The Effects of the Digital Transition on the Environment and Human Well-Being. From Cognitive and Evaluative Protocols to Possible Actions for Regional Planning

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Abstract. The digital transition represents one of the most impactful processes of transformation in contemporary society, capable of producing dual effects (positive and negative). This contribution, which is part of the PRIN 2022 PNRR project titled "Housing mobility and digital transition: assessment tools and technologies to understand current and future housing needs of people, supporting governance processes and territorial regeneration, starting from the analysis of the impacts of the digital transition," first proposes a systematisation of the normative (hard) and cultural (soft) methodological approaches for managing the digital transition. It then offers an integrated governance proposal that combines normative (hard) and cultural (soft) tools to support regional planning and the consequent housing policies potentially induced by the digital transition.

Keywords: Digital Transition · environmental sustainability · human well-being · Territorial governance · Urban planning

1 Introduction

Digital transformation represents one of the most significant processes of change in the 21st century. It includes the widespread adoption of digital technologies such as artificial intelligence, the Internet of Things (IoT), cloud computing, big data, blockchain, 5G/6G networks, digital platforms, and advanced automation systems. This shift, accelerated over the past two decades, has impacted manufacturing sectors, public services, education, healthcare, finance, and social relationships, leading to profound changes in everyday human life [1, 2].

Meanwhile, the global society faces two systemic challenges: the environmental crisis and the deterioration of many aspects of human well-being, including mental health, socio-economic inequalities, and job precariousness [3, 4].

The shift of traditionally physical functions to digital platforms – work, commerce, public services, communication, entertainment, education – is often described as a process of 'dematerialisation'. However, recent literature encourages distinguishing

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between apparent dematerialisation and invisible material reconfiguration [5]. Digitalisation sometimes does not eliminate matter; rather, it reorganises it in space and within value chains. This has effects on both the environment and society. Its environmental impacts need to be analysed on multiple levels: CO_2 emissions, traffic, land use, impacts on the atmosphere, hydrosphere, and subsoil. It is necessary to understand these effects. Several studies recognise that digitalisation can replace some physical activities, with potential positive effects on the environment [6–8]. 'Dematerialisation' – that is, the replacement of physical goods and services with digital equivalents—has, for example, reduced the need for physical transportation of people and materials, with potential positive impacts on CO_2 emissions associated with urban and interurban traffic [9].

Furthermore, digitalisation has profoundly transformed daily routines: work, relationships, consumption, learning, leisure. The ability to carry out activities online reduces spatial constraints but alters the perception of time [10]. Physical space can lose its functional centrality and its social value. These are changes that have deep environmental impacts: smart working reduces traffic but modifies domestic energy consumption [11]; e-commerce changes urban logistics and consumption habits [12]; administrative digitalisation reduces paper use but increases ICT infrastructure; quality of life depends on the ability to integrate environmental efficiency, psychological well-being, and social equity [13].

In light of the issues outlined above, it is necessary to establish how to manage changes in the physical spaces of cities and to understand the related changes in residential patterns. The research "Housing Mobility and Digital Transition: Tools and Evaluation Technologies to Understand Current and Future Housing Needs of People, Supporting Governance and Territorial Regeneration Processes," funded under the PRIN 2022 PNRR, examined how digital transition, by effectively altering customs and ways of life, can open new possibilities in terms of choosing where to live. This contribution, within the scope of the research and subject to experimentation in the metropolitan area of Florence, explores the intersections among digitalisation, environmental sustainability, and quality of life. It highlights the effects of digital transition on the environment (both positive and negative), with the aim of outlining methodological approaches and actions—both regulatory (hard) and cultural (soft)—to turn the impact of digital transition on a specific theme, urban policies, and territorial governance into an opportunity rather than a threat.

The operational result of the contribution is a proposal/protocol for assessing the impact of the digital transition on housing mobility, aimed at supporting public decision-making in regional planning processes. The proposed approach aims to provide an interpretative and operational framework for urban planning and territorial governance, as well as housing policies, that supports a more sustainable, inclusive, and equitable digital transition.

Below is a proposed literary review (paragraph 2) aimed at: i) identifying the effects of the digital transition in terms of systemic interaction between the environmental dimension and well-being within the framework of digital transformation; ii) exploring the opportunities offered by the digital transition in terms of reorganising settlement functions from a digital plane to a material plane. Subsequently, a procedure (paragraph 3) is proposed to validate the experimentation of the aforementioned PRIN 2022

PNRR Research, with the aim of defining the methodological approaches preparatory to the identification of key elements for 'managing/governing' the digital transition in the settlement context, with reference to residential functions. Following this, an operational proposal (paragraph 4) is developed, integrating possible hard and soft actions for regional planning activities. Finally, the conclusions (paragraph 5) of this work are drawn.

2 Literary Review: The Effects of the Digital Transition

Digital transition, understood as the spread of information technology, communication, and the automation of production processes in services and daily practices, is frequently associated with a process of modernisation deemed positive, capable of bringing significant benefits to the global community as a whole. However, various studies and research over the past fifteen years have analysed, alongside the positive aspects of the topic, also the negative ones, highlighting how digital transition is not constituted in an immaterial realm, but rather consists of an important material technological-social network: just think of data centres, telecommunication networks, logistics chains, etc., which must necessarily be created for the proper utilisation of digital technology [14–16]. This, of course, has positive impacts by reducing travel and time, but can sometimes have environmental repercussions. Furthermore, digitalisation particularly affects human well-being and individuals' everyday experiences: in this case as well, while it brings enormous advantages (such as easy access to services and information, reduced travel, and better organisational work), it can also negatively influence aspects related to social relationships, which tend towards isolation, and consequently impact mental and physical health [17–20].

The following review summarises recent literature on the impacts of the digital transition, analysing both the environmental effects resulting from the digitalisation of physical functions and those on human well-being related to people's daily experiences. The main objective is to define the state of the art regarding the positive and negative effects of the digital transition on the environment and quality of life.

2.1 Environmental Impacts of the Digital Transition

A significant body of literature interprets digitalisation as an enabling infrastructure for decarbonisation and the efficient use of resources, thereby supporting the ecological transition [21]. More generally, recent literature tends to interpret this phenomenon within the framework of the so-called "Twin Transition", emphasising how digital and ecological transitions can mutually reinforce each other only in the presence of appropriate governance and regulatory policies [22]. Numerous factors define positive environmental effects; for example, devices capable of monitoring and optimising energy consumption in real time (IoT, sensors, advanced analytics, etc.) allow the identification of operational inefficiencies, thereby reducing waste and improving the allocation of energy resources, especially in industrial contexts responsible for the highest energy consumption globally [23, 24]. This dynamic is often linked to the Industry 4.0 paradigm, which describes the interaction between cyber-physical systems, IoT sensors, data analysis, and advanced

automation in manufacturing processes, aiming to improve operational efficiency and resource management [25]. Furthermore, several studies emphasise that assessing the actual environmental benefits of these solutions requires a life-cycle assessment (LCA) approach that considers not only the use phase but also the production, maintenance, and end-of-life of digital technologies. Equally relevant is the theme of dematerialisation, understood as the substitution of goods, supports, and material activities with digital elements, a potentially environmentally sustainable factor. This phenomenon leads to the so-called "substitution effect": for example, the introduction of digital databases and archives increasingly impacts positively on reducing paper consumption, bringing significant environmental benefits (such as less deforestation); additionally, the spread of online public services (digitalisation of public administration), telemedicine, smart working, etc., is gradually decreasing CO2 emissions, with positive impacts on environmental pressure [26]. On the other hand, the dematerialisation effect can also be interpreted differently: Coroama, Moberg, and Hilty (2015) [27] demonstrate that electronic media can be a more energy-efficient alternative to some traditional activities, such as long-distance travel or certain physical supports. However, the same authors emphasise that these technologies can integrate with existing practices rather than replace them. In such cases, the effect is not a reduction in impact but an overall increase (rebound effect). This dynamic is often understood considering the so-called Jevons Paradox, which states that efficiency improvements can lead to an overall increase in consumption rather than a decrease. For this reason, the availability of compact and efficient devices does not guarantee dematerialisation: the entire lifecycle of media systems must be considered, especially the macro-level effects on the total volume of production and consumption. Another consideration concerns the themes of circular economy and traceability: digital technologies, such as supply chain information systems and, in some interpretations, blockchain, are proposed as tools to increase transparency along the supply chain and improve the monitoring of product lifecycle [28, 29]. Traceability can make reuse strategies more effective and efficient, increasing producer responsibility and thus facilitating environmental impact analysis and compliance with standards. The urban planning sector is also not immune to the new technologies arising from the digital transition; in particular, smart city models contribute positively to reducing emissions, urban transport networks, water supply, and waste disposal, resulting in a favourable environmental impact. These processes are further accelerated by the introduction of Artificial Intelligence (AI), which requires high computational capacity. While adopting these models positively impacts the environment, it also entails significant demand for digital infrastructure, hardware, and devices, which, in turn, increases energy consumption for their operation and contributes to increased electronic waste (e-waste). Digital materials are heavily dependent on critical minerals and rare-earth elements (such as lithium, cobalt, and neodymium), which are necessary for producing batteries, smartphones, servers, and other electronic infrastructure. These activities are sometimes responsible for current deforestation, which negatively affects biodiversity and contaminates soil and groundwater. Added to this is the well-known issue of electronic waste disposal, a rapidly growing global flow that, if not properly managed, risks causing serious environmental and health problems. Moreover, the energy-intensive use of AI systems, driven by the high energy consumption of data centres, is increasing sharply, with a peak expected

by 2030 [30]. Additionally, the ICT sector is currently estimated to be responsible for between 2% and 4% of global greenhouse gas emissions, an increase attributable to the expansion of data centres, transmission networks, and computational loads associated with Big Data and Artificial Intelligence [31, 32]. Furthermore, a factor not to overlook is that these systems require a large volume of water for server cooling (see evaporative cooling systems), which can increase water stress. Although studies on the energy efficiency of data centres have improved over time, progress in this area has sometimes been offset by increased data traffic and computational demand [33].

The production of sensors, IoT devices, and data centres involves a significant carbon footprint, sometimes increasing energy demand rather than reducing it. Additionally, many of the environmental costs of digitalisation are unevenly distributed along global value chains: while a substantial part of the benefits is concentrated in highly digitalised countries, numerous material, extractive, and disposal impacts fall on the countries of the Global South, raising issues of environmental and digital justice [34]. It is therefore clear that if such policies are not supported by appropriate green energy infrastructure and circular economy processes, smart cities risk producing unintended effects [30, 35, 36].

To summarise the main environmental effects of the digital transition identified in the analysed literature, Table 1 presents the main areas of application and their associated positive and negative effects.

Table 1. The effects of the digital transition on the environment

TOPIC	POSITIVE EFFECTS	NEGATIVE EFFECTS
Energy efficiency	• Monitoring of consumption; • Reduction of waste; • Optimisation of production processes	• Increase in the necessary digital infrastructure; • Increase in computational consumption
Dematerialization	• Reduction of paper use; • Minor physical supports; • Fewer movements	• Rebound effect; • Increase in digital consumption
Circular Economy and traceability	• Product lifecycle monitoring; • Supply chain transparency	• Technological complexity; • Increase in the use of digital infrastructure
Smart cities	• Transport optimisation; • Efficient management of services	• Increase in energy demand; • Increase in connected devices
AI and digital infrastructure	• Better management of urban and industrial systems	• High energy consumption (data centre, e-waste)

Overall, the literature shows that the digital transition presents ambivalent environmental effects: while it can contribute to greater efficiency in resource use and the reduction of certain environmental pressures, it also entails new impacts related to the energy consumption of digital infrastructure, resource extraction, and electronic waste

production, underscoring the need for sustainable governance. From this perspective, the environmental impact of digitalisation cannot be assessed solely in terms of local efficiency; instead, it must be analysed considering the entire socio-technical system in which the technologies are integrated, including the modes of production, use, and final disposal.

2.2 Impacts of the Digital Transition on Human Well-Being

As anticipated in the introductory section, the digital transition not only impacts the environmental level but also profoundly affects the social dimension and that of individuals, sometimes significantly altering daily practices (socialisation, work, education, etc.). Numerous studies on smart working and remote work highlight contrasting impacts: on one hand, this new productive modality offers greater flexibility and autonomy in work practices, balancing work and private life with potential positive effects on job satisfaction [37]; on the other hand, phenomena of blurring between the two spaces (work and private) can contribute to burnout and stress, preventing clear temporal boundaries between work activities and rest. This concept can be summarised in the paradigm of "work-life flow", recently introduced by Joanna Wells and Fiona Scheibein (2023) [38]. Furthermore, particularly in remote work, there is a high likelihood of developing professional isolation (loneliness paradox) [19], understood as disconnection from the social network of work, composed of colleagues, clients, etc., with possible negative effects on the sense of belonging and psychological well-being. The lack of physical contact and nonverbal signals can reduce oxytocin production, the social bonding hormone. However, there is no evidence that this influences emotional attachment to the organisation [39]. More generally, some studies show that excessive digital connections, whether work-related or leisure-related, can be associated with increased stress, reduced concentration, and mental fatigue [40, 41]. Intensive use of digital technologies can indeed generate phenomena of information overload and technostress, linked to the constant availability of information, notifications, and attention requests. Another branch of the literature concerns the impact of social platforms on psychological well-being. Several studies highlight that intensive use of social media can be associated with increased perceived loneliness, anxiety, and depressive symptoms, especially among adolescents and young adults [42, 43]. In this context, the phenomenon of Fear of Missing Out (FOMO) and continuous social comparison mediated by algorithms can reduce subjective life satisfaction and promote compulsive connection practices [44, 45].

Similarly, the increasingly immediate access to online shopping platforms operates on a dual track: on one hand, it contributes to more efficient time management and can reduce physical travel related to purchasing goods; on the other hand, it can generate potential forms of compulsive consumption and accelerate technological replacement cycles [46], contributing to the mass production of objects and services, with significant implications not only in terms of energy consumption and carbon footprint (see paragraph 2.1), but also in persistent dissatisfaction and possible conditions of stress, psychological discomfort, and depressive symptoms. This new culture of online shopping can also induce behaviours such as sedentariness and micro-movements, and some studies have associated this new way of living daily life with a primary driver of type 2 diabetes.

Online connectivity, however, especially in contexts where digital access represents an indicator of social inclusion, can be correlated with subjective well-being [47]. It is evident that, conversely, the so-called digital divide phenomenon is developing, highlighting how minority social groups (the elderly, populations with fewer technological skills, etc.) can sometimes be completely excluded from various dynamics and the benefits derived from the use of online tools, thereby increasingly exacerbating socio-economic inequalities [48]. Digitalisation has also generated positive effects on educational and informational offerings, contributing to the dissemination of new learning opportunities and the gradual democratisation of access to training through the availability of digital educational resources, online courses, and open learning platforms [49]. Not only do some studies show that students who have taken online courses achieve slightly better results than those attending in-person courses [50]. Finally, digitalisation has contributed to the spread of new forms of work organisation based on digital platforms, often referred to as the gig economy. Although these models offer new income opportunities and flexible working arrangements, several studies also highlight precarious working conditions, job instability, and limited protection for workers on digital platforms [51]. As in the previous paragraph (2.1), to summarise the main effects of the digital transition on human well-being identified in the literature, Table 2 is presented, which highlights the positive and negative aspects of each analysed theme.

Table 2. The effects of digital transition on human well-being

TOPIC	POSITIVE EFFECTS	NEGATIVE EFFECTS
Digital work (smart working, platforms, gig economy))	• Greater flexibility in working arrangements; • Reduction of travel; • New opportunities in digital work	• Blurred boundaries between work and private life; • Stress and burnout; • Professional isolation; • Job insecurity
Intensive use of digital technologies	• Access to information and immediate communication; • Social connectivity;	• Technostress; • Information overload; • Mental fatigue
Digital consumption and online platform	• Time savings in shopping; • Accessibility to goods and services	• Compulsive consumption; • Acceleration of the replacement cycles of goods; • Stress and psychological discomfort
Digital access and social inclusion	• Greater social integration; • Access to services and information; • Increase in subjective well-being	• Digital divide
Access to digital education and training	• Democratisation of access to education; • Better results	• Differences in digital skills

Overall, the literature highlights how the impacts of the digital transition on human well-being are deeply ambivalent: alongside benefits in terms of access, flexibility, and inclusion, there are critical issues related to stress, isolation, surveillance, and digital inequalities, confirming the need for governance capable of guiding digitalisation towards socially sustainable outcomes.

3 Methodological Approaches to Managing the Digital Transition: Hard-Normative and Soft-Cultural Tools

As highlighted by the literature in paragraph 2, the shift of face-to-face activities towards digital forms not only reduces environmental impact but also involves a complex reorganisation of new material and energy flows, through which the new global technological infrastructure is activated, with possible negative environmental effects. From the perspective of daily practices, a significant transformation is observed: digitalisation offers numerous advantages, such as flexible working (smart and remote work), new opportunities to access services, information, training, and socialisation. However, it also presents negative effects on psychological well-being: many forms of digital stress, isolation, and inequality are indeed evident. Digitalisation, therefore, cannot be considered inherently sustainable or unsustainable: its impact largely depends on the institutional, cultural, and energy framework within which it is implemented. In this context, the main challenge lies in conscious management of the digital transition, that is, in the ability to reduce or at least mitigate negative impacts, both from an environmental perspective and in terms of human well-being. Analysis of the literature reveals the need for a systemic approach that integrates regulatory tools (hard) and cultural (soft) factors, as well as multi-level governance, to reconcile technological progress, environmental sustainability, and human well-being, and to counteract the negative effects of digitalisation. This work, therefore, proposes a definition of these regulatory tools to assist institutions in guiding the digital transition towards objectives of environmental sustainability and human well-being.

3.1 Hard-Normative Tools

From a regulatory perspective, several studies highlight the need to strengthen environmental regulation in the ICT sector. Energy efficiency standards for data centres and digital infrastructure, transparency obligations regarding emissions, and incentives for the use of renewable energy sources are essential tools to reduce the climate impact of digitalisation. Some authors also propose introducing mandatory environmental impact assessments for large digital projects, like those required for other industrial infrastructure projects. Another area of intervention concerns the sustainable design of digital technologies. From this perspective, the principle of ‘sustainability by design’ should be adopted as a genuine criterion for evaluation within public regulation. This implies that technology companies and policymakers systematically incorporate, from the early design stages, a checklist of key questions related to the entire lifecycle of the digital product, capable of translating negative effects into positive outcomes of the digital transition. These checklists can serve as a powerful operational tool to support public administration, enabling systematic verification and monitoring of the environmental

and social sustainability of digital solutions before implementation. An example of such a checklist, addressing the negative effects on the environment, could be as follows (Table 3):

Table 3. Example of an operational checklist

TOPIC	ANSWERS	NEGATIVE EFFECTS	POSSIBLE ACTIONS
Energy efficiency	1. Is the planned infrastructure truly necessary? 2. Are minimum energy efficiency standards expected? 3. Does the energy used come from renewable sources?	• Increase in the necessary digital infrastructure; • Increase in computational consumption	• Standard energy practices for data centres; • Use of renewables; • Load optimisation; • Assessment of energy impact
Dematerialization	4. Does the digital solution truly replace a physical function or does it add to it? 5. Have the environmental benefits been measured across the entire lifecycle?	• Rebound effect; • Increase in digital consumption	• LCA assessment; • Monitoring of uses; • Limits on the duplication of services and processes
Circular Economy and traceability	6. Does the technology used truly improve traceability? 7. Does the environmental benefit outweigh the cost of infrastructure? 8. Do the collected data lead to concrete actions of reuse and recycling?	• Technological complexity; • Increased use of digital infrastructures	• Minimum traceability requirements; • Data interoperability; • Circular design standards

(*continued*)

Table 3. (*continued*)

TOPIC	ANSWERS	NEGATIVE EFFECTS	POSSIBLE ACTIONS
Smart cities	9. Are the connected devices proportionate to the expected benefits? 10. Is an impact assessment on energy, water, and soil planned? 11. Is the territory capable of absorbing the costs?	• Increase in energy demand; • Increase in connected device	• Locational planning; • Sustainability thresholds; • Preventive environmental assessments; • Territorial governance
AI and digital infrastructureale	12. Are there less energy-intensive alternatives? 13. Are there measures in place for efficiency and for managing the hardware's lifecycle?	• High energy consumption; • • Use of data centres; • Growth of e-waste	• Criteria of necessity for use; • Efficiency standards; • Sustainable procurement

This checklist can be operationally adopted by public decision-makers as an evaluative toolkit to guide calls for proposals, incentives, and authorisations, and constitutes a structural element of hard-normative instruments. By making 'sustainability by design" a systematic and mandatory criterion, public policies gain a new tool to steer digital transformation towards tangible environmental sustainability objectives.

3.2 Soft-Cultural Solutions and Digital Literacy

Alongside regulatory tools, literature emphasises the importance of cultural and educational interventions. The spread of digital technologies indeed makes a new form of literacy necessary, aimed at promoting a conscious and sustainable use of technological tools. It is for this reason that, as with nutritional or environmental education, this new form of digital education should also be integrated to develop critical skills in the use of digital media, which can help prevent phenomena such as technological dependence, information overload, and digital stress. In this context, there is also an increasing debate on the right to disconnect, considered by many scholars as a fundamental tool to protect workers' psychological well-being in the era of hyperconnectivity and to establish clearer boundaries between professional and private life.

3.3 Hard and Soft Integrations for Regional Planning

The Italian urban planning policy, based on Law 1150/42, is outdated and no longer responds to the dynamics of contemporary society. In this context, it is evident that there is a need to move beyond compartmentalised sectoral policies and to promote a planning approach with multiple interpretative keys, capable of integrating digital, climate, and social policies. The effectiveness of the digital transition indeed depends on the ability to coordinate technological innovation strategies with the objectives of decarbonisation, circular economy, and the protection of human well-being.

The governance of the territory and urban planning policies must therefore be restructured in both their methodological aspects and their analysis and forecasting. As extensively discussed in the previous paragraphs, the use of digital technologies and remote work profoundly alters mobility patterns, migratory flows, and settlement dynamics, necessitating the update of planning tools traditionally based on historical data. A concrete example of this evolution is the use of real-time urban dashboards that collect and display data from sensors distributed throughout the city (traffic, noise, air quality, pedestrian flows). These platforms allow urban planners to monitor infrastructure usage in real time and anticipate overload or emerging needs. For instance, detecting significant increases in traffic flows during certain time slots through analysis of aggregated data can support targeted decisions, such as temporary modifications to traffic management or the regulation of access in ZTLs (Limited Traffic Zones), or dynamically guide public transport planning. Similarly, a growing trend of increased use of public spaces in peripheral areas, revealed by heatmaps generated from urban monitoring systems, could suggest revising zoning criteria or allocating new resources for services and urban greenery in those districts, translating digital analysis into concrete actions for territorial governance. To fully understand these phenomena, planning activities must be as interdisciplinary as possible, integrating analyses of the lifecycle of digital infrastructures, longitudinal studies on the effects of technology use on psychological well-being, and research that combines environmental, social, and economic indicators. Ultimately, digital transition can only be considered truly sustainable if it is managed as an integrated process, capable of maximising technological benefits while minimising environmental and social costs. Only through a coordinated approach involving technological innovation, public policies, and cultural transformations will it be possible to steer digitalisation towards development models that are compatible with the planet's ecological limits and the improvement of human quality of life. Considering these considerations, the following paragraph proposes an operational framework to translate the effects of the digital transition into actions and tools for good land governance.

4 Operational Proposal for Territorial Planning and Programming

Digital transition, as highlighted in the literature review, does not produce linear or unambiguous effects: it can reduce certain environmental pressures (e.g., commuting mobility) but also generate new ones (energy consumption, logistics, ICT infrastructure); it can expand opportunities for access to services and employment, but also exacerbate inequalities, isolation, and vulnerabilities (digital divide, precariousness, digital stress). However, negative effects should not be viewed solely as elements to be mitigated, but

rather as territorial and social signals that, if properly identified, can guide the development of governance tools capable of steering towards a more sustainable and balanced digitalisation. In this context, the built environment, and in particular residential patterns, becomes a crucial area for observation and intervention: the increasing flexibility of work times and locations (smart working, hybrid functions, online services) tends to recalibrate housing choice criteria and redefine models of territorial attractiveness. This creates a need for Public Administrations and territorial governance bodies to equip themselves with knowledge and assessment tools capable of capturing these transformations in an integrated manner, anticipating trade-offs and guiding policies towards sustainability, inclusion, and quality of life.

Building on these considerations, this contribution proposes an operational framework to interpret the effects of the digital transition through the lens of residential well-being and to translate them into concrete territorial governance actions. The procedure, tested in the PRIN 2022 PNRR Research, is based on the integration of three dimensions of residential well-being: (i) territorial-objective dimension, (ii) economic dimension, and (iii) subjective dimension. The fundamental assumption is that none of these components, considered in isolation, is sufficient to guide robust decisions: territorial analysis, derived from planning tools, provides the material and functional structure of contexts; market analysis explicates the selective mechanisms regulating access to residence; and the analysis of preferences and perceptions allows understanding the emerging housing demand, which today is also influenced by the digitalisation of daily practices. The integration of the three dimensions, however, enables the construction of unified interpretative frameworks useful for reading convergences and misalignments (for example, areas with high urban quality but economically inaccessible; accessible areas but perceived as lacking identity; territories with high environmental quality but with deficits in services and connections), transforming them into governance scenarios and operational guidelines. Operationally, the protocol can be organised into a sequence of modular and scalable phases tailored to the intervention context, each culminating in outputs immediately usable by the Public Administration: maps, synthetic indicators, and priority matrices. After each phase, explicit decision points (go/no-go checkpoints) are introduced, allowing the administration to evaluate the results obtained and decide transparently whether to proceed, deepen the analysis, or reallocate resources. This approach enhances the clarity and practicality of the protocol, facilitating operational decisions throughout the process. Below are the phases of the operational framework, subsequently summarised in a graphical form (Fig. 1):

1. **Construction of the territorial knowledge framework** (*objective dimension*). The first component concerns the reconstruction of urban and territorial quality through objective indicators, consistent with the strategies and contents of planning tools (territorial/metropolitan plans, structural/operational plans, PUMS, sectoral and civil protection plans). The aim is not to produce a mere inventory but to structure a set of criteria capable of representing, at an appropriate scale, the conditions of liveability and accessibility: service provisions, infrastructure, environmental quality, risks, connectivity and digital provisions, quality of the building heritage. In this phase, the public administration can enhance official open sources and institutional databases to ensure transparency, up-to-date information, and replicability. Processing in a GIS

environment enables the creation of comparable cartographic layers and the identification of territorial gradients and discontinuities, which are useful for guiding rebalancing policies.

2. **Analysis of economic accessibility and the residential market** (*economic dimension*). The second component aims to measure the sustainability of living and the socio-spatial selection mechanisms induced by the market. The analysis integrates homogeneous micro-areas of the real estate market (zones and subzones), property values (OMI and/or complementary sources), and income distribution to calculate affordability indicators (e.g., income-to-value ratios or indices based on sustainability thresholds). This dimension is essential to 'make visible' the gap between territorial quality and actual accessibility: in highly attractive contexts, digitalisation can further increase settlement pressure and competition for access, amplifying phenomena of gentrification and displacement. For public administration, these results provide a technical basis for regulatory and rebalancing policies (social housing, subsidised housing, equalisation tools, public-private agreements, rent containment measures), distinguishing between areas where the criticality is mainly 'market-driven' and those where it is instead 'related to infrastructure'.
3. **Analysis of preferences, perceptions, and propensities for mobility** (*subjective dimension*). The third component examines subjective well-being and housing demand using primary data (surveys) or participatory tools to assess residential satisfaction, perceived quality, emerging needs, and willingness to relocate. In a digital transition context, this level becomes crucial because it captures transformations that cannot be deduced solely from structural data: for example, an increased demand for domestic spaces suitable for hybrid work, greater attention to green spaces and environmental quality, or new preferences related to proximity to digital services and fast connections. The results can be categorised by territorial type (city centres, intermediate hubs, peri-urban and mountain areas), assigning synthetic scores to areas and producing maps of 'demand for well-being', useful for understanding where the digital transition is effectively opening new settlement trajectories.
4. **Integration and multi-criteria reading for governance** (*decision support tools*). The three dimensions are then integrated using SMCDA procedures, selecting techniques consistent with the administrative objective: when it is necessary to produce a synthetic index and a comparable spatial classification, a non-linear compensatory approach (e.g., MAUT) proves effective, capable of modelling thresholds and non-proportional effects, while maintaining transparency and reproducibility. The integration is not only for descriptive purposes: it allows the construction of scenario matrices that associate recurring performance combinations (high/low for each dimension) with typical criticalities and policy packages. In this way, the final output is not just a map, but a set of 'governance classes' (territories to regulate, territories to enhance, territories to rebalance, territories to make accessible), directly translatable into strategies and tools.
5. **From knowledge to action: hard and soft approaches**. Based on the integrated results, the Public Administration can structure actions into two complementary plans. At this stage, the operational checklists proposed in the work serve as decision support, enabling the translation of issues identified through the multidimensional analysis of residential well-being into evaluation criteria and policy directions.

On the hard-normative level, interventions include measures on planning tools and programmes: guidelines for the regeneration of existing assets (rather than expansion), standards and provisions, housing policies and market regulation, sustainable infrastructure and mobility, and criteria for the location of digital infrastructures with impact assessments (energy, water, land). On the soft-cultural level, digital literacy and inclusion (reducing the digital divide), the promotion of community practices and place-making, participatory tools, and public communication aimed at raising awareness of digital impacts (digital hygiene, right to disconnect, work-life balance) are central. The core idea is that a credible "twin transition' requires technological innovation to be accompanied by territorial policies oriented towards social and environmental justice, preventing the benefits of digitalisation from being concentrated in a few areas while costs are borne elsewhere.

In summary, the proposal outlines an operational decision-support device for territorial governance bodies, based on replicable protocols, transparent datasets, and cartographic and decision-making outputs. Its utility lies in its ability to interpret the transformations induced by the digital transition not as abstract phenomena, but as territorialised, differentiated, and governable processes. The integration of plan analysis, market reading, and subjective demand interpretation allows strategic planning and, subsequently, operational programming to be directed towards selective and coherent interventions, aimed at maximising the benefits of digitalisation while minimising environmental and social costs, with particular attention to residential living and quality of life. However, the framework may present some methodological limitations, including, for example, the variability and reliability of territorial and economic data, which can vary significantly between different urban contexts, affecting the comparability of outcomes, as well as biases in the detection of subjective preferences, which, although providing valuable information, can vary depending on the selection or representativeness of the analysed samples.

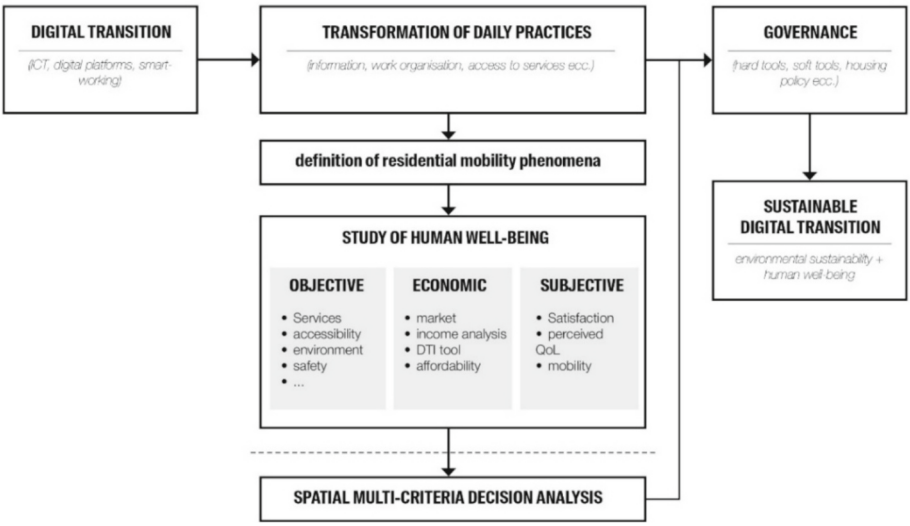

Fig. 1. Conceptual framework of digital transition, residential well-being and territorial governance

5 Conclusions

Digital transformation is one of the most important processes in modern societies, but its effects are ambivalent, creating opportunities and critical issues both environmentally and socially. From an environmental perspective, it can reduce some pressures through dematerialisation and energy optimisation, but it also increases energy, water, and critical resource consumption, as well as the production of electronic waste. Recent literature emphasises how digitalisation transforms, rather than eliminates, environmental impacts, making them less visible and more distributed across space. This questions its environmental sustainability, requiring a systemic approach that considers the entire lifecycle of digital technologies, from materials to waste, including induced effects on consumption patterns. Socially, digitalisation alters daily practices and relationships: it increases access and flexibility, but also generates vulnerabilities such as technostress, isolation, and inequalities, thereby widening the digital divide.

In this perspective, the contribution of this work lies in highlighting the need for analytical and operational tools capable of reading the environmental and social effects of the digital transition in an integrated manner. In particular, the methodological proposal outlined in the previous paragraph suggests adopting multidimensional approaches that combine territorial, economic, and subjective analyses of residential well-being to support decision-making by public administrations and territorial governance bodies. The integration of territorial data, market dynamics, and residents' perceptions allows for the identification of misalignments and emerging critical issues in settlement processes, providing a useful knowledge base to guide planning and programming policies that are more aligned with the objectives of the so-called twin transition, namely the integration of digital transition and ecological transition. Within this analytical framework, the work

also proposes the use of operational decision-support tools, such as assessment checklists, to translate the negative effects of the digital transition identified in the literature into analysis criteria and guiding questions to shape public policies. Checklists are a very useful operational tool, capable of linking the environmental and social criticalities of the digital transition to the three dimensions of residential well-being, supporting public decision-makers in defining targeted actions. In conclusion, the digital transition can truly contribute to improving the quality of life and reducing pressure on ecosystems only if it is managed as a multidimensional process, capable of integrating technological innovation, environmental sustainability, and social justice. In the absence of such an integrated approach, there is a risk that the benefits of digitalisation will be concentrated in certain exclusive areas or territories, while environmental and social costs are transferred elsewhere, making digital transformation less equitable and less sustainable in the long term.

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