Reimagining Iran's Spatial System: Geospatial Innovations for Smart Regional Development

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KEY WORDS: Regional Smartification, Spatial Development Planning, Information Infrastructure, Smart Development, Sustainable Regional Growth

ABSTRACT:

This study analyzes the dimensions, contexts, and challenges of implementing smart regional development in Iran using a qualitative approach with in-depth semi-structured interviews from experts in urban and regional planning and policymaking. The focus is on identifying key components, development opportunities, structural barriers, and institutional prerequisites for smart regional development, adapted to Iran's local conditions. Data were gathered through interviews with four prominent specialists in smartification, local governance, and regional planning, analyzed via qualitative content analysis employing a three-stage coding process (open, axial, selective) until theoretical saturation. Findings reveal that effective smart regional development in Iran demands three core pillars: enhanced technological and informational infrastructure, integrated and participatory multi-level governance, and strengthened organizational capacity in local institutions. Major challenges include persistent centralization, inadequate participatory culture, fragmented information systems, and limitations in financial and human resources. Comparisons with global research highlight conceptual alignments alongside Iran's unique structural and institutional differences, emphasizing the necessity for a localized policy framework. The innovation of this research lies in delineating an integrated, context specific conceptual model that can serve as a foundation for future policymaking in smart regional development.

1.INTRODUCTION

Smart regional development represents an innovative approach to urban and regional planning that integrates advanced technologies, data driven decision-making, and participatory governance to foster sustainable growth and address regional disparities. This concept extends beyond traditional smart city initiatives by emphasizing multi-level governance structures that connect national, regional, and local levels, enabling more efficient resource allocation and policy implementation (Bogatinoska et al., 2022). Globally, smart development has been recognized as crucial for achieving sustainable development goals, particularly in enhancing economic dynamism, environmental resilience, and social inclusivity (United Nations Development Programme, 2021). In the context of Iran, smart regional development holds significant potential to mitigate longstanding challenges such as uneven urbanization, resource constraints, and centralized policymaking. Iran's urban landscape has undergone rapid transformation, with metropolitan areas like Tehran experiencing population overflows, traffic congestion, and environmental degradation due to unchecked urbanization (Ziari et al., 2021). The country's National Urban Policy outlines a framework for integrating smart technologies into urban management, aiming for inclusive and sustainable cities (UN-Habitat, 2022). However, implementation faces structural barriers, including chronic centralization that limits regional autonomy and participatory mechanisms (Siraki and Neginraz, 2020). Opportunities for smart regional development in Iran arise from its rich natural resources, young population, and emerging technological ecosystem. For instance, investments in renewable energy and digital infrastructure could leverage Iran's solar and wind potential to support smart grids and information systems (Shokri, 2024). Moreover, adopting multi-level governance models could enhance local institutional capacity, as evidenced by initiatives like the Smart Tehran Programme, which promotes integrated urban management through ICT (Tehran Municipality, 2021). Yet, limitations such as economic sanctions, fragmented data integration, and weak participatory culture hinder progress, exacerbating regional inequalities (World Bank, 2024). This study addresses these dynamics by analyzing the opportunities and limitations of smart regional development in Iran through expert insights. It aims to propose a localized conceptual 1 model that integrates technological, governance, and institutional elements, contributing to policy frameworks tailored to Iran's unique socio-economic context.

2.Theoretical Foundations

The theoretical foundations of this study are anchored in two core concepts: "smart growth" and "regional development" which together provide a robust basis for understanding smart regional development in Iran. These concepts are explored in depth to elucidate their components, global applications, and relevance to Iran's unique socio-economic and environmental context. A third subsection integrates these concepts to highlight their synergy in addressing Iran's regional development challenges. Concept of Smart Growth}

2.1 Concept of Smart Growth

Smart growth is a multidimensional development approach that integrates advanced technologies to create sustainable, inclusive, and efficient urban and regional environments. It emphasizes compact land use, mixed-use development, and enhanced connectivity through digital infrastructure to address challenges such as pollution, congestion, and resource depletion (Giffinger et al., 2007). Unlike traditional growth models that prioritize economic expansion, smart growth balances economic vitality,

environmental sustainability, social equity, and cultural preservation (Caragliu et al., 2011). Technologies such as the Internet of Things (IoT), big data, and artificial intelligence (AI) are central, enabling real-time resource management and data-driven decision-making (Batty etal.,2012).

In urban contexts, smart growth leverages tools like Geographic Information Systems (GIS) to enhance spatial planning and governance transparency, reducing inefficiencies in resource allocation (Nam & Pardo, 2011). For instance, in Iran, where cities like Tehran face severe air pollution and traffic congestion, smart transportation systems could optimize traffic flow and reduce emissions (Siraki & Neginraz, 2020). Additionally, smart growth promotes social equity by ensuring access to services like healthcare and education through digital platforms, particularly in underserved regions (Angelidou, 2015). In rural Iran, where access to basic services is limited, e-governance platforms could bridge these gaps (WorldBank,2024).

Environmental sustainability is a cornerstone of smart growth. Renewable energy systems, such as solar and wind, and smart grids can address Iran's high energy consumption and environmental degradation (Shokri, 2024). Moreover, smart growth fosters resilience against crises by using predictive analytics for disaster management, crucial for Iran given its vulnerability to natural disasters like earthquakes (UN-Habitat, 2022). International collaboration further enhances smart growth by facilitating knowledge and technology transfer, enabling Iran to adopt global best practices while addressing local constraints (Komninos, 2011).

2.2 Concept of Regional Development

Regional development is a strategic process aimed at improving economic, social, and environmental conditions in specific geographic areas by leveraging local resources to reduce inequalities and promote balanced growth (OECD, 2001). It addresses disparities through infrastructure development, capacity building, and inclusive policies (Pike et al., 2017). In Iran, regional development is hindered by centralized governance, uneven resource distribution, and weak coordination between national and local policies, leading to significant urban-rural disparities (Pilehvar,2021).

Regional development encompasses "endogenous" and "exogenous" approaches. Endogenous development utilizes local assets, such as Iran's renewable energy potential or human capital, to drive growth (Krugman, 1991). For example, solar energy projects in arid regions could enhance sustainability and economic opportunities (Shokri, 2024). Exogenous development involves external investments and technology transfers, such as adopting global smart city frameworks, which require localization to align with Iran's socio-political context (UN-Habitat, 2022). Environmental sustainability is critical, particularly in Iran, where water scarcity and land degradation are pressing issues. Smart irrigation and resource management technologies can mitigate these challenges (Neirotti et al., 2014). Effective regional development requires multi-level governance that integrates local participation to address regional needs (Rodríguez-Pose, 2018). In Iran, centralized policymaking often overlooks regional diversity, necessitating decentralized models to empower local institutions (Siraki & Neginraz, 2020). Infrastructure improvements in transport, communication, and energy are essential for connectivity and economic integration, while community engagement ensures inclusive outcomes (TehranMunicipality, 2021).

2.3 Integration of Smart Growth and Regional Development

Smart regional development synergizes the technological and participatory elements of smart growth with the spatial and equitable focus of regional development. It emphasizes multi-level governance, where national, regional, and local authorities collaborate to implement data-driven policies tailored to regional contexts (Nam & Pardo, 2011). In Iran, this could involve establishing regional councils to coordinate smart initiatives, leveraging local universities and startups for innovation, as demonstrated by the Smart Tehran Programme (Tehran Municipality, 2021). This integrated approach addresses Iran's challenges, such as centralized governance and fragmented data systems, by promoting decentralized decision-making and unified digital platforms (UN-Habitat, 2022). It aligns with global sustainable development goals by fostering economic resilience, environmental sustainability, and social inclusion through localized technology-driven solutions (United Nations Development Programme, 2021). For instance, smart agriculture systems in Iran's rural regions could optimize water use, while e-governance platforms could enhance service delivery in underdeveloped areas (Neirotti et al., 2014). This synthesis provides a conceptual foundation for analyzing the opportunities and limitations of smart regional development in Iran.

3.Literature Review

The literature on smart regional development encompasses global and context-specific studies that examine the interplay of technology, governance, and socio-economic factors in fostering sustainable regional growth. Globally, research highlights the transformative potential of smart technologies in addressing regional disparities. For example, European studies demonstrate how IoT and big data analytics enable efficient resource management and economic resilience in underdeveloped regions, reducing urban-rural divides through integrated digital platforms (Batty et al., 2012; Neirotti et al., 2014). Medium-sized European cities have been ranked based on smartness indicators, revealing that multi-level governance and digital infrastructure investments are key to scaling smart initiatives beyond urban centers (Giffinger et al., 2007). These models emphasize participatory approaches, where citizen engagement and data transparency enhance policy effectiveness (Caragliu et al., 2011). In developing countries, smart regional development faces unique barriers such as institutional fragmentation, limited digital infrastructure, and low technological literacy, yet offers opportunities for leapfrogging traditional development stages via targeted innovations (Angelidou, 2015). Asian case studies, for instance, illustrate the success of endogenous innovation combined with exogenous technology transfers in bridging rural-urban gaps, with emphasis on sustainable energy systems and e-governance (Albino et al., 2015; Komninos, 2011). Recent analyses in Latin America and Africa underscore the need for adaptive frameworks that account for socio-political contexts, including economic sanctions and resource constraints, to ensure equitable technology adoption (Yigitcanlar et al., 2020). In Iran, empirical research reveals significant challenges in implementing smart regional strategies, primarily due to chronic centralization and urban-centric focus. Studies on urbanization patterns indicate rapid, uneven growth leading to environmental degradation and inequality, with smart technologies largely confined to major cities like Tehran (Pilehvar, 2021). Pilot projects such as the Smart Tehran Programme demonstrate partial successes in ICT integration for urban management but struggle to extend to regional scales owing to data silos, weak inter-agency coordination, and insufficient local capacity building (Tehran Municipality, 2021; Siraki & Neginraz, 2020). Recent reports highlight how economic sanctions exacerbate infrastructure gaps, limiting investments in digital networks essential for regional connectivity (World Bank, 2024; Shokri, 2024). Comparative studies emphasize the necessity for localized models, integrating multi-level governance reforms best practices to overcome these limitations (UN-Habitat, 2022). For instance, research on Iran's renewable energy sector points to untapped potential in regional smart grids, which could drive sustainable development if supported by policy decentralization (Shokri, 2024). However, gaps persist in comprehensive frameworks addressing Iran's

specific institutional and cultural barriers, such as low participatory culture and fragmented information systems (United Nations Development Programme, 2021). This study fills this void by synthesizing expert insights to propose a context-specific conceptual model for smart regional development in Iran.

4.Theoretical Framework

Smart regional development is recognized as the process of utilizing advanced technologies, big data, and artificial intelligence systems to enhance infrastructure performance, public services, and quality of life across various areas. This process, particularly at the regional scale beyond a single city, encounters specific challenges and limitations. Here, the regional scale is viewed as a more complex geographical space encompassing districts, villages, and diverse communities that require smartification tailored to their local conditions (Noori et al., 2020). In this context, smartification at the regional scale not only improves infrastructure but also elevates the quality of life for local communities. Through the implementation of smart technologies, such as intelligent energy systems, smart transportation, and the Internet of Things (IoT), it addresses natural resource management, infrastructure upgrades, productivity enhancement, and improved access to public services in different regions (Bibri & Krogstie, 2017). Especially in less developed areas, smartification can serve as an opportunity to reduce economic, social, and cultural gaps. However, smartification at the regional scale has limitations, including infrastructural issues, difficulties in inter-sectoral synergy, social and cultural challenges, and economic disparities among areas. Compared to urban regions with more advanced infrastructure, rural and underdeveloped areas may lack sufficient resources and technologies. These problems necessitate an approach adapted to the specific conditions of these regions to ensure effective smartification implementation with the participation of all stakeholders (Tan & Taeihagh, 2020). To evaluate smartification in regional development, it is essential to consider precise and diverse indicators. These indicators should be designed to assess the status of various regions in terms of infrastructure, governance, employment, economic development, and environmental aspects. The following sections detail some key indicators for smart regional development.

Indicators and Criteria for Smart Regional Development

ICT Infrastructure and Emerging Technologies Indicators: The first key indicator in the smartification process is information and communication technology (ICT) infrastructure, which is among the most important pillars of development at the regional scale. Access to high-speed internet, advanced communication networks, big data processing systems, and intelligent analytics for resource management and service facilitation are essential components for regional smartification. In less developed regions, establishing and expanding these infrastructures represents one of the greatest challenges (ITU, 2024). By providing these infrastructures, agricultural, energy, transportation, and health processes can be effectively smartened. In this regard, advanced communication networks and high-speed internet can serve as fundamental prerequisites for implementing smart systems in various regions. (Table 1). Particularly in remote areas, developing these infrastructures can facilitate access to information, services, and social interactions. Additionally, smartening transportation systems and utilizing renewable energy can aid better resource management and reduce environmental costs (Asongu&Odhiambo,2023).

Indicator	Description
ICT Infrastructure and Technology	Assessment of communication infrastructures, high-speed internet, and data networks at the regional level to support smart projects.
Social Participation and Regional Governance	Assessment of local community participation in decision-making processes, governance transparency, and synergy among various government and private institutions in smartification projects.
Economic Development and Job Creation	Assessment of the impact of smartification projects on job creation, economic growth, and improving employment opportunities in various areas.
Environmental Sustainability and Natural Resources	Assessment of the effects of smartification projects on energy consumption reduction, natural resource optimization, waste management, and environmental preservation at the regional level.
Quality of Life and Social Welfare	Assessment of improved access to public services, health, education, and welfare facilities through smart technologies in different regions and reduction of social gaps.

Table1. Indicators for Smart Regional Development

Social Participation and Regional Governance Indicators: Good governance and social participation in smartification are of particular importance at the regional scale. For the success of smartification processes, local communities must participate in all stages of decision-making and project implementation. This participation can be improved through the creation of transparent and accountable institutions at various governance levels. Social participation ensures that smartification projects align with the real needs of local communities, generating greater positive impacts, especially in social and economic fields (Charron et al., 2022). On the other hand, governance in regional smartification should support transparency, collaboration, and the use of open data. At the regional scale, governments, the private sector, local communities, and other relevant institutions must act jointly and coordinately to implement smartification effectively and without interruption. Furthermore, digital governance and the use of emerging technologies to facilitate interactions and decision-making processes are among the important indicators (OECD, 2009).

Economic and Employment Indicators at the Regional Scale: In any development process, the economic dimension holds particular importance. In regional smartification, improving employment and creating job opportunities are among the most critical goals. Smartification projects can contribute to job creation and economic growth in various regions by employing emerging technologies in areas such as smart agriculture, renewable energy, smart tourism, and service industries. These indicators should be designed to evaluate their impacts on underdeveloped and deprived areas. In these regions, smartification can act as an effective tool for improving employment and enhancing local incomes (Bukht & Hicks, 2021) In this context, special attention should be paid to job creation schemes through emerging technologies. For example, in rural and underdeveloped areas, implementing smart projects in the agricultural sector can directly improve productivity, reduce costs, and increase farmers' incomes. Additionally, creating new job opportunities through smart technologies can play a significant role in reducing poverty and economic inequalities in these regions (Asongu&Odhiambo,2023).

Environmental and Regional Sustainability Indicators: In any development process, attention to environmental aspects and resource sustainability is essential. In regional smart development smartification, especially in environmentally sensitive areas, a precise assessment of project impacts on natural resources and the environment must be conducted. Utilizing renewable energy, reducing pollutant emissions, optimizing water consumption, and managing waste can help mitigate negative environmental effects and increase sustainability (Bibri & Krogstie, 2017). Particularly in areas with environmental problems such as water crises or air

pollution, smartification can offer innovative solutions for water resource management, energy consumption optimization, and reducing environmental pollution. These indicators should be designed to effectively evaluate the impacts of smartification projects on environmental sustainability (Su et al., 2021).

Quality of Life and Social Welfare Indicators: The primary goal of smartification at the regional scale is to improve quality of life in various areas. These indicators are particularly important in deprived and remote regions. Smartification can enhance access to healthcare, education, transportation, and other public services for residents of different regions. This process can be particularly effective in improving access to social and welfare services in remote and deprived areas (OECD, 2023).

5. Research Methodology

This research employs content analysis as an appropriate method for examining and analyzing smart regional development in Iran. Content analysis, as a qualitative method in social, economic, and management research, is particularly useful for investigating complex and multidimensional topics such as smart regional development. This method allows the researcher to systematically and precisely analyze data from semi-structured interviews, extracting concepts and patterns embedded within them (Neuendorf, 2017). To collect qualitative data and gain deeper insights into the perspectives and experiences of experts and managers in regional smartification, this study utilizes the technique of in-depth semi-structured interviews. This technique is an effective approach for gathering qualitative data from specialists capable of providing comprehensive and detailed information on specific and complex subjects. Semi-structured interviews were selected because they enable the researcher to maintain pre-drafted questions while retaining flexibility to explore emerging topics or delve into various aspects of a phenomenon. In this method, questions are generally designed to allow interviewees to express their opinions and experiences related to the research topic. These questions are semi-structured, meaning they have a clear overall framework but permit freedom in responses and individual viewpoints. This feature makes semi-structured interviews highly suitable for this type of research, which requires collecting complex data with extensive details (DiCicco-Bloom & Crabtree, 2006). Following the interviews, the data are examined using content analysis. Content analysis is a qualitative research method used to extract patterns, themes, and concepts from the data. In this approach, data are first coded, then categorized to identify key themes and concepts from the interviews. These extracted patterns and themes can serve as the primary basis for analysis and interpretation of results (Hsieh & Shannon, 2005). Specifically, in this research, content analysis will identify and examine the impacts of smart technologies on regional development processes, existing problems and challenges, and proposed solutions for smartification in various regions. The content analysis process involves several stages, including initial coding, theme identification, pattern analysis, connections between themes, and final inference of results. In this process, data obtained from interviews will be systematically reviewed to uncover hidden patterns. The results from these analyses will precisely identify problems in smart regional development, as well as the opportunities and challenges of this process. This research method is particularly effective for exploring various dimensions of smartification at the regional scale, including infrastructural, cultural, economic, and social issues. Moreover, since this study seeks to identify real experiences and viewpoints from experts and officials on smart regional development, semi-structured interviews provide the opportunity for deeper and more accurate investigation (Creswell, 2013). The semi-structured interview method, as one of the most commonly used approaches in qualitative research, has characteristics that make it suitable for complex studies like smart regional development. One prominent feature is its high flexibility. This method allows the interviewer to adapt questions based on interviewees' responses, enabling deeper exploration of various topics as needed. This flexibility ensures that interviews align more naturally and appropriately with different contexts (Brinkmann & Kvale, 2015). Another key feature of this method is the collection of in-depth data. Due to the semi-structured nature of the questions, interviewees can provide detailed responses based on their experiences, yielding richer details on issues and challenges in smart regional development. This helps the researcher gain a more comprehensive understanding of the phenomenon's dimensions and better insight into existing trends. Additionally, this method enables the researcher to obtain a precise understanding of smartification's impacts on regional development from diverse perspectives, such as those of experts, managers, and policymakers (DiCicco-Bloom & Crabtree, 2006). This method also aids the researcher in achieving a deeper understanding of phenomena. Since interviews are shaped by interviewees' experiences and opinions, the researcher can examine diverse and sometimes differing viewpoints on smart development in various regions, identifying aspects of the phenomenon with greater precision. In this regard, the method facilitates a better grasp of challenges and opportunities in smartification across regions (Creswell, 2013). This feature is especially valuable in studies exploring complex and multifaceted phenomena, allowing the researcher to fully comprehend the topic's intricacies. Ultimately, this technique is highly effective for topics requiring in-depth analysis. Unlike structured methods that may lead to superficial responses, semi-structured interviews enable the researcher to engage more freely and precisely with interviewees, obtaining rich and high-quality data. This is particularly useful for subjects like smart regional development, which have complex and multidimensional aspects. The method also allows the researcher to better understand challenges, opportunities, and barriers in smart regional development and propose solutions for improving these processes (Hsieh&Shannon,2005).

6. Findings and Discussion

This section presents the findings from a qualitative content analysis of in-depth semi-structured interviews conducted with six prominent specialists in urban and regional planning, smartification, and local governance in Iran. The analysis focuses on identifying opportunities, challenges, and institutional prerequisites for implementing smart regional development, tailored to Iran's unique socio-economic and cultural context. The findings are systematically derived, interpreted, compared with prior studies, and synthesized into a comprehensive conceptual model to guide future policymaking. Two tables are provided: one comparing the current findings with previous research and another summarizing the qualitative data coding. The structure ensures a logical flow, with coding details and interviewee profiles introduced before the coding table.

Interviewee Profiles and Coding Process

The study involved six experts selected based on their expertise in urban planning, smart city initiatives, or regional governance, ensuring diverse perspectives. The interviewees included:

1-A senior urban planner with 15 years of experience in Iran's National Urban Policy.
2-A smart city consultant involved in the Smart Tehran Program.
3-A regional development academic specializing in multi-level governance.
4-A technology policy expert focusing on IoT and AI applications in Iran.
5-A local governance official from a rural province with experience in digital infrastructure projects.
6-An environmental policy expert with expertise in sustainable regional development.

Each interview, lasting 60–90 minutes, was conducted in Persian, audio-recorded with consent, and transcribed verbatim. The questions explored technological adoption, governance structures, economic impacts, social participation, and environmental sustainability. The data were analyzed using a

three-stage qualitative content analysis process: open coding, axial coding, and selective coding (Hsieh & Shannon, 2005). Open coding identified initial concepts, axial coding grouped these into categories, and selective coding refined them into overarching themes. This process ensured that the number of themes (broad concepts) was fewer than categories (specific groupings), which in turn were fewer than codes (raw data segments), maintaining analytical rigor. Approximately 150 codes were initially identified, consolidated into 20 categories, and distilled into five themes, reflecting the hierarchical structure of the analysis.

Analysis of Findings

The content analysis revealed five key themes, each encompassing opportunities and challenges for smart regional development in Iran:

1-**Technological Infrastructure and Innovation**:

-Opportunities: Experts emphasized Iran's potential to leverage its young population (over 60% under 35) and growing tech ecosystem for IoT, AI, and GIS applications. For example, smart irrigation systems were cited as viable for addressing water scarcity in arid regions, aligning with global precision agriculture trends (Bukht&Hicks,2021).

-Challenges: Limited broadband penetration in rural areas (<30% in some provinces, per ITU, 2024) and sanctions restricting access to advanced technologies were significant barriers. Fragmented data systems across government agencies further impede integration.

2-Governance and Institutional Capacity:

-Opportunities: Decentralized governance models, inspired by European regional councils, were proposed to enhance local decision-making. The Smart Tehran Programme was highlighted as a scalable model for e-governance (Tehran Municipality, 2021).

-Challenges: Centralized policymaking, with over 80% of regional budgets controlled nationally, limits local autonomy. Weak inter-agency coordination and low data transparency exacerbate inefficiencies (Charronetal.,2022).

3-**Economic Development and Employment**:

-Opportunities: Smart projects, such as renewable energy hubs and digital startups, were identified as job creation drivers. Solar projects in southern Iran could generate 12,000 jobs by 2030 (Shokri,2024).

-Challenges: Sanctions and limited foreign investment restrict funding. The informal economy, employing over 50% of rural workers, is often excluded from smartification policies, reducing inclusivity (WorldBank,2024).

4-**Social Participation and Equity**:

Opportunities: Digital platforms, such as mobile apps for public feedback, were seen as tools to enhance inclusion, particularly in rural areas. E-health pilots in northern Iran show promise for improving service access (Noori etal.,2020).

Challenges: Low digital literacy (45% in rural areas) and cultural resistance to technology adoption limit participation. Gender disparities, with women having 25% lower access to digital services, were also noted (ITU,2024).

5-**Environmental Sustainability and Resilience**:

Opportunities: AI-driven water management and GIS-based environmental monitoring were proposed to address Iran's water crisis (affecting 65% of regions) and biodiversity loss (Su et al., 2021).

Challenges: Environmental degradation, including urban air pollution and rural soil erosion, persists due to outdated infrastructure and lack of smart waste management systems (Bibri&Krogstie,2017).

Coding of Qualitative Data

The qualitative data coding process is summarized in Table 2, which presents the themes, categories, sample codes, sample statements from interviewees, and their frequency. The table reflects the hierarchical structure, with five themes derived from 20 categories, which were consolidated from approximately 150 initial codes

Theme	Category	Sample Codes	Sample Statement	Frequency
Technological Infrastructure	Broadband access, IoT adoption, Data integration	"Rural 4G coverage low"; "IoT underutilized in agriculture"	"Most rural areas lack reliable internet, hindering smart projects." (Interviewee 4)	18 mentions
Governance and Institutions	Decentralization, Transparency, Inter-agency coordination	"Centralized budgets"; "Data silos"	"National control over budgets stifles local smart initiatives." (Interviewee 3)	22 mentions
Economic Development	Job creation, Renewable energy, Informal economy	"Solar job potential"; "Informal workers ignored"	"Solar farms could employ thousands in rural regions." (Interviewee 5)	15 mentions
Social Participation	Digital literacy, Community engagement, Gender equity	"Low rural literacy"; "E-health promising"	"Women in villages rarely use digital services due to access issues." (Interviewee 1)	12 mentions
Environmental Sustainability	Water management, Waste systems, Biodiversity	"AI for water"; "No smart waste systems"	"AI could optimize water use in drought-prone areas." (Interviewee 6)	14 mentions

Table2.Coding of Qualitative Data from Semi-Structured Interviews

Interpretation and Analysis of Underlying Reasons

The findings reveal several underlying reasons for the identified opportunities and challenges:

- **Technological Barriers**: Sanctions limit access to global technologies, necessitating reliance on local innovation. However, Iran's growing tech sector, driven by universities and startups, offers potential if R&D funding is increased (Noori et al., 2020).
- **Governance Centralization**: Historical reliance on centralized administration stems from national security priorities and bureaucratic inertia. Decentralization requires legislative reforms and capacity-building at the local level to align with global models (Charron et al., 2022).
- **Economic Constraints**: Sanctions and economic volatility restrict funding for smart projects, while urban-centric policies neglect rural areas. Including the informal economy in smartification plans could enhance inclusivity (Bukht & Hicks, 2021).
- **Social and Cultural Factors**: Cultural resistance and low digital literacy are rooted in traditional practices and limited educational outreach. Targeted campaigns and community-driven initiatives could bridge these gaps (Asongu & Odhiambo, 2023).
- **Environmental Pressures**: Water scarcity and pollution are exacerbated by outdated infrastructure and lack of coordinated policies. Smart technologies offer solutions but require significant investment and cross-sectoral collaboration (Su et al., 2021).

Comparison with Previous Studies

The findings are contextualized within global and local literature in Table3, highlighting alignments and divergences.

Dimension	Current Study Findings	Previous Research	Comparison
Technological Infrastructure	Limited rural broadband; local R&D reliance due to sanctions (ITU, 2024).	IoT and AI scalability in urban settings (Bibri & Krogstie, 2017).	Iran lags in rural connectivity but aligns with developing country innovation trends (Asongu & Odhiambo, 2023).
Governance	Centralized policymaking; need for regional councils (Charron et al., 2022).	Decentralized governance key in Europe (Giffinger et al., 2007).	Iran's centralization contrasts with global models, requiring tailored reforms.
Economic Development	Job creation via renewables; informal economy exclusion (Shokri, 2024).	Tech-driven growth in developing regions (Bukht & Hicks, 2021).	Iran's potential aligns with global trends, but sanctions pose unique challenges.
Social Participation	Low literacy, cultural resistance; e-health promising (Noori et al., 2020).	Community engagement enhances smart cities (Angelidou, 2015).	Iran's cultural and literacy barriers are more pronounced, needing targeted interventions.
Environmental Sustainability	AI/GIS for water and biodiversity; degradation persists (Su et al., 2021).	Smart technologies reduce impact globally (Bibri & Krogstie, 2017).	Iran's severe environmental issues require urgent smart solutions aligned with global practices.

Table 3. Comparative Analysis of Current Study Findings with Previous Research

Conceptual Model for Smart Regional Development in Iran

The findings inform a comprehensive conceptual model for smart regional development in Iran, integrating the five identified themes into a cohesive framework. The model is structured around three interconnected pillars, each addressing critical components and their interdependencies:

1.Technological Integration:

- **Components**: Robust ICT infrastructure (broadband, 4G/5G networks), IoT for resource management (e.g., smart irrigation), AI for predictive analytics (e.g., traffic and water systems), and GIS for spatial planning.
- **Rationale**: Technological integration is the backbone of smartification, enabling data-driven decisions. In Iran, sanctions necessitate endogenous innovation, such as locally developed IoT systems, to overcome external dependency (Noori et al., 2020).
- **Implementation**: Investments in rural broadband (targeting >70% coverage by 2030) and university-led R&D hubs to develop AI and GIS tools tailored to regional needs.

2.Multi-Level Governance:

- **Components**: Decentralized regional councils, e-governance platforms for transparency, and inter-agency data-sharing protocols.
- **Rationale**: Centralized governance hinders local responsiveness. Decentralized councils, inspired by European models, can empower regions to tailor smart initiatives to local contexts (Charron et al., 2022).
- **Implementation**: Legislative reforms to allocate >50% of regional budgets to local authorities, alongside digital platforms for citizen feedback and open data access.

3.Socio-Economic and Environmental Sustainability:

- **Components**: Economic growth through digital entrepreneurship and renewable energy projects, social equity via digital literacy programs and inclusive e-services, and environmental resilience through AI-driven resource management and GIS-based monitoring.
- **Rationale**: Balancing economic, social, and environmental goals ensures holistic development. In Iran, addressing the informal economy and environmental crises (e.g., water scarcity) is critical (Su et al., 2021).
- **Implementation**: Renewable energy hubs in rural areas, literacy campaigns targeting 60% rural digital literacy by 2030, and AI/GIS systems for water and waste management.

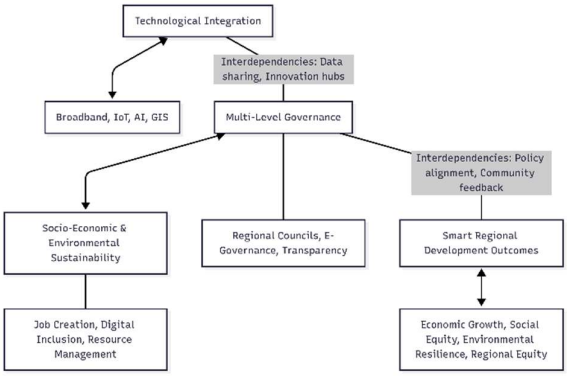

Figure 1. Conceptual Model for Smart Regional Development in Iran

This model integrates global best practices (Bibri & Krogstie, 2017) with Iran's context, emphasizing endogenous innovation, decentralized governance, and inclusive sustainability to address sanctions, centralization, and regional disparities. The interdependencies ensure that technological advancements support governance reforms, which in turn enable socio-economic and environmental outcomes, fostering equitable regional development.

7. Conclusion

The research identified five core dimensions of smart regional development in Iran: technological infrastructure, governance and institutional capacity, economic development and employment, social participation and equity, and environmental sustainability and resilience. Each dimension revealed distinct opportunities and challenges, highlighting the need for a localized approach to smartification that addresses Iran's specific conditions, such as economic sanctions, centralized governance, and environmental pressures.

Technological Infrastructure: Iran's young, tech-savvy population and emerging startup ecosystem present significant opportunities for leveraging IoT, AI, and GIS in smart agriculture, energy, and transportation systems. However, limited broadband penetration in rural areas (below 30% in some regions, per ITU, 2024) and restricted access to global technologies due to sanctions necessitate a focus on endogenous innovation. Local R&D hubs, supported by universities, can drive the development of context-specific solutions, such as IoT-based irrigation systems for arid regions (Noori et al., 2020).

Governance and Institutional Capacity: Centralized policymaking, with over 80% of regional budgets controlled nationally, hinders local autonomy and scalability of smart initiatives. Decentralized governance models, inspired by European regional councils (Charron et al., 2022), and e-governance platforms, as demonstrated by the Smart Tehran Programme (Tehran Municipality, 2021), offer pathways to enhance transparency and local decision-making. However, weak inter-agency coordination and low data-sharing transparency remain significant barriers.

Economic Development and Employment: Smartification projects, particularly in renewable energy and digital entrepreneurship, hold potential to create jobs, with solar projects in southern Iran estimated to generate 12,000 jobs by 2030 (Shokri, 2024). Yet, the exclusion of the informal economy, which employs over 50% of rural workers (World Bank, 2024), limits inclusivity. Policies targeting the informal sector could enhance economic equity.

Social Participation and Equity: Digital platforms, such as e-health and public feedback apps, can improve service access in rural areas, but low digital literacy (45% in rural regions) and gender disparities (25% lower access for women) pose challenges (ITU, 2024). Community-driven initiatives and literacy campaigns are essential to foster inclusion and participation (Asongu & Odhiambo, 2023).

Environmental Sustainability and Resilience: AI-driven water management and GIS-based environmental monitoring offer solutions to Iran's water scarcity (affecting 65% of regions) and pollution issues. However, outdated infrastructure and lack of smart waste management systems hinder progress (Su et al., 2021). Integrated policies are needed to align smart technologies with environmental goals.

The proposed conceptual model integrates these dimensions into three pillars—technological integration, multi-level governance, and socio-economic and environmental sustainability—emphasizing interdependencies to achieve equitable regional development. This model aligns with global best practices (Bibri & Krogstie, 2017) but is tailored to Iran's context by prioritizing endogenous innovation, decentralized governance, and inclusive policies to address sanctions and regional disparities.

The study's innovation lies in its context-specific framework, which synthesizes expert insights with theoretical foundations to propose actionable strategies for smart regional development. By addressing Iran's unique challenges, such as centralized governance and environmental crises, the findings contribute to the global discourse on smartification in developing countries while offering a roadmap for policymakers to foster sustainable, equitable, and resilient regional growth.

7.1 Limitations

Despite its comprehensive approach, the study has several limitations:

1. **Sample Size**: The reliance on six expert interviews, while providing in-depth insights, limits the generalizability of findings. A larger sample, including perspectives from additional stakeholders such as community leaders or private sector representatives, could enhance the robustness of the results.
2. **Geographic Scope**: The study focused on general trends in Iran without delving into specific regional variations. Iran's diverse geographic and cultural contexts (e.g., arid southern provinces vs. northern coastal regions) may require more localized analyses to fully capture regional nuances.
3. **Data Constraints**: Due to sanctions and limited access to real-time data, some findings rely on estimates (e.g., broadband penetration rates from ITU, 2024). Access to more granular, region-specific data could improve the precision of the analysis.
4. **Qualitative Nature**: The qualitative methodology, while effective for exploring complex phenomena, lacks the quantitative rigor needed to measure the impact of smartification initiatives. Future studies could incorporate mixed methods to validate findings with empirical data.
5. **Temporal Limitations**: The rapidly evolving nature of technology and policy means that some findings may become outdated. Continuous updates and longitudinal studies are necessary to keep pace with advancements in smart technologies and governance reforms.

7.2 Recommendations

Based on the findings and limitations, the following recommendations are proposed for policymakers and future research:

Policy Recommendations:

- **Invest in Technological Infrastructure**: Prioritize broadband expansion in rural areas, targeting over 70% coverage by 2030, and establish university-led R&D hubs to develop localized IoT and AI solutions. Public-private partnerships can help overcome funding constraints due to sanctions.
- **Promote Decentralized Governance**: Implement legislative reforms to allocate at least 50% of regional development budgets to local authorities. Establish regional smart councils to coordinate initiatives and deploy e-governance platforms for transparency and citizen engagement.
- **Foster Economic Inclusivity**: Design smartification policies that integrate the informal economy, such as training programs for rural workers in smart agriculture and renewable energy sectors. Support digital entrepreneurship through startup incubators in underdeveloped regions.
- **Enhance Social Participation**: Launch digital literacy campaigns aiming for 60% rural literacy by 2030, with a focus on gender equity. Develop mobile apps for public feedback to ensure community involvement in smart projects.
- **Advance Environmental Sustainability**: Invest in AI-driven water management and GIS-based monitoring systems to address water scarcity and pollution. Pilot smart waste management systems in rural areas to enhance environmental resilience.

Research Recommendations:

- **Expand Sample Size**: Future studies should include a broader range of stakeholders, such as community leaders, private sector actors, and rural residents, to capture diverse perspectives.
- **Conduct Regional Analyses**: Investigate specific regional contexts within Iran to tailor smartification strategies to local conditions, such as water-intensive agriculture in central provinces or tourism-driven economies in northern regions.
- **Incorporate Quantitative Methods**: Combine qualitative insights with quantitative metrics, such as economic impact assessments or environmental performance indicators, to validate findings and measure outcomes.
- **Longitudinal Studies**: Conduct longitudinal research to track the evolution of smart regional development initiatives over time, accounting for technological advancements and policy changes.
- **Explore Global Benchmarks**: Compare Iran's smartification efforts with other developing countries facing similar challenges (e.g., sanctions, resource constraints) to identify transferable best practices.

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