principles, with 422 units and design features inspired by the Modulor. Later alterations (1994-96) in the rental section changed its appearance without improving energy performance. A first research phase showed that user behavior accounts for up to 40% of energy demand. Empirical occupancy-based scenarios indicated a 6–8% reduction in heating needs compared to regulatory models. Based on this, a minimally invasive retrofit strategy – 'Réhabilitation 2.0' – was proposed, involving residents and real-use data. Recent developments include tools for managing energy data to guide low-impact, heritage-respecting interventions.

Keywords
Modèles Innovation, André Wogenscky, Energy renovation, Occupancy variable, Decision-making tools.

Introduction

In 1971, France launched the *Plan Construction*, an inter-ministerial programme to foster research and experimentation in housing. Between 1973 and 1975, it promoted *Modèles Innovation*, prototypes aiming to modernise social housing through industrialised processes. Among the most well-known *Modèles Innovation* are the *Maillard model*, *La Salamandre*, *M+m* and the *Maisons Gradins Jardins*. Studies by Richard Klein and Caroline Bauer[1] underline their importance in post-war housing innovation. These projects responded to rapid modernisation needs but now raise pressing questions of redevelopment and sustainability. Often overlooked, many *Modèles Innovation* have suffered alterations compromising their integrity, from superficial changes in colour to major transformations or even demolition. Recent research has restored their visibility, leading the Ministry of Culture to award some the *Architecture contemporaine remarquable* (ACR) label, a first step towards recognising 20th-century architecture, even if it does not guarantee protection equivalent to that of *Monuments Historiques*. However, energy-efficiency regulations complicate their preservation. Renovation rules in France vary: major works must meet global performance targets (*réglementation thermique globale*), while smaller interventions follow more flexible criteria (*réglementation thermique par élément*). Decree No. 2016-711[2] imposing external cladding on post-1948 buildings drew criticism, but exemptions were later granted to ACR-labelled sites. Newer standards[3] (RT2012, RE2020) emphasise integrated approaches, including comfort and life-cycle impact, indirectly shaping strategies for existing buildings.

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Fig. 1 La Salamandre: Privately old section. © Lacth Vincent Lecigne.

Fig. 2 La Salamandre: rental section after energy retrofitting. © Pierre Thibaut.

The case study on a social housing model *La Salamandre*

Our research focuses on the La Salamandre model of social housing, which is the result of postmodern thinking. Inspired by Le Corbusier's ideas, the project was developed by André Wogenscky, who collaborated with Le Corbusier from 1936 to 1956. Wogenscky died in 1974, eight years before the official launch of the first *Modèle Innovation* at Firminy. Developed with Sud Atelier – a studio founded in 1967 by Alain Amédéo, the model adopted a sociological approach centred on inhabitants and spatial flexibility. Continuity with the Modern Movement appears in the functional interior layout, the use of polychromy, and the incorporation of wooden partitions and other construction elements. This system was applied to over 7,000 homes throughout France between 1974 and 1982, establishing it as one of the most widespread *Modèle Innovations*. The analysed example, located in Villeneuve d'Ascq in northern France and inaugurated in 1979, comprises 422 housing units (105 in private ownership and 317 intended for social housing) (Fig. 1–2). These were built according to standardised typologies (one-, two-, three-, and four-room apartments) combining prefabrication with flexibility of use. The load-bearing framework consists of reinforced concrete walls cast in situ and arranged according to a modular pattern that facilitates mass production. The system is completed with prefabricated elements, such as internal walls, loggias and parapets. The prefabricated façades feature painted timber frames, which were an economical solution compatible with the concrete systems of the time. Although the system met the objectives of speed and economy in the 1970s, it now shows limitations in energy and materials: poor insulation, single glazing, and material deterioration. In 1994, the rental part of the complex underwent extensive upgrades to the envelope, with external thermal insulation, new cladding, and a refreshed colour scheme (orange terracotta with black/white bands and light fluted blocks on the ground floor). Windows and doors were also replaced with

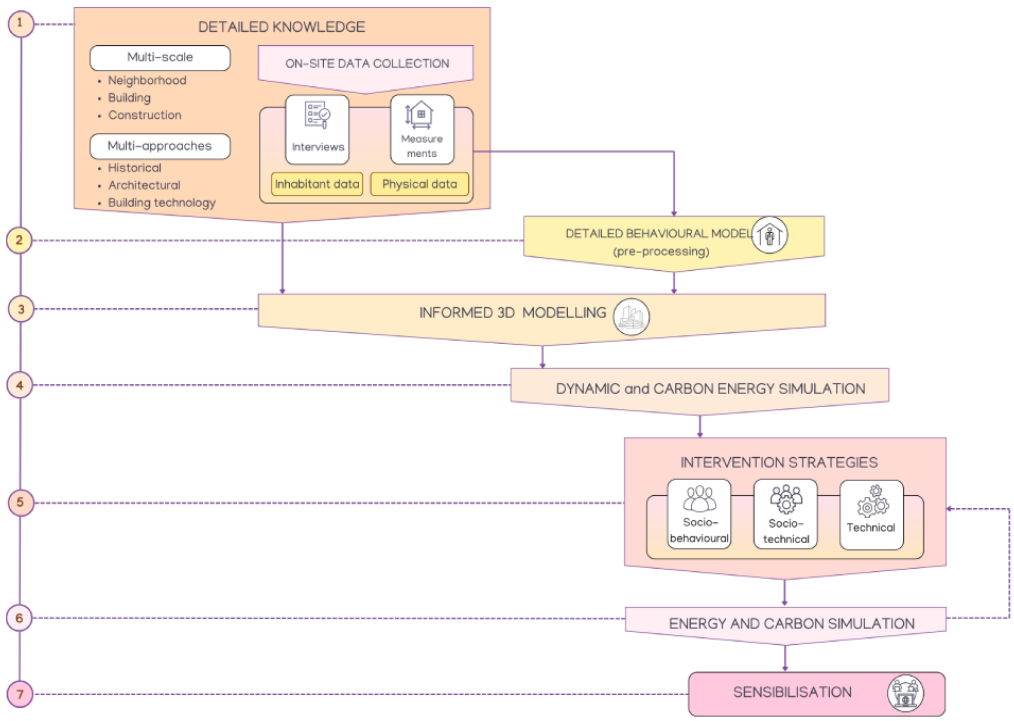

Fig. 3 Workflow of the proposed methodology.

PVC frames and double glazing. While this met the energy efficiency requirements of the time, the 1994 renovation significantly altered the original architectural design, raising concerns about the balance between redevelopment and preservation. Listed in 2016 as *Patrimoine du XXe siècle*, now *Architecture contemporaine remarquable* (ACR), the *Salamandre* exemplifies the challenge of reconciling regulatory demands with the preservation of recent architectural heritage. It aimed to develop a methodology capable of defining tailored intervention strategies for 20th-century buildings, in line with the principle advocated by Ambrogio Annoni[4] at the Politecnico di Milano in the 1940s. The approach integrates occupant behaviour data with technical and construction analyses to guide appropriate, case-by-case interventions.

Methodology of 'in-depth' occupant behaviour study

The proposed methodology is based on numerical simulations and in-depth analyses. It assumes that variations in occupants' energy behaviour influence intervention strategies in relation to usage, housing type, and the level of energy awareness. This approach emphasises the participatory and interactive nature of the process by considering the active role of users and the relationship between their habits and the built environment. This enhances the complexity of the context, incorporating historical, architectural and social aspects. As illustrated in figure 3, the methodology consists of several integrated phases[5]. The initial building analysis combined a documentary and historical study with an in situ survey at architectural and construction scales. In parallel, a questionnaire survey was conducted to collect data on living practices, perceived comfort, and energy consumption. Some flats were fitted with environmental sensors to monitor temperature, humidity, window openings and occupancy, in order to correlate internal conditions with occupant behaviour. The occupancy

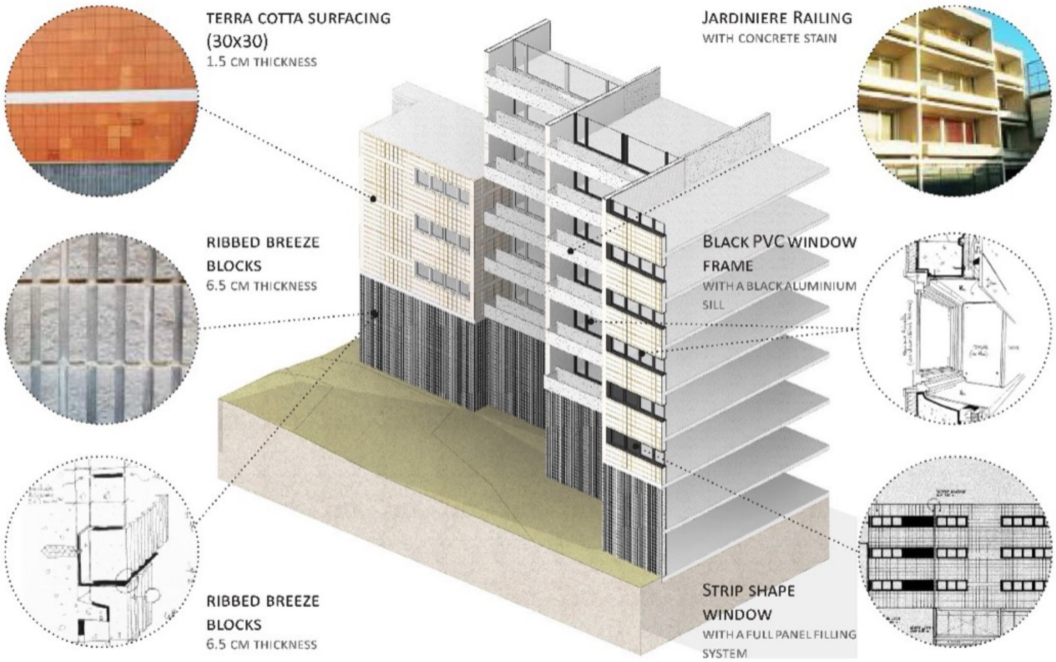

Fig. 4 BIM 3D Model of 'La Salamandre' social housing complex.

profiles obtained in this way made it possible to define a user model, which was used in the preprocessing phase for dynamic energy simulations (SED). This model is based on a deterministic approach and considers five main variables: heating; indoor supply; domestic hot water; ventilation; and lighting. These data were integrated into an informed BIM model (Fig.4) that is interoperable with SED tools (e.g. EnergyPlus®, Archiwizard®, DesignBuilder®) to enable consistent energy assessments to be made that consider historical changes and differences between units. Based on these analyses, progressive intervention scenarios were developed, ranging from behavioural and low-impact socio-technical to more invasive techno-constructive. Post-intervention simulations estimate the benefits in terms of consumption, comfort and carbon footprint, including embodied carbon. The final stage involves raising awareness among inhabitants by presenting the results and promoting sustainable practices, thereby contributing to energy-conscious management before and after redevelopment.

Results and discussion

The research methodology identified six representative housing types occupied by households and student co-housing groups. Among the analysed units, a 78 m² T3 flat located on the sixth floor of the rented portion of the building was selected as a case study. It is inhabited by a family of two adults and one child who are highly sensitive to energy saving. To demonstrate the effectiveness of the proposed methodology, the actual energy consumption of the case study was compared with the estimated energy consumption according to regulations. The actual data, based on electricity bills and the actual use of appliances, lighting, and hot water, reflects the

Fig. 5 Top left: Monthly electricity use (kWh) comparing standard (green), actual (grey), and billed (blue) occupant profiles. Bottom left: Energy impact of window replacement – actual (blue) vs. standard (green) profile in owned and rented units. Right: Comparison of occupancy rates (top) and internal gains (bottom) – standard (green) vs. proposed method (blue).

residents' habits. The comparison revealed differences between the actual energy profile (3,473 kWh/year) and the normative standard (2,798 kWh/year). The energy consumption reported in the bills is lower than the normative simulation (Fig. 5: Top left). For the normative profile, the internal contribution (occupancy and use of household appliances) is estimated at around 30% of the total heating demand. By comparison, a real occupant profile based on empirical data collected through questionnaires and on-site measurements covers up to 40% of the unit's heating demand, i.e. 10% more than the normative profile (Fig. 5: Right).

This gap highlights the importance of integrating real behavioural data into energy simulation models to make more reliable predictions and develop more targeted intervention strategies. To assess the relevance of the 1994 interventions, a comparative analysis was conducted using the flat's dynamic energy model (DES), comparing the original state with a real occupancy profile and the post-renovation state with a standard profile. Notably, the heating demand in the original state is slightly lower than in the current state of the housing unit simulated with the standard profile. As an alternative to conventional external thermal insulation (ITE), the analysis simulated only the replacement of the windows and doors, which is to be implemented at an early stage of the overall energy requalification project of the *Résidence Salamandre*. In the BIM model developed for the analysis, the original wooden windows and doors were replaced with PVC double-glazed frames, while keeping all the other features of the building envelope unchanged. The results of the dynamic energy simulation, based on the integration of real occupancy profiles, show that, although minimally invasive, this intervention would result in energy savings of 21 kWh/m²/year for heating requirements compared to the existing building stock baseline scenario (Fig. 5: Bottom Left). Analysing the project's carbon footprint made it possible to compare CO_2 emissions before and after the redevelopment in 1994. The comparison between the pre- and post-intervention states shows a slight increase in the carbon footprint, resulting in an initial carbon debt. According to Autodesk

Insight 360 simulations, the intervention led to an increase of 252,055 $kgCO_2e$ in embodied carbon and 55,865 $kgCO_2e$ in operational carbon. However, this can be offset over time through energy savings during use. The largest emissions are still related to structural elements, with facades showing a more pronounced increase due to new insulation materials.

Conclusions

The rehabilitation of 20th century buildings requires an approach that combines energy efficiency and interior comfort with the preservation of the original architectural style. The variety of these buildings' models and construction techniques requires an alternative, non-standard approach to energy rehabilitation. Fortunately, the development of digital tools in architecture now makes it possible to meet this challenge by integrating information throughout the design process. The results demonstrate that an approach based on analysing real usage conditions would have enabled interventions that are more compatible with the original architectural characteristics, resulting in a lower environmental impact during use and aligning with the RE2020 objectives. Variations in energy efficiency linked to occupancy, metabolic activity or appliance use allowed recurring use scenarios to be identified based on the behaviour of the inhabitants. Together with an in-depth knowledge of the building and its context, these scenarios prove fundamental for developing tailor-made interventions for the energy upgrading of 20th century buildings. This methodology has been applied to other social housing typologies, demonstrating that this approach can be adapted and replicated in different housing contexts[6].

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