DECISION-MAKING TO SUPPORT UPGRADING PROCESSES[1]

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ABSTRACT

Housing upgrading programs and their immediate surroundings play a crucial role in reducing energy consumption and advancing the decarbonisation of the built environment. In the housing industry these initiatives often face challenges impacted by their social and physical contexts. The level of investment required and the inherent complexity of interventions further influence the feasibility and implementation of these actions. However, upgrading measures are affected by a wide range of variables. Decision-makers must consider environmental, energy-related, financial, legal, and social factors to determine appropriate upgrading measures. This research seeks to analyse and classify potential upgrading actions based on their investment demands and complexity, to support decision-making processes in housing upgrading processes. The study proposes a framework for organizing interventions according to these criteria. A contribution of the research is the development of a decision-making matrix that supports the identification of the most suitable actions for specific contexts, addressing both mandatory and non-mandatory upgrading processes.

Keywords: Decision-making; Housing Upgrading; Actions.

RESUMO

Programas de requalificação habitacional e de seus entornos desempenham um papel crucial na redução do consumo energético e no avanço da descarbonização do ambiente construído. No setor habitacional, essas iniciativas enfrentam desafios influenciados por seus contextos sociais e físicos. O nível de investimento exigido e a complexidade das intervenções impactam a viabilidade e a implementação dessas ações. No entanto, tais ações são afetadas por diferentes variáveis. Os tomadores de decisão devem considerar fatores ambientais, energéticos, financeiros, legais e sociais para determinar ações mais adequadas. Esta pesquisa busca analisar e classificar as ações de melhorias com base no investimento e na complexidade envolvida, de modo a apoiar os processos de tomada de decisão em programas de requalificação habitacional. O estudo propõe uma estrutura para organizar as intervenções segundo esses critérios. A pesquisa contribui com o desenvolvimento de uma matriz de tomada de decisão que auxilia na identificação das ações mais adequadas para contextos específicos, abrangendo processos obrigatórios e não obrigatórios.

***Palavras-chave**: Tomada de Decisão; Melhorias de Habitação; Ações.*

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1. INTRODUCTION

Mandatory upgrading of buildings has been in place for some years in developed countries. Interventions in the existing building stock are especially necessary to upgrade housing estates to bring these to current living and technological standards, in view of new social, cultural and environmental realities (Scuderi, 2019). Upgrading programs play a crucial role in supporting the policy objectives in response to climate change. To reduce energy consumption, aligned with energy efficiency, and achieve until 2050 an 80% reduction in CO2 emissions, as a decarbonisation process are essential to mitigate climate change and preserve as well as improve human well-being (Albatici et al., 2016; De Mel et al., 2023).

Upgrading programmes should make sure that homes are in a good state of repair, safe and secure. Housing should also be well managed, and located in safe and pleasant neighbourhoods. Users should live in comfort, concerning functional, thermal, lighting and acoustic conditions. Environmental comforts that include thermal, acoustic, visual, indoor, airflow, privacy, and light should be considered. For thermal comfort, homes should be adequately heated or cooled, and this implies that they are well insulated, to be energy-efficient, avoiding fuel poverty of users (Poortinga et al., 2017). Environmental comfort and efficient use of resources may be considered in upgrading processes.

Environmental psychology and user requirements represent many transformations to respond to users' desires in housing upgrading (Muianga; Kowaltowski, 2024). With inadequate housing conditions social costs may be incurred indicating degrees of upgrading of most of the existing housing stock around the world (Muianga; Kowaltowski, 2025). Also public spaces, amenities, infrastructure and mobility impacts dwellers in some monofunctional zones (Muianga et al., 2022).

Upgrading processes can lower household energy consumption while offering financial benefits and fostering community empowerment and cohesion (Sdei et al., 2015). These interventions are categorized into "additive" and "passive" strategies.

Additive strategies include structural replacements, thermal insulation, and upgrades to heating systems, while passive strategies aim to improve energy efficiency and comfort. Upgrading may also enhance functionality and accessibility such as adding elevators or balconies, especially relevant for aging populations and changing regulations. Active strategies like installing solar panels and photovoltaic systems further support energy generation and sustainability (Tagliabue; Buzzetti; Manfren, 2013).

A passive strategy may consist in measures such as creating solar greenhouses by closing the balconies, existing or newly added as an additive strategy. Trombe solar walls and shading systems such as brise-soleils, are passive strategies, often considered additive solutions.

Refurbishment, retrofit, and renovation or upgrading projects have a wide range of goals but primarily are concerned with improving the sustainability performance and living conditions of SH developments (Monteiro, 2017). Shallow and deep invasive interventions can be distinguished to address maintenance issues, increase a building´s performance and attend to new functional, technical, legal and social requirements.

Despite the widespread dissemination of upgrading programs, countries not covered by mandatory processes face significant barriers to their implementation. A gap exists in understanding how upgrading can benefit non-mandatory interventions. Therefore,

analysing decision-making for the gradual implementation of upgrading measures is crucial to achieving the benefits of improvement actions, especially considering varying levels of complexity and investment opportunities.

Decision-making process must be guided by evaluations of economic feasibility as well as assessments of social, environmental sustainability, and complexity (Della Spina, L.; Calabrò, F.; Rugolo, 2020). However, interventions in existing buildings are highly specific and influenced by numerous variables. To decide on the actions or interventions to take, decision-makers must consider environmental, energy-related, financial, legal, and social factors (Albatici et al., 2016).

Improving people's wellbeing is related to environmental psychology, user requirements and desires. The external environment around a housing structure demands actions on landscaping and urban design and services. Having data on such wider issues is often not available or incomplete although necessary to guide upgrading projects. When it comes to less complex projects a process may be recommended to support decision making through gradual iterations adjusted according to the investment and technical complexity context (Muianga et al., 2022). Thus, the main objective of this research is to analyse such a decision-making process.

2. BACKGROUND OF UPGRADING CONTEXT

2.1 Upgrading Challenges

Reducing the carbon footprint of housing offers environmental, economic, and social benefits (Cauvain; Karvonen; Petrova, 2018). However, even in countries with mandatory refurbishment policies, challenges remain due to high investment costs and complex technical solutions (Kowaltowski et al., 2024). Barriers include not only financial and technological issues but also informational and behavioural factors (Pillai; Reanos; Curtis, 2021). Social housing upgrades often require advanced technologies with high upfront costs and long payback periods Jenkins, 2010; Monteiro et al., 2017). Limited access to information on regulations, technologies, installation, and potential energy savings, further complicates implementation efforts (Monteiro et al., 2017).

2.1.1 Technology and investment barriers

Low-carbon heating technologies are essential to improve energy efficiency of buildings. To reduce carbon emissions in housing upgrades, a key action is replacing the heating system, which often requires additional measures like facade insulation and window replacement to minimize heat loss (De Mel et al., 2023). Despite potential energy savings for low-income tenants, complex social, economic, and infrastructural conditions may hinder decarbonisation efforts. User resistance to new systems and the need for costly upgrades to inadequate infrastructure can pose significant barriers (Elsharkawy; Rutherford, 2018).

Upgrading buildings requires high initial investment but can offer long-term financial and energy efficiency benefits. However, costs may be prohibitive for many social housing estates, making decision-making complex (Lilley; Davidson; Alwan, 2017). In developed countries, low-income households often spend a large share of their income on heating due to aging housing stock and limited access to efficient appliances, affecting comfort, health, and finances (Sojkova et al., 2019). Poor lighting and ventilation also contribute to higher energy use, while lower energy bills are strong

incentives for improvement (Che Husin; Mohd Zaki; Abu Husain, 2019; Jenkins, 2010).

2.1.2 Behaviour and information barriers

Additional barriers to housing upgrades include communication failures among stakeholders. Even when subsidies are available, some households may reject upgrades due to a lack of understanding of the benefits rather than financial constraints (Pillai; Reanos; Curtis, 2021). Behavioural changes are often required, making participatory approaches essential to ensure stakeholder engagement, knowledge exchange, and commitment (Sham et al., 2013; Jones et al., 2016; Lilley; Davidson; Alwan, 2017). Frequent, clear, and positive interactions throughout the process help align expectations and foster trust. Understanding user preferences and addressing misunderstandings are key to successful implementation (Konstantinou et al., 2020). Community engagement can further support resident involvement during all stages of the upgrading process (Sdei et al., 2015).

Communication gaps between stakeholders can hinder housing upgrades, even when subsidies are available, as some households may reject improvements due to limited understanding rather than cost concerns. Since upgrades often require behavioural changes, participatory approaches are crucial to build trust, align expectations, and ensure commitment. Frequent, clear engagement and community involvement throughout all stages of the process help address misunderstandings and support successful implementation.

2.2 Upgrading procedures

Upgrading must meet safety and environmental standards while achieving energy savings and ensuring economic and social sustainability (Boeri; Gabrielli; Longo, 2011). This requires multidisciplinary expertise to address design, technical, economic, and energy aspects. Key factors to consider include building characteristics, occupant needs and behaviour, social context, and financial conditions of tenants and owners. Effective upgrading involves multiple phases (Scuderi, 2019), such as:

- *Diagnostic assessment:* involves assessing the building's structural integrity, architectural features, conservation status, existing materials, and potential impacts of interventions (Scuderi, 2019).
- *Planning and Design:* focuses on detailed analysis of required upgrades through inspections, technical and physical assessments, cost evaluation, sustainability planning, and technical information necessary for the process, including the desires and needs of users to come up with intervention solutions (Walker; Lowery; Theobald, 2014). This includes the use and choice of materials and technologies, life cycle and energy performance through natural sources and technological interventions, as well as maintenance plans (Scuderi, 2019).
- *Implementation*: during construction, tenants must be informed about disruptions (e.g., noise, dust, privacy issues), and temporary relocation may be necessary. A facilitator can help manage communication and prevent conflicts.
- *Monitoring and maintenance:* post-upgrade performance should be monitored to evaluate the effectiveness of interventions. Technical outcomes and user satisfaction must be assessed to support ongoing engagement and long-term maintenance (Jenkins, 2010).

2.3 Decision-making

A crucial part of decision-making in upgrading projects is defining clear objectives, evaluating cost-benefits, and identifying viable technical solutions. This informed process should actively involve all stakeholders, including design and construction professionals, owners, and occupants (Konstantinou et al., 2020).

Investment planning for upgrading projects can follow two approaches: a straightforward cost estimation and revenue analysis, or a more comprehensive cost-effectiveness analysis that evaluates the performance of the final outcome. When aiming for energy efficiency and decarbonisation, assessments should include emission reductions and pollution impacts on user health in non-monetary terms (Boeri; Gabrielli; Longo, 2011). Additionally, upgrading can foster social integration and generate social benefits by promoting more inclusive communities (Sham et al., 2013).

To facilitate this process and identify the required investment levels for specific interventions, a decision-making matrix can be developed to guide action selection, aiming to balance occupants' needs and environmental objectives. This matrix should be structured based on the complexity of potential actions and the associated implementation costs.

Upgrading may involve significant alterations to the original building design, with energy and carbon performance improvements often requiring costly and technically complex measures. Conversely, less extensive and more affordable upgrades typically consist of simpler interventions (Walker; Lowery; Theobald, 2014).

Upgrading initiatives must align with specific social and physical contexts, financial constraints, ingrained habits, and existing infrastructure to minimize implementation challenges (Elsharkawy; Rutherford, 2018). Low-carbon upgrading may also include interventions beyond the built environment, such as social programs, education, and health services, to reduce the carbon footprint and promote lasting, broad impacts (Cauvain; Karvonen; Petrova, 2018).

3. METHODOLOGY

Our study is based on a metasynthesis of a systematic literature review that synthesizes qualitative research findings from individual studies to generate new interpretations and advance a field of knowledge. This method is developed through four phases, comprising the: identification and quality assessment of relevant studies; extraction of key findings from multiple studies; combination of findings to create new interpretations of the research field; application of the findings to create new theories or hypotheses (Jensen; Allen, 1996). Through metasynthesis, our research analysed the potential issues for decision-making of upgrading programs based on data extracted from literature to guide more precise interventions for improvements in housing, in different contexts of complexity and investment necessities.

Previous studies provided a database of actions for upgrading processes, these can be found in Muianga et al. (2022) and Muianga; Kowaltowski (2024). To construct the decision-making matrix, actions identified in previous studies were categorized into different categories: (i) environmental comfort, efficient use of resources, and innovation; (ii) environmental psychology and user requirements; (iii) external housing environment, urban services, and elements; and (iv) housing installations.

These actions were further classified according to two dimensions: level of complexity, distinguishing actions that require technical specification and supervision from those

that do not. Also investment demands, differentiating between high and low-cost interventions were identified (Table 1).

Based on this dual classification, the actions were mapped into a four-quadrant matrix (Figure 1), representing the intersection of complexity and investment levels. This structure enabled the identification of actions ranging from those requiring minimal investment and technical effort to those demanding substantial resources and specialized execution.

4. RESULTS AND DISCUSSION

By conducting a comprehensive examination of prior studies and an in-depth review of existing research, we compiled actions that can positively impact on upgrading processes (Table 1). By synthesizing these actions, light can be shed on the multifaceted issues that contribute to deciding the best actions for a specific context with various possibilities for improvement.

The upgrading actions need to be effective and environmentally acceptable and feasible, considering housing project characteristics, such as local climatic conditions, available resources, socio economic and cultural levels of users, and law constraints. Based on the matrix, Figure 1, a range of upgrading measures are presented and classified.

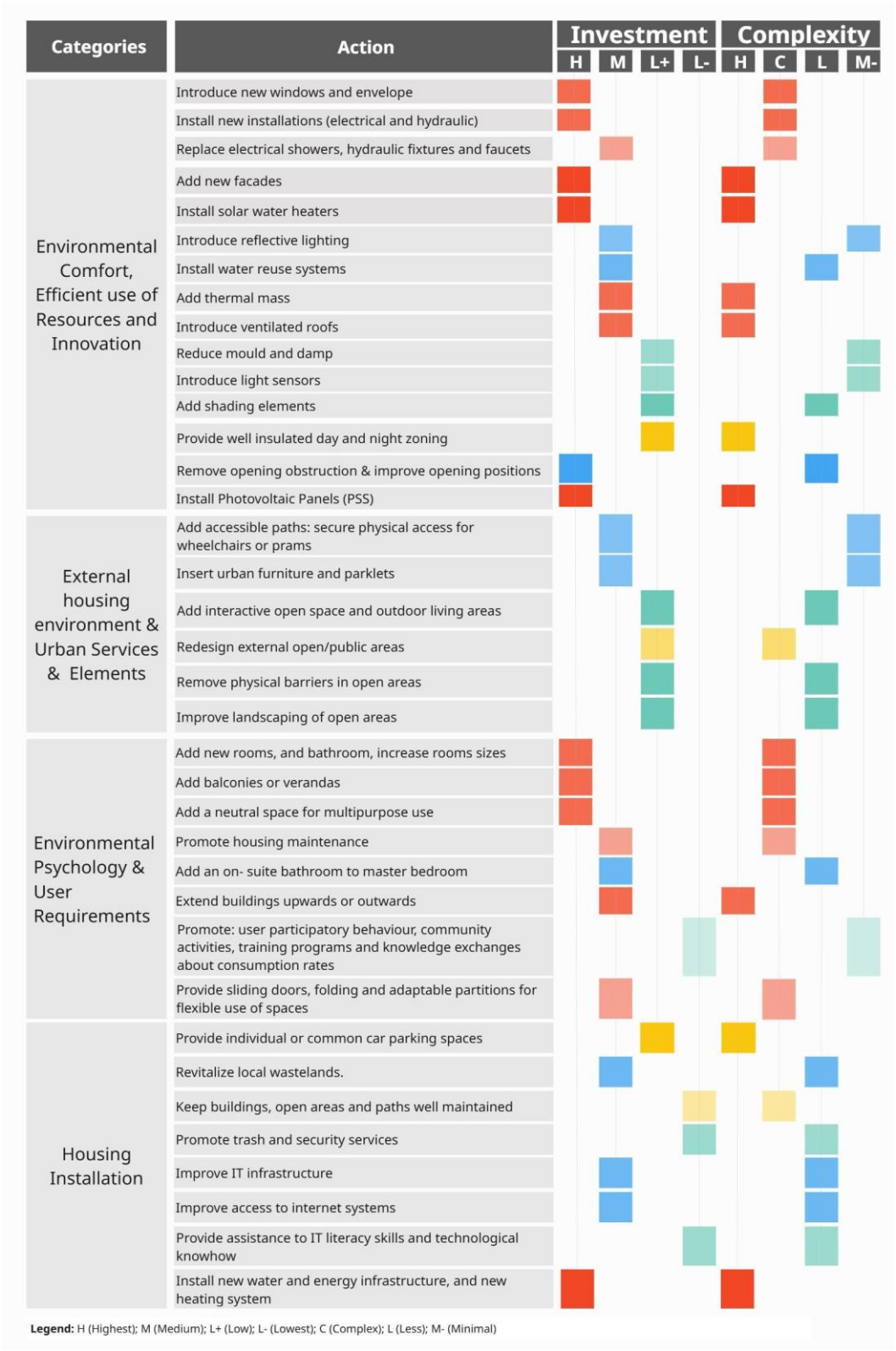
Considering the matrix, in decision-making processes for non-mandatory upgrading scenarios, actions positioned in the fourth quadrant tend to be more viable due to their lower complexity and investment requirements. Similarly, actions in the third quadrant, while also characterized by low and lowest costs, but with a degree of complexity, may be effectively implemented if supported by public entities or guided by relevant public policies. In contrast, actions in the first and second quadrants present investment challenges. Although actions in the first quadrant are less complex, they still demand considerable financial resources, making public policy support crucial to assist residents in their implementation. Actions in the second quadrant, which combine high complexity and investments, require coordinated efforts from multiple stakeholders and are therefore appropriate for mandatory upgrading processes (Kowaltowski et al., 2024).

Most actions to improve housing cover the second and fourth quadrants. Actions that improve environmental comfort and the efficient use of resources are essential. Many of these can also contribute to user requirements and their environmental psychology. Actions concerning these improvement issues are found in all four quadrants, although with a majority considered complex and with high investment.

Furthermore, less complex actions but with high investments, as well as those considered low investments but highly complex interventions indicate actions which may be in part executed by users, however with extensive technical assistance. Some programs, such as the recently created "housing improvement KIT[2]", in Brazil is seen as a step in the right direction to support upgrading processes in a country without mandatory energy efficiency programs.

[2]https://www.gov.br/cidades/pt-br/acesso-a-informacao/acoes-e-programas/habitacao/programa-minha-casa-minha-vida/minha-casa-minha-vida-rural/arquivos/composicao-dos-kits_mel__2023_site.xls/view

Table 1 – Actions with a pronounced influence on upgrading processes

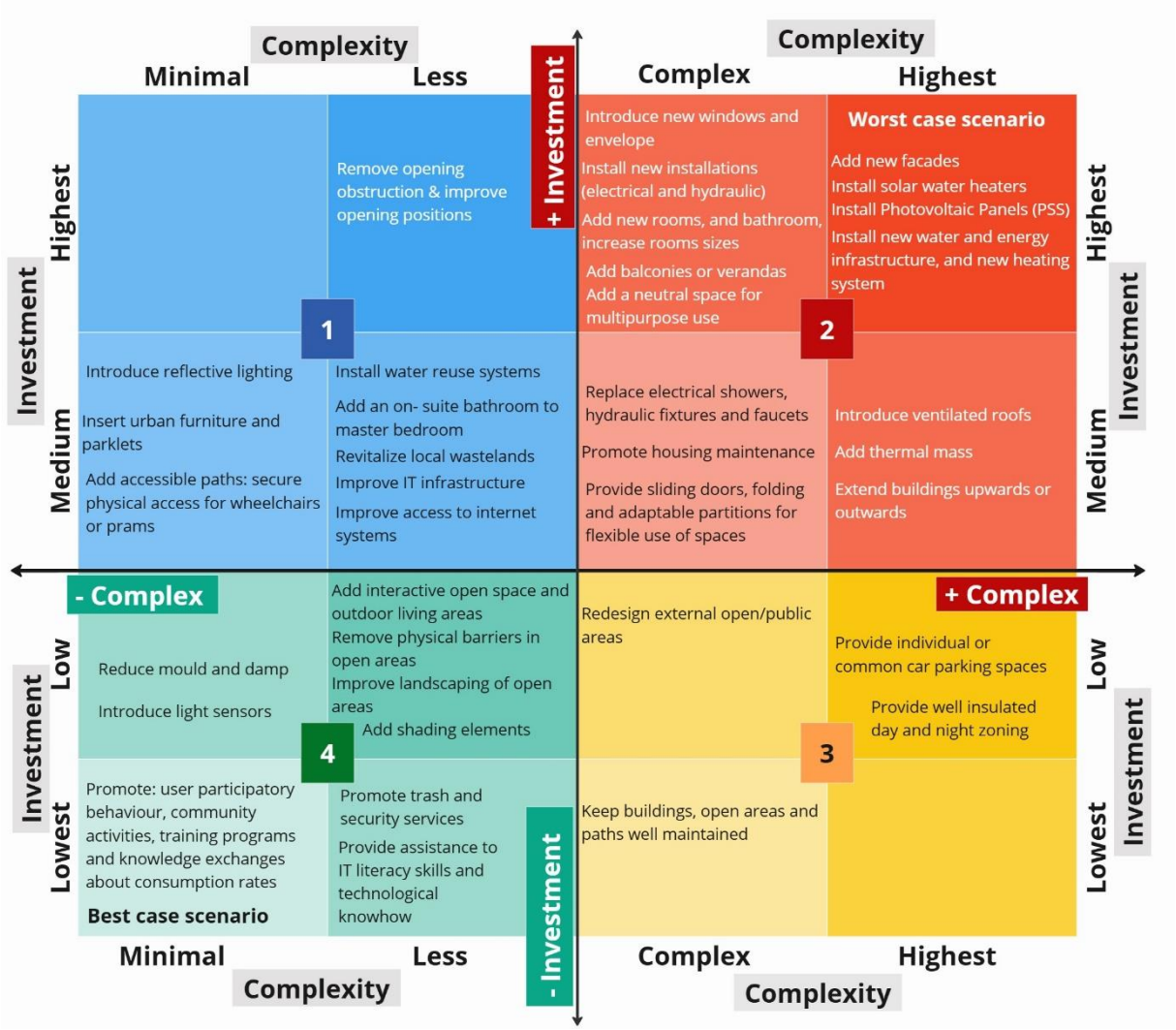


Categories	Action	Investment				Complexity			
		H	M	L+	L-	H	C	L	M-
Environmental Comfort, Efficient use of Resources and Innovation	Introduce new windows and envelope								
	Install new installations (electrical and hydraulic)								
	Replace electrical showers, hydraulic fixtures and faucets								
	Add new facades								
	Install solar water heaters								
	Introduce reflective lighting								
	Install water reuse systems								
	Add thermal mass								
	Introduce ventilated roofs								
	Reduce mould and damp								
	Introduce light sensors								
	Add shading elements								
	Provide well insulated day and night zoning								
	Remove opening obstruction & improve opening positions								
	Install Photovoltaic Panels (PSS)								
External housing environment & Urban Services & Elements	Add accessible paths: secure physical access for wheelchairs or prams								
	Insert urban furniture and parklets								
	Add interactive open space and outdoor living areas								
	Redesign external open/public areas								
	Remove physical barriers in open areas								
	Improve landscaping of open areas								
Environmental Psychology & User Requirements	Add new rooms, and bathroom, increase rooms sizes								
	Add balconies or verandas								
	Add a neutral space for multipurpose use								
	Promote housing maintenance								
	Add an on- suite bathroom to master bedroom								
	Extend buildings upwards or outwards								
	Promote: user participatory behaviour, community activities, training programs and knowledge exchanges about consumption rates								
	Provide sliding doors, folding and adaptable partitions for flexible use of spaces								
Housing Installation	Provide individual or common car parking spaces								
	Revitalize local wastelands.								
	Keep buildings, open areas and paths well maintained								
	Promote trash and security services								
	Improve IT infrastructure								
	Improve access to internet systems								
	Provide assistance to IT literacy skills and technological knowhow								
	Install new water and energy infrastructure, and new heating system								

Legend: H (Highest); M (Medium); L+ (Low); L- (Lowest); C (Complex); L (Less); M- (Minimal)

Source: The Authors

Figure 1: Decision-making for a range of proposed intervention measures



Source: The authors

5. FINAL REMARKS

While upgrading for energy efficiency is crucial, the long-term viability of refurbishment programs relies on sustainable and holistic strategies that address functional needs, infrastructure, and economic feasibility. Although non-mandatory upgrading initiatives may include measures beyond energy efficiency, there is a lack of studies that consider the diverse variables involved in such interventions. Thus, the decision-making matrix proposed may aid to identify and prioritise potential actions within specific housing upgrading contexts, applicable to both mandatory and non-mandatory processes. When applied in participatory planning frameworks, this matrix can support the selection of actions that align with user needs and environmental goals, and contributing to climate change mitigation.

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