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Smart City as a Catalyst for Enterprise Development

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Abstract

This article examines how smart cities can act as catalysts for enterprise development by integrating technological, infrastructural, governance and human capital dimensions into a coherent urban innovation ecosystem. Drawing on an extensive literature review, the study first conceptualizes smart cities as adaptive systems that combine physical infrastructure, digital data layers, and institutional frameworks, creating conditions for knowledge spillovers, entrepreneurial opportunities, and business model innovation. Empirically, the research is based on an expert survey conducted among 54 specialists from academia, business, and public administration, who assessed the importance of technological, infrastructural, governance, innovation ecosystem, and human capital factors for enterprise development in the context of smart cities. The results suggest that advanced digital technologies, smart infrastructure, open data, R&D support, startup programs and talent development are perceived by experts as key, mutually complementary drivers of firms' innovation, efficiency, sustainable growth, and competitiveness, with notable differences between expert groups. On this basis, the study proposes a synthetic model of relationships and impact pathways linking smart city components with enterprise outcomes. The paper concludes with a discussion of the study's limitations, related to the expert-based, country-specific, and perceptional character of the data, and outlines directions for further quantitative and qualitative research on the firm-level effects of smart city development.

Keywords: smart city; enterprise development; innovation ecosystem; digital and innovative infrastructure

1. Introduction

Cities are undergoing a fundamental transformation: the convergence of rapid urbanization, digital technology, and mounting sustainability pressures is compelling municipalities worldwide to move beyond traditional governance models toward integrated, data-driven approaches to urban management.

Therefore, the strategic role of cities in the further development of civilization and humanity is gaining particular importance—it is precisely cities that concentrate key resources, innovation processes, economic activity, and social life, while at the same time most directly experiencing the effects of climate change, geopolitical tensions, social crises, and rapid technological progress. From this perspective, the need to move from a traditional model of city management to an approach based on the integration of physical infrastructure, digital solutions, human capital, and new forms of co-governance involving multiple stakeholders is becoming increasingly evident. This transition reflects a broader institutional evolution:

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from traditional public administration models to New Public Management and, subsequently, to digitally enabled governance frameworks, in which local authorities become platform orchestrators of sustainable urban ecosystems.

This article contributes to the scientific debate on the impact of the smart city on the enterprise sector, business creation, opportunities for firm growth, and the shaping of a supportive environment for the entrepreneurial ecosystem. The literature increasingly emphasizes that smart cities are not merely a collection of advanced technologies but complex innovation ecosystems in which enterprises act both as beneficiaries and co-creators of solutions. In this context, it becomes particularly important to understand how digital technologies, infrastructure, public policies, and human capital translate into concrete development opportunities for firms of different sizes, activity profiles, and business models.

The aim of the study was to analyze and assess the potential impact of smart city centres on enterprise development. The central research question driving this study is: To what extent, and through which mechanisms, can smart city infrastructure and governance create conditions that support enterprise development? Despite growing scholarly interest in smart cities, most quantitative studies approach this question from a macroeconomic angle—examining listed companies or urban GDP indicators via quasi-experimental panel designs applied to Chinese city policy programs [1,2]. This leaves a significant gap in the literature: the multi-stakeholder perception of smart city drivers across diverse professional groups—academics, technology providers, operators, and public administrators—remains understudied, particularly in the Central and Eastern European institutional context.

The present study addresses this gap through a structured expert survey conducted among 54 Polish specialists representing academia, the smart city solutions industry, and enterprise implementation roles. The survey assessed the perceived importance of five dimensions of smart city impact on enterprise development: advanced digital technologies, infrastructure, smart governance, innovation ecosystem and regulatory support, and human capital. Expert-based assessment was chosen as a methodological complement to secondary-data studies: while panel data studies measure average firm-level outcomes, structured expert judgement captures the perceived importance of specific mechanisms—a necessary precursor to targeted hypothesis formation and strategy design.

The study is guided by three research questions:

- Q1—What are the dominant market trends in smart city implementation?
- Q2—Through which mechanisms can smart city solutions influence enterprise development?
- Q3—Which technological, infrastructural, governance, ecosystem, and human capital factors are perceived by experts as most strongly associated with enterprise development?

These questions are explored through an integrated theoretical framework combining Innovation Ecosystem Theory, Transaction Cost Theory, and Absorptive Capacity Theory, developed in the literature review.

The article consists of six parts: the introduction; the literature review; materials and methods, which include a description of the objectives, research questions, methods, and procedures; the analysis of results; the discussion of findings, including comparisons and references to other authors' studies; and the conclusion, which presents the main findings, limitations, and proposals for further research.

2. Literature Review

The literature review is organized to build directly toward the empirical investigation. Section 2.1 establishes the conceptual boundary of the smart city—clarifying which dimensions of the concept are relevant to enterprise development and why definitional precision matters for the questionnaire design. Section 2.2 analyzes the mechanisms through which smart cities affect firms, structured around the three theoretical traditions that underpin the study's hypotheses (Innovation Ecosystem Theory, Transaction Cost Theory, and Absorptive Capacity Theory). Each subsection of the review concludes with an identification of gaps or inconsistencies in the existing literature that the present expert survey is designed to address.

2.1. The Specificity and Concept of Smart Cities

Efforts aimed at ensuring coherence between social, economic, and environmental phenomena are becoming increasingly important. Constant improvement of processes and the growth of mobility through the sharing economy are priority issues in an age of universally increasing urbanization. Cities of the future must adapt to changing environmental conditions to respond rapidly to climate change, population size, growing globalization of the economy, demographic changes, technological development, threats and geopolitical transformations, human mobility (including migration), population aging, conflicts, and social inequalities [3–10]. To care for urbanized centres and their users, both local and central authorities increasingly implement the smart city concept. This concept is gradually becoming a strategic plan for numerous agglomerations—in Poland, in Europe, and worldwide.

The smart city concept has evolved since the late 1990s—from early notions of the "virtual city" and "digital city" [11–16] to contemporary multi-dimensional frameworks [17–20]—yet no universally accepted definition has emerged [21–32].

According to A. Caragliu [4–6], a city becomes smart when it invests in human and social capital while traditional and modern ICT support sustainable economic growth and high quality of life. S. Mohanty, in turn, sees a smart city as a place where traditional networks and services become more flexible, efficient, and sustainable [33]. They rely on the use of information, digital, and telecommunication technologies to improve functionality for the benefit of residents, making cities greener, safer, faster, and more livable [4]. N. Komninos defines a smart city as an area (municipality, district, cluster, or city) consisting of four main components [31,34]:

- A creative population engaged in intensive, knowledge-based activities or clusters of such activities.
- Efficiently operating institutions with their own procedures for knowledge creation, acquisition, adaptation, and further development.
- Well-developed broadband infrastructure, digital spaces, e-services, and online knowledge management tools.
- A documented ability to innovate, manage, and solve unprecedented problems, as innovation and management under uncertainty are key to assessing intelligence.

A broader definition was proposed in the report Mapping Smart Cities in the EU, which views a smart city as one that addresses public challenges through ICT-based solutions and multi-stakeholder partnerships of a self-governing nature. ICT technologies connect various urban systems and stimulate innovations that facilitate the implementation of urban policy goals [35].

Implementing such solutions, while safeguarding social aspects such as well-being, cultural offerings, and life expectancy, requires a new, holistic model of city management where bottom-up governance cooperates with top-down management, enabling participation from many stakeholders (city users such as residents, businesses, NGOs). The idea behind the smart city is to create and leverage connections between human and social capital and ICT to generate sustainable urban growth and improve residents' quality of life [36–39].

The literature identifies six characteristic dimensions of the smart city, smart economy, smart mobility, smart environment, smart people, smart living, and smart governance [3–10,40–45], with the economic dimension—encompassing support for entrepreneurship, innovativeness, and enterprise productivity—constituting the primary analytical focus of the present study.

A smart city is thus creative and sustainable, where the quality of life improves and economic growth prospects are strengthened. Its distinguishing feature is intelligence, understood as the sum of various improvements to the functioning of urban infrastructure, resources, and social services [42–45].

The conceptualization and practical implementation of smart city solutions are inseparably linked to the evolution of public administration paradigms. The concept of New Public Management (NPM), which emerged in the 1980s and gained international traction in the 1990s in the United States and the United Kingdom, introduced a fundamental transformation in the management of public institutions: emphasis was placed on performance evaluation, process streamlining, cost efficiency, and the enhancement of the ethical profile of public management [46–49]. NPM redefined the role of city governments from hierarchical providers of services to outcome-oriented managers of complex urban systems, opening space for public–private cooperation and digital solutions.

This trajectory was further reinforced by the normative framework of sustainable development introduced by the World Commission on Environment and Development in its landmark report Our Common Future [50]. The report defined sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs”, and directed urban governance toward long-term integration of economic growth, social well-being, and environmental responsibility. The smart city concept can be understood as the culmination of this evolutionary process at the local level: it translates the normative aspirations of sustainable development into concrete technological and institutional instruments managed by local public administrations. In this view, smart cities are not merely technological artefacts—they are a governance innovation that extends and digitizes the NPM reform agenda, enabling cities to deliver better outcomes for citizens and the business ecosystem simultaneously [51].

According to the World Health Organization, by 2050, the global population will double, and 70% of it will live in cities. Urban areas are growing by 60 million people annually. Cities account for about 80% of global GDP, bringing increased demand for utilities (energy, water, gas), transportation, and housing services and limiting public space. Consequently, cities require efficient solutions that foster sustainable growth and social welfare, improving the quality of life of residents. Moreover, in the face of global warming and economic instability, cities have become arenas for various social experiments addressing contemporary challenges. The smart city is one such example [52].

This indicates that modern technology is not the only element defining the term “smart” within urban functioning. Other factors, such as creativity, innovation, and democracy, also play vital roles. The modernist vision of an ideal city focused mainly on individualism is gradually being replaced by more integrated and collective models.

Additionally, business plays a fundamental role in the development of future cities—enterprises introducing smart solutions into public space, homes, and daily life. These may include organizations using technology, creativity, and open data while addressing human needs—creating software that enhances quality of life, increases efficiency, and bridges the gap between the city and traditional business in the creation of social innovation. Other enterprises manufacture hardware and software that improve energy efficiency, based on smart algorithms (e.g., smart homes), complementing smart energy grids designed to minimize energy losses.

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The smart city concept thus represents a transformative paradigm for modern urban management, where the economic sphere serves as a fundamental catalyst for systemic change. In this context, enterprises are key actors in the smart city ecosystem, fulfilling multiple functions—from implementing innovative technologies and breakthrough innovations to creating socially oriented solutions. Companies specializing in software, energy-saving devices, smart algorithms, and data management systems are the driving force behind practical smart city implementation. At the same time, traditional enterprises integrating into the digital urban ecosystem gain strategic access to data, intellectual potential, and collaboration opportunities, leading to innovative business models and increased profitability. The dynamic growth of technology firms, startups, and consulting companies directly contributes to generating high-quality jobs, attracting talent, and building the region's long-term competitive advantage [53].

An economy based on the smart city concept is highly innovative and technologically advanced, thanks to intensive ICT use, which enables value creation and the formation of strategic local and global connections. International exchange of goods, services, and knowledge forms the foundation for building cities' competitive positions in the globalized economy.

2.2. The Impact of Smart Cities on Stimulating Enterprise Development

A smart city is defined as a comprehensive spatial system in which the city's physical infrastructure—transport networks, energy resources, water supply systems, buildings—is integrated with a digital information layer through sensor networks (IoT), data analytics platforms, artificial intelligence systems, and communication interfaces. A fundamental feature of a smart city is its ability to collect, process, and use data in real time in order to optimize the functioning of the urban system and improve the efficiency of public services [48,49,54].

From the perspective of systems theory, a smart city constitutes an adaptive system—that is, one that can modify its operational parameters on the basis of feedback from its environment. In this view, smart cities are characterized by three fundamental properties [55,56]:

- Sensory awareness—the ability to measure and monitor the state of the system via a distributed network of IoT devices;
- Analytical capability—the ability to process large datasets (big data) in order to identify patterns, anomalies, and forecasts;
- Responsiveness—the ability to rapidly implement changes and adjustments on the basis of analyses.

The literature typically distinguishes five dimensions of a smart city: the economic dimension (smart economy), mobility (smart mobility), the environment (smart environment), people (smart people), and governance (smart governance). The economic dimension, which is the subject of analysis in this study, refers specifically to the city's capacity to support entrepreneurship, innovativeness, and productivity growth among local enterprises.

In this context, the impact of a smart city is multi-dimensional and relates to the creation of an innovation ecosystem, effects on enterprise performance, heterogeneity of impacts, competitiveness, sustainable development of organizations, geographic context, and the role of public policy.

2.2.1. Smart City as an Innovation Ecosystem

The theoretical framework for understanding the impact of smart city on enterprises is the concept of the innovation ecosystem. In this approach, a smart city is not perceived as a collection of technologies, but as a broad system of relationships and interactions between multiple actors: public administration, technology companies, startups, research institutions, non-governmental organizations, and citizens [55,57].

The innovation ecosystem is characterized by a dynamic flow of knowledge, resources, and information between actors. In the context of smart cities, these flows are enhanced through access to open data, APIs (Application Programming Interfaces), collaboration platforms, and shared infrastructures for testing new solutions. This dense network of connections creates conditions for the emergence of so-called knowledge spillovers—the unintended spread of knowledge and skills between organizations, which leads to the acceleration of innovation and efficiency of the entire system [58].

Within the smart city innovation ecosystem, several key functions can be distinguished: opportunity generation—cities provide data and infrastructure that reveal new problems to solve; resource linking—the ecosystem facilitates access to funding, talent, and business partners; uncertainty reduction—enterprises can test solutions in real urban conditions, reducing implementation risk; scaling—cities serve as testbeds for solutions that can then be replicated in other cities [55,57].

Significant for ecosystem theory is the concept of complementarity—the degree to which different elements of the system mutually support and reinforce each other. In smart cities, complementarity manifests itself in the synergy between technical infrastructure (hardware), software, human resources (wetware), and institutions (orgware). Cities that can build high complementarity between these dimensions generate greater economic value and attract more enterprises [56].

This ecosystem perspective justifies the inclusion of governance, data, and collaboration variables alongside purely technological items in the expert questionnaire—they are theoretically constitutive of the innovation environment, not peripheral to it.

2.2.2. Mechanisms of Smart City Impact on Enterprise Performance

One of the fundamental mechanisms is the reduction in transaction costs. In institutional economics, transaction costs are defined as the costs of searching for information, negotiating contracts, monitoring their execution, and enforcing agreements. In traditional cities, enterprises had to incur significant expenses to obtain information about available suppliers, customers, market conditions, and regulatory requirements [55].

Smart cities, through a digital information layer, dramatically lower these costs. Urban data platforms provide enterprises with information about traffic conditions, demand for services, market prices, resource availability, and infrastructure challenges in real time. Access to such information enables firms to make more effective and efficient business decisions, respond faster to changing market conditions, and allocate resources more efficiently [54,57].

The reduction in transaction costs translates directly into lower operating costs for enterprises, which under conditions of perfect competition, should lead to lower prices for consumers and higher margins for firms with a greater ability to efficiently use data. In the literature, the impact on firms' financial performance is particularly evident in capital-intensive industries, where process optimization yields significant savings (transport, logistics, energy production, natural resource management) [59].

The second important mechanism is improved access to capital and business resources. Information asymmetry constitutes one of the main barriers to the development of small- and medium-sized enterprises (SMEs)—financial institutions have a more limited range of information about SMEs' ability to repay loans, which results in higher interest rates and lower credit availability for these entities. Smart cities can reduce this asymmetry by providing financial institutions with data on firms (e.g., regularity of tax payments, foot traffic in premises, the number of served customers based on mobility data) [56].

Moreover, smart cities create institutional conditions for the emergence of new forms of financing—equity crowdfunding platforms, green bonds, venture capital funds specializing in smart city solutions. The concentration of technology companies in smart cities attracts investors, which lowers the cost of capital for startups and SMEs. In conventional cities, it is difficult for a startup to find venture capitalists or angel investors; in a smart city, such resources are within easy reach [58].

Access to shared infrastructure—incubators, laboratories, office spaces with flexible rental conditions, 5G networks, and data centres—also reduces entry barriers for new firms and lowers operating costs for existing ones. This expands the pool of enterprises able to survive on the market and the time they can afford before reaching profitability. Smart cities are natural centres for technology transfer from research centres to business practice. Universities located in smart cities can immediately test research results in real-life urban conditions—whether in terms of traffic optimization, energy management, or resource management systems. Enterprises, in turn, can gain direct access to the latest technological discoveries, instead of waiting for their commercialization by specialized firms [60].

This transfer is particularly important for sectors with high innovation density—biotechnology, advanced materials, artificial intelligence, robotics. When a university in a smart city achieves a scientific breakthrough, the local entrepreneurial ecosystem can quickly mobilize resources for its commercialization. In a traditional city, an innovation might remain within academia for many years before someone decides to commercialize it. Technology transfer is also strengthened through the possibility of observation and imitation—entrepreneurs can observe how other firms in the ecosystem use new technologies, which lowers the perceived uncertainty associated with adoption. This "social proof" effect is particularly important for startups, which institutionally lack the capacity to design entirely new solutions [61].

Smart cities also stimulate innovation at the level of business and organizational models. Access to real-time data enables enterprises to shift from a product-based business model to a model based on services and data. For example, a car manufacturer can become a mobility services provider; an energy producer can become an operator of a peer-to-peer energy exchange system; a water producer can become an operator managing water resource-saving systems. These model innovations can have profound implications for margins and revenue growth. The service model allows for variable billing tied to actual usage, thus enabling better alignment of revenues with the value delivered to the customer. The data-based model allows for personalization and segmentation of the offer, making it possible to raise prices for customer segments willing to pay more. In addition, access to the innovation ecosystem favours the adoption of modern organizational practices—agile management, design thinking, lean startup—which are promoted in smart city environments and among collaboratively working teams [56,57].

Smart cities attract highly qualified workers thanks to better quality of public services (transport, education, healthcare), greater density of employment opportunities, a dynamic cultural scene, and the perceived status of being modern and aspirational places. For enterprises, this means access to a talent pool—employees with specialized knowledge in digital technologies, data analysis, design, and engineering. Competition for talent in smart cities also favours higher wages and better working conditions, which, although they increase firms' operating costs, at the same time improve productivity and reduce employee turnover. In the new knowledge-based economy, access to talent is often a more restrictive barrier than access to capital [62].

These mechanisms—transaction cost reduction, capital access, technology transfer, and talent attraction—directly correspond to the five thematic blocks assessed in the expert survey and provide the theoretical rationale for expecting differential assessments across stakeholder groups.

2.2.3. Heterogeneity of Effects and Determinants

The impact of smart city on enterprise development is not uniform for all types of firms and sectors. Small- and medium-sized enterprises (SMEs) generally derive greater relative benefits from smart city infrastructure and data than large corporations. This follows from the fact that large enterprises possess internal resources (own research centres, IT departments, data analytics units), whereas SMEs cannot afford to maintain such structures. For SMEs, access to open data, analytical platforms, or smart city test laboratories represents only a fraction of the cost of maintaining internal structures [1,54].

Moreover, small firms are more organizationally flexible and can adapt more quickly to change. In SME structures, decisions can be made faster, and implementing changes is simpler. Consequently, SMEs can draw benefits from data and opportunities revealed by smart city infrastructure more quickly [54].

Capital-intensive sectors (energy, water, transport, logistics) achieve particularly large gains from process optimization made possible by smart city data. In service sectors—especially those where decisions are heavily knowledge-intensive (fintech, healthtech, edtech)—access to data and the innovation ecosystem also constitutes a key competitive advantage. In contrast, traditional sectors that are weakly instrumented and low-value-added may derive smaller benefits from smart city infrastructure unless they undergo substantial business transformation [57].

A crucial role is played by the firm's absorptive capacity—i.e., the ability to recognize the value of new knowledge, assimilate it, and apply it in business practice. Enterprises with higher absorptive capacity (more employees with higher education, larger R&D budgets, more experienced management) can make better use of smart city opportunities. Firms with lower absorptive capacity may waste many benefits, as they will not be able to translate access to technology and data into concrete business actions [56–59].

The absorptive capacity argument is central to H2: it predicts that enterprise operators, whose day-to-day work demands integration with smart infrastructure, will rate infrastructure and sustainability factors significantly higher than technology providers focused on discrete solution sales.

2.2.4. Impact on Innovation and Competitiveness

Smart city influences the innovativeness and competitiveness of enterprises through a multi-dimensional mechanism. First, access to data opens new spaces for product innovation—when real problems and user needs are known (identified through smart city data), firms can design solutions more accurately. Second, access to the innovation ecosystem and shared infrastructure reduces R&D costs for startups and the small- and medium-sized enterprise sector. Third, competition within the smart city ecosystem fosters innovativeness—every firm knows that others are improving their solutions, which compels it to engage in a continuous improvement process. Fourth, the possibility of rapidly testing solutions in real-world conditions (living labs) reduces time to market and the number of costly errors [57–59].

In the context of inter-city and international competitiveness, cities that effectively build innovation ecosystems attract enterprises, talent, and investments—local economies of innovation hubs with global reach are created. Firms located in such cities gain a competitive advantage both through access to technology and through their perceived status [54,57].

These innovation and competitiveness mechanisms motivate the inclusion of R&D investment, startup program, and technology cluster variables in Block 4 of the questionnaire.

2.2.5. Smart City and Sustainable Enterprise Development

The impact of smart city on the sustainable development of business activity manifests itself at multiple levels. At the environmental level, real-time data on energy consumption, water usage, and gas emissions allow for monitoring and reducing the ecological footprint of enterprises. Many firms operating in traditional cities simply did not have access to such information—now they can identify areas of resource waste. At the social level, smart cities can support enterprises in making decisions that better account for social impact (data on unemployment, public health, and education in the vicinity of the firm's location). At the governance level, data transparency supports compliance and business transparency, which builds greater trust in economic entities. Research indicates that firms operating in smart cities and effectively using available data to manage their environmental and social impact achieve better ESG (environmental, social, governance) scores, which translates into access to cheaper financing and the loyalty of long-term investors [1,62].

The sustainability dimension of smart city–enterprise interactions is central to the mission of this journal. Conceptually, the smart city can be understood as an institutional architecture that simultaneously advances all three pillars of sustainable development—economic efficiency (through transaction cost reduction and productivity gains), social inclusion (through open data, e-participation, and equitable access to innovation infrastructure), and environmental responsibility (through smart energy management, circular economy integration, and real-time emissions monitoring) [1,63]. From this perspective, enterprise development in smart cities is not merely an efficiency gain: it represents co-production of urban sustainability value, in which firms become embedded partners in the delivery of environmental and social outcomes alongside technological innovation. Empirically, Tang et al. demonstrated a positive association between pilot smart city programs and manufacturing firms' ESG performance, mediated by green innovation and strengthened internal governance systems. The present expert survey corroborates this finding: academic and operator respondents consistently rated smart energy management and circular economy among the highest-priority infrastructure factors, indicating that sustainability-oriented infrastructure is perceived as a genuine source of competitive advantage—not merely a regulatory compliance burden.

This finding anchors the ESG and circular economy items in Block 2 of the questionnaire and informs the sustainability dimension of the study's contribution to the journal's scope.

2.2.6. Geographic Context: Differences Between Countries and Regions

The impact of smart city on enterprises differs significantly depending on the geographical context, level of economic development, the nature of institutions, and the cities' ability to mobilize resources.

In highly developed countries, smart city develops under conditions of already existing high informatization of the economy, well-functioning public institutions, and a high level of education. Under these conditions, smart city represents an incremental improvement of the system—enhancing efficiency where it already functions. In rapidly growing countries, smart city is more often implemented as a transformative solution—a complete change in the way the city operates. In these contexts, the impact on enterprises can be dramatically greater, as firms transition from a low to a high level of digitalization. In Central and Eastern European countries, in turn, smart city develops under intermediate conditions—building upon an already established level of informatization, but still having significant reserves in public administration efficiency and business readiness for transformation [63,64].

This contextual specificity justifies the Polish–CEE focus of the expert sample and frames the study's contribution as filling a regional gap in the predominantly East-Asian empirical literature.

2.2.7. The Role of Public Policy

The impact of smart city on enterprises is largely conditioned by the role of public policy. Cities that adopt a strategy of opening public data, supporting innovation through public procurement and creating regulatory frameworks conducive to experimentation, achieve a significantly greater effect on the business ecosystem than cities that invest solely in technical infrastructure. Public–Private Partnerships (PPPs) constitute a key mechanism for mobilizing the resources and competencies of both sectors. The public sector contributes access to data, regulations, and funding; the private sector—technologies, efficiency orientation, and the ability to scale solutions. Cities that can effectively structure such partnerships can accelerate the impact of smart city on enterprises [65–68].

From the perspective of public administration theory, the transformation of city governance toward a smart city model follows the trajectory initiated by NPM reforms, which shifted the focus from procedural compliance to outcomes and citizen value. However, more recent scholarship emphasizes that the smart city also transcends NPM: where NPM prioritized market mechanisms and outsourcing, smart city governance relies on collaborative networks, co-creation with citizens and enterprises, and the use of digital platforms to integrate multiple stakeholders. Local public administrations thus occupy a dual role—as regulators setting the rules of the urban ecosystem, and as platform orchestrators that curate data, infrastructure, and institutional conditions in which enterprises can develop. This governance dimension is reflected in the expert survey results of the present study: the high ratings assigned to open data, e-government services, and Public–Private Partnerships by academic and operator respondents confirm that governance instruments are perceived as no less important than technological ones.

This governance rationale is directly reflected in the survey design: Blocks 3 and 4 of the questionnaire contain twelve governance and ecosystem items, whose relative importance compared to technological variables constitutes one of the central empirical questions addressed in Section 4.2.

2.2.8. Integrated Theoretical Framework and Research Hypotheses

The literature reviewed in Sections 2.2.1–2.2.7 draws on three complementary theoretical traditions that, taken together, provide the conceptual architecture for the present study.

- Innovation Ecosystem Theory conceptualizes the smart city as an adaptive, multi-actor system in which knowledge spillovers, complementarity between infrastructure layers, and co-creation between enterprises, universities, and public actors generate conditions for innovation and enterprise development. The value of smart city investment is not captured by any single actor but emerges from the density of interconnections across technological, institutional, and human capital layers [69]. In this framework, the role of governance instruments—open data, e-government platforms, and Public–Private Partnerships—is not secondary to technology; it is constitutive of the ecosystem's capacity to generate enterprise value [55].
- Transaction Cost Theory explains the microeconomic mechanism through which smart cities affect firms directly: digital infrastructure dramatically lowers the costs of information search, contract negotiation, and partner monitoring, thereby expanding the viable range of market exchanges—particularly for SMEs that cannot afford to maintain internal intelligence systems [70]. This mechanism predicts that technology providers, whose core value proposition lies in discrete solution sales, will assign sys-

tematically lower importance to institutional and systemic factors than firms directly embedded in urban operational processes.

- Absorptive Capacity Theory introduces the firm-level condition that mediates how much value any given enterprise can extract from the smart city ecosystem. Enterprises with higher absorptive capacity—larger R&D budgets, more qualified employees, stronger university linkages—systematically benefit more from the same urban infrastructure than firms with lower absorptive capacity [71]. This theory predicts systematic heterogeneity in expert assessments: implementers and operators, whose roles demand deep organizational integration with smart city infrastructure, should develop greater sensitivity to sustainability and governance factors than providers focused on product-level technological performance.

The three theories operate at different levels of analysis (ecosystem, market exchange, and firm levels) but are mutually reinforcing: smart city creates the ecosystem conditions (Innovation Ecosystem Theory) and lowers coordination costs (Transaction Cost Theory), while the firm's capacity to benefit depends on its internal knowledge base (Absorptive Capacity Theory). Taken together, they generate the following testable predictions:

- H1—Technology as ecosystem infrastructure: Advanced digital technologies—IoT, AI/ML, 5G, Big Data, and Cloud platforms—are perceived as high-priority drivers of enterprise development across all expert groups, reflecting their universal role in reducing transaction costs and enabling knowledge flows regardless of stakeholder position.
- H2—Absorptive capacity differential (infrastructure and sustainability): Infrastructure and sustainability-oriented factors (smart energy management, circular economy, intelligent transport systems) are perceived as significantly more important by enterprise operators than by technology providers. Organizations that directly embed smart infrastructure in operational practice develop greater organizational absorptive capacity for recognizing its systemic value.
- H3—Systemic undervaluation of governance instruments by market actors: Smart governance and ecosystem support instruments (open data, e-government, PPP, startup programs, R&D investments) are perceived as most important by academic experts and significantly less important by technology providers. Academics, who analyze the systemic logic of smart cities rather than immediate commercial returns, are theoretically predicted to be more attuned to institutional and collective-action conditions for enterprise development.
- H4—Absorptive capacity–ecosystem nexus: Human capital factors (STEM education, talent attraction, university collaboration, reskilling) are positively and strongly correlated with governance and ecosystem support factors, reflecting the theoretical co-constitution of knowledge-capital investment and open institutional infrastructure.

H1, H2, and H3 are tested using the Kruskal–Wallis H-test with post hoc multiple comparison tests and ordinal eta-squared effect sizes. H4 is tested using Spearman rank correlation analysis. The results are presented in Section 4.2.

In summary, the smart city concept today represents one of the most important directions of urban development worldwide. In the context of enterprises, smart cities create new business opportunities, mechanisms supporting innovativeness, and digital infrastructure that fundamentally changes the way firms operate in the urban environment, as well as the entities responsible for developing and implementing smart solutions in urban areas.

Despite the growing body of empirical evidence, several gaps in the literature remain. First, most quantitative studies focus on the macroeconomic level (urban or regional) or on listed companies, while research capturing the micro-level perceptions of diverse expert groups—practitioners, academics, and administrators—is sparse. Second,

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the European, and in particular Central and Eastern European, institutional context is underrepresented in comparative smart city research. Third, existing studies rarely integrate all five dimensions of smart city (technology, infrastructure, governance, ecosystem, and human capital) into a single analytical framework. The present study is designed to address these three gaps simultaneously.

3. Materials and Methods

The main objective of the study is to assess the potential impact of smart city on enterprise development.

With regard to the potential stimulation of enterprise development, aspects of the design, implementation, and management of infrastructure and software within smart city solutions will be analyzed, along with a range of technological, infrastructural, innovation-related, human capital, and administrative factors (included in the expert survey). The study employed various methods depending on the phase (preparation, implementation, and results analysis). Below is a description along with an indication of their application at individual stages of the study.

Research preparation phase

The authors formulated the following research problems:

- Q1: What are the market trends in the creation and implementation of smart city solutions?
- Q2: How can smart city solutions influence enterprise development?
- Q3: Which technological, infrastructural, administrative, innovation-related, legal, human capital, and sectoral factors can most strongly influence enterprise development (in the opinion of experts)?

Desk research is a research method involving the analysis of already existing sources of information. This process encompasses their systematic collection, critical verification, and appropriate elaboration, which allows for the formulation of reliable conclusions regarding the subject under investigation [72,73]. This method was used in developing the study assumptions and preparing the expert questionnaire.

Research implementation phase

The expert survey involves collecting research material using a developed questionnaire form by obtaining responses from study participants selected based on defined criteria. The expert survey constitutes a special type of research method, as it draws on the knowledge and ingenuity of individuals who are experts in a given field. The questions contained in the expert survey are not limited solely to facts or attitudes toward them, but also include attempts to explain and predict them. It is assumed that professionally qualified respondents possessing expert knowledge can propose interesting analytical conclusions. Thanks to their professional knowledge and "reality-based imagination," they can also create valuable (realistic) forecasts regarding the development of situations in a specific area of economic and social reality [74–76].

The survey was conducted from 7 October to 12 December 2025. Experts for the survey were selected based on purposive sampling, ensuring high quality and reliability of the study. The group consisted of academics, business representatives, and public administration officials, with a minimum of 7–10 years of professional experience in fields directly related to smart city, digital transformation, and business innovation. Business experts held managerial positions in enterprises, with proven experience in implementing smart city technologies. Administration representatives were employees of cities and government institutions responsible for smart city strategy, digital transformation, and innovation policy. A total of 54 experts participated in the study.

Experts were recruited via three independent institutional channels: university research networks, industry associations affiliated with the smart city and digital transformation sector, and municipal smart city units. No respondent was affiliated with the research team. This procedure—purposive (criterion-based) sampling—maximizes informational content per respondent, but does not produce a statistically representative sample; findings accordingly represent structured expert judgements rather than population-level frequency estimates. The group of public administration representatives (C2, $N = 2$) was excluded from inferential analysis due to insufficient group size for reliable statistical comparison. This exclusion reduces the multi-stakeholder completeness of the study and should be addressed in future replications through targeted recruitment of a minimum of 10–15 administrative respondents. Group B2 ($N = 7$) was retained in analyses; results for this subgroup should be treated as indicative rather than conclusive given the limited statistical power associated with this group size.

The total sample size of 54 experts is consistent with established standards for purposive expert surveys in smart city and urban innovation research, where sample sizes of 30–60 participants are widely accepted when respondents are selected on the basis of demonstrated expertise and institutional diversity rather than random probability. The key quality criterion in purposive sampling is the informational density of each response, not sample volume per se: each participant in this study holds a minimum of 7–10 years of domain-specific experience, and the three institutional channels of recruitment (academia, industry, administration) ensure multi-perspective coverage of the phenomenon. The use of nonparametric statistical methods (Kruskal–Wallis, Spearman correlation) is explicitly appropriate for this sample size and measurement scale, as these methods do not require large samples for valid inference. Future studies should nonetheless seek to replicate findings with larger and more geographically diverse samples to strengthen generalizability.

The expert questionnaire, based on the conducted literature review, contained the following factors subject to assessment (each factor was evaluated using a Likert scale from 1 to 5):

- Technological innovations:
  - Internet of Things (IoT);
  - Artificial Intelligence (AI) and Machine Learning (ML);
  - 5G Network;
  - Big Data;
  - Business process automation;
  - Digital platforms and cloud services;
  - Other, specify;
- Infrastructure:
  - Intelligent transport systems;
  - Technological infrastructure (broadband and charging stations for electric vehicles);
  - Smart energy management systems;
  - Circular economy (as a systemic solution for infrastructure);
  - Digital twins;
  - Other, specify;
- Smart governance:
  - Open Data platforms;
  - E-government services;
  - Digital participation tools;
  - Other, specify;
- Innovation ecosystem and regulatory/policy support:
  - Programs supporting the development of startups and innovative enterprises;
  - Technology clusters;

- Investments in scientific research and technological development;
- Business networking;
- Participation in projects implementing smart city solutions and technologies;
- Tax incentives and grants (financial incentives for companies applying sustainable solutions);
- Public-Private Partnerships (PPP) (in the implementation of smart city projects)
- Regulatory sandbox
- Availability of venture capital and innovation funds
- Urban crowdfunding platforms
- Other, specify

- Human capital:
  - Programs for attracting and retaining talent;
  - STEM education and digital literacy programs;
  - Professional reskilling/upskilling programs;
  - Collaboration with higher education institutions;
  - Other, specify.

Market analysis constitutes the totality of activities that allow for the interpretation of the situation in a given sector. The study reveals the value, potential related to the scale of demand growth, and fundamental trends. It is a systematic process of collecting, processing, and interpreting data about the business environment [77]. In the present study, market analysis refers to smart city solutions, technologies, and infrastructure.

Results analysis phase

The analysis of the results employed descriptive statistics (arithmetic mean, median, standard deviation, quartiles) and inferential methods. Between-group differences were tested using the Kruskal–Wallis H-test—a nonparametric equivalent of one-way ANOVA appropriate for ordinal data and unequal group sizes—complemented by post hoc multiple comparison tests to identify significantly differing pairs. Relationships between variables were assessed using Spearman's rank correlation coefficient (ρ), chosen for its robustness to non-normal distributions and the ordinal nature of the Likert-scale data. All analyses were performed in Statistica 13.1 at a significance level of α = 0.05. Nonparametric methods were adopted given the ordinal measurement scale, the inequality of group sizes, and the relatively small size of the smallest subgroup [78,79].

All statistical analyses were conducted using the Statistica 13.1 software package. In all tests, a statistical significance level of α = 0.05 was adopted. Due to the nature of the collected data, nonparametric methods were applied. Expert assessments were made on a five-point Likert scale, which is ordinal rather than quantitative in nature. This means that intervals between successive scale values cannot be treated as equal, which precludes the use of classical parametric methods based on means and the assumption of normal distribution. Additionally, the sizes of individual expert groups were unequal, and the smallest group was relatively small, which also argued for the application of nonparametric methods robust to violations of assumptions about data distribution.

To quantify the magnitude of between-group differences identified by the Kruskal–Wallis test, ordinal eta-squared (η^2_H) was calculated for each variable using the formula [80]:

$$\eta^2_H = \frac{H - k + 1}{N - k}$$

where H is the Kruskal–Wallis test statistic, k is the number of groups (k = 3), and N is the total number of observations (N = 52). Effect sizes are interpreted as small ($\eta^2_H < 0.06$), moderate ($0.06 \leq \eta^2_H < 0.14$), and large ($\eta^2_H \geq 0.14$) following conventional thresholds [80].

The research is conducted from the perspective of Polish experts, but with a general perspective on the functioning of smart cities in the context of their potential to influence business development.

The scheme of the research process is illustrated in Figure 1.

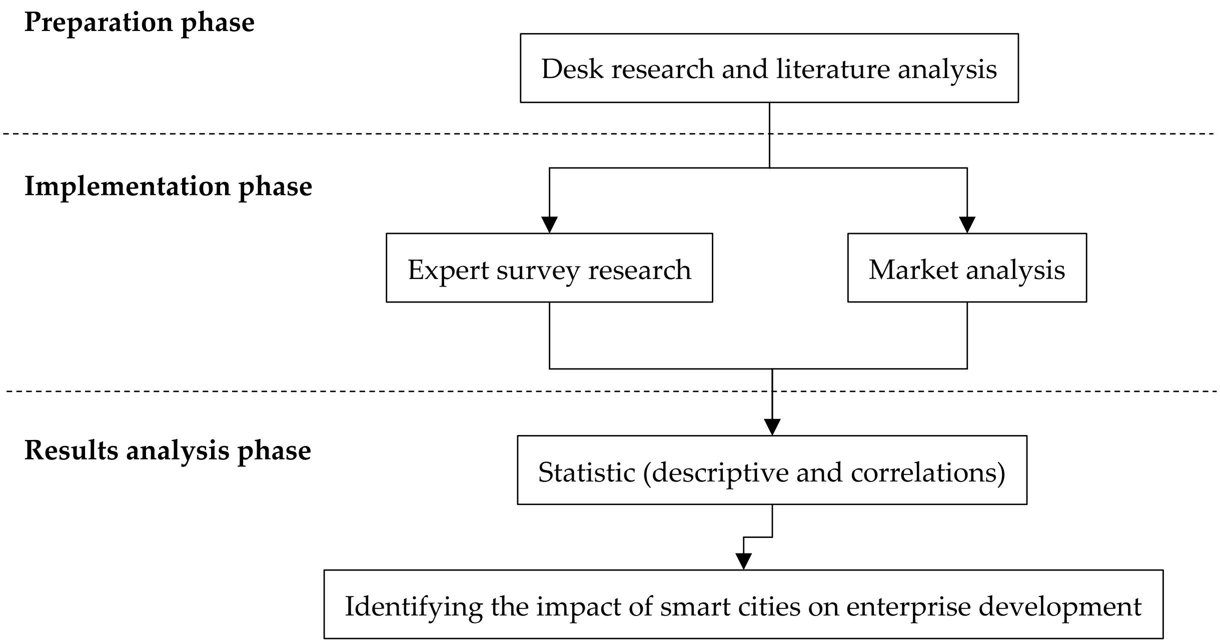


Figure 1. The scheme of the author's research. Source: Own study.

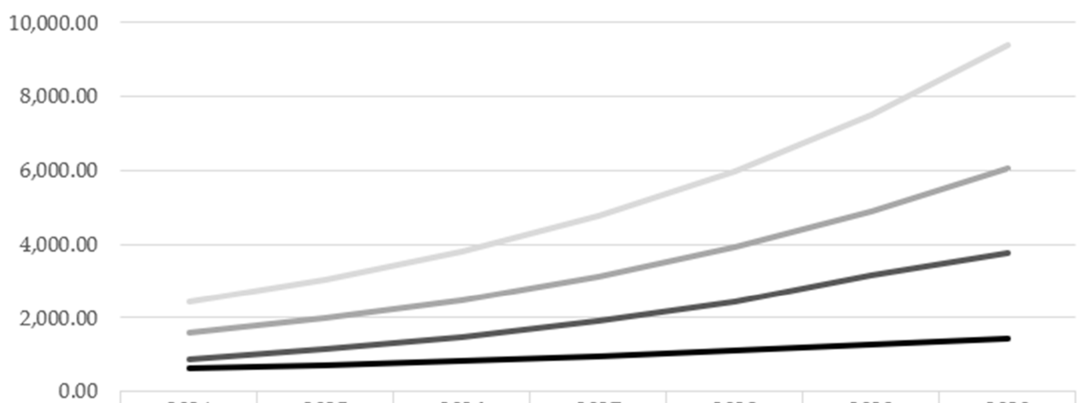
4. Results

4.1. The Potential of Smart Cities to Stimulate Business Development

The smart city market is experiencing dynamic growth driven by increasing urbanization, government initiatives, and technological advancement. Based on several industry reports, the value of the smart city market in 2024 ranges from USD 615.70 billion (Markets and Markets) to USD 2431.35 billion (Industry ARC), with an average of USD 1379.43 billion. By 2030, forecasts indicate growth to levels ranging from USD 1445.60 billion to USD 9409.24 billion, with an average of USD 5168.43 billion (Figure 2).

The discrepancies in forecasts result from differences in the definition of the smart city market and the scope of analyzed components. Allied Market Research adopts a broader definition, encompassing smart infrastructure, governance, energy, mobility, and healthcare, which results in a baseline value of USD 648.36 billion in 2020 and a forecast of USD 6061 billion in 2030 at a CAGR of 25.2%. Grand View Research focuses more on application segments, estimating the market in 2024 at USD 877.6 billion with the highest CAGR of 29.4% through 2030.

Market trends bear direct relevance to the enterprise development mechanisms identified in the literature review. First, the documented shift from product sales to outcome-based service contracts and SaaS platforms reflects the transaction cost reduction mechanism: as cities become data-rich environments, the cost of specifying, monitoring, and enforcing service contracts declines, enabling new forms of public–private value co-creation. Second, the rapid expansion of smart energy, environmental monitoring, and digital twin segments confirms that investment flows are concentrating precisely in the infrastructure and sustainability domains where transaction cost reduction and ecosystem complementarity are theoretically most operative. Third, the fastest-growing segment—smart transportation (~33% CAGR, 2025–2030)—generates demand for data integration and operational optimization capabilities that are fundamental to the technological and infrastructural dimensions of smart city development analyzed in this study. Taken together, these trends indicate that the smart city market is not growing uniformly—it is accelerating most rapidly in the segments most closely tied to the governance, data infrastructure, and human capital conditions that the literature identifies as key enablers of enterprise development. Enterprises seeking to leverage smart city development should therefore concentrate on these convergence zones between market growth and institutional ecosystem quality.



	2024	2025	2026	2027	2028	2029	2030
Allied Market Research	1593.07	1994.52	2497.14	3126.41	3914.27	4900.67	6061.00
Grand View Research	877.60	1135.61	1469.49	1901.51	2460.56	3183.96	3757.90
Industry ARC	2431.35	3046.49	3817.25	4783.01	5993.11	7509.37	9409.24
Markets and Markets	615.70	711.75	822.78	951.14	1099.51	1271.04	1445.60

Figure 2. Analysis of the smart city market value in 2024–2030 [USD billion]. Source: Own study based on [81–84].

4.2. Analysis of the Expert Survey Results

The expert survey was conducted from 7 October to 12 December 2025. A total of 54 experts participated in the study, constituting the following groups:

- A: Researchers, academics (*N* = 28, share in structure: 53.85%);
- B1: Business representatives from the smart city solutions industry (technology and systems providers) (*N* = 17, share in structure: 32.69%);
- B2: Business representatives implementing solutions (infrastructure operators, developers, design firms) (*N* = 7, share in structure: 13.46%);
- C2: Administration representatives (*N* = 2; however, this group was excluded from further analyses due to its low size).

The analysis of responses was divided into the following blocks: technological innovations, infrastructure, smart governance, innovation ecosystem and support, and human capital. Individual factors were coded (Appendix A).

Technological Innovations

The analysis of expert responses regarding factors from the technological innovations category is presented in Table 1.

In the Technological Innovations block, statistically significant differences in ratings between expert groups were found for all analyzed variables. In each case, the Kruskal-Wallis test indicated a divergence of opinions among academics, business representatives from the smart city solutions sector (technology and system providers), and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms).

Table 1. Block 1: Technological innovations (scale 1–5). Source: Own elaboration.

Variables	Group	M	SD	Me	Min	Max	Q1	Q3	Kruskal–Wallis Test
IoT	A	4.71	0.46	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 8.71$ $p = 0.013$
	B1	4.53	0.51	5.00	4.00	5.00	4.00	5.00	
	B2	4.00	0.58	4.00	3.00	5.00	4.00	4.00	
AI_ML	A	4.64	0.49	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 12.48$ $p = 0.0019$
	B1	4.59	0.51	5.00	4.00	5.00	4.00	5.00	
	B2	3.71	0.49	4.00	3.00	4.00	3.00	4.00	
5G	A	3.82	0.48	4.00	3.00	5.00	4.00	4.00	$H(2, N = 52) = 15.65$ $p = 0.0004$
	B1	4.47	0.51	4.00	4.00	5.00	4.00	5.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	
BIGDATA	A	4.61	0.50	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 12.16$ $p = 0.0023$
	B1	4.35	0.49	4.00	4.00	5.00	4.00	5.00	
	B2	3.71	0.49	4.00	3.00	4.00	3.00	4.00	
AUTOM	A	3.93	0.38	4.00	3.00	5.00	4.00	4.00	$H(2, N = 52) = 23.76$ $p < 0.00001$
	B1	4.35	0.49	4.00	4.00	5.00	4.00	5.00	
	B2	3.14	0.38	3.00	3.00	4.00	3.00	3.00	
CLOUD	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 13.02$ $p = 0.0015$
	B1	4.76	0.44	5.00	4.00	5.00	5.00	5.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	

Group: A—academics; B1—business representatives from the smart city solutions industry (technology and systems providers); B2—business representatives implementing solutions (infrastructure operators, developers, design firms). M—arithmetic mean; SD—standard deviation; Me—median; Q1—first quartile; Q3—third quartile.

For the IoT—Internet of Things variable, the Kruskal-Wallis test revealed significant differences $H(2, N = 52) = 8.71$, $p = 0.013$. The highest ratings were assigned by academics (M = 4.71, Me = 5.00, Q1 = 4.00, Q3 = 5.00), slightly lower by business representatives from the smart city solutions sector (technology and system providers) (M = 4.53, Me = 5.00, Q1 = 4.00, Q3 = 5.00), and noticeably lower by business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) (M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00). Multiple comparison tests revealed a significant difference between academics and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.035$, indicating that this group rated the importance of IoT significantly lower than academics.

For the AI and Machine Learning variable, significant differences were also found $H(2, N = 52) = 12.48$, $p = 0.0019$. Academics (M = 4.64, Me = 5.00, Q1 = 4.00, Q3 = 5.00) and business representatives from the smart city solutions sector (technology and system providers) (M = 4.59, Me = 5.00, Q1 = 4.00, Q3 = 5.00) rated the importance of this technology very highly and at a similar level, whereas business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) rated it markedly lower (M = 3.71, Me = 4.00, Q1 = 3.00, Q3 = 4.00). Multiple comparison tests confirmed significant differences between academics and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.007$, and between business representatives from the smart city solutions sector (technology and system providers) and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.023$, indicating that this group rates the impact of AI and Machine Learning on enterprise development significantly lower than the other groups.

Regarding the 5G Network variable, the Kruskal-Wallis test revealed significant differences $H(2, N = 52) = 15.65$, $p = 0.0004$. The highest ratings were assigned by business representatives from the smart city solutions sector (technology and system providers) (M = 4.47, Me = 4.00, Q1 = 4.00, Q3 = 5.00), lower by business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) (M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00), and the lowest by academics (M = 3.82, Me = 4.00, Q1 = 4.00, Q3 = 4.00). Multiple comparison tests revealed a significant difference between academics and business representatives from the smart city solutions sector (technology and system providers) $p = 0.0052$, indicating that academics rated the importance of 5G networks significantly lower than this group.

For the Big Data variable, significant differences were recorded $H(2, N = 52) = 12.16$, $p = 0.0023$. The highest ratings were again assigned by academics (M = 4.61, Me = 5.00, Q1 = 4.00, Q3 = 5.00), lower by business representatives from the smart city solutions sector (technology and system providers) (M = 4.35, Me = 4.00, Q1 = 4.00, Q3 = 5.00), and the lowest by business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) (M = 3.71, Me = 4.00, Q1 = 3.00, Q3 = 4.00). Multiple comparison tests revealed a significant difference between academics and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.0077$, indicating that this group rates the importance of Big Data significantly lower than academics.

For the Business Process Automation variable, the differences were the strongest $H(2, N = 52) = 23.76$, $p < 0.00001$. The highest ratings were assigned by business representatives from the smart city solutions sector (technology and system providers) (M = 4.35, Me = 4.00, Q1 = 4.00, Q3 = 5.00), lower by academics (M = 3.93, Me = 4.00, Q1 = 4.00, Q3 = 4.00), and decisively the lowest by business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) (M = 3.14, Me = 3.00, Q1 = 3.00, Q3 = 3.00). Multiple comparison tests revealed significant differences between academics and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.018$, and between business representatives from the smart city solutions sector (technology and system providers) and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.000$, indicating that this group rates the importance of automation significantly lower than the other groups.

For the Digital Platforms and Cloud Services variable, significant differences were also found $H(2, N = 52) = 13.02$, $p = 0.0015$. The highest ratings were assigned by business representatives from the smart city solutions sector (technology and system providers) (M = 4.76, Me = 5.00, Q1 = 5.00, Q3 = 5.00) and academics (M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00), while lower ratings were given by business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) (M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00). Multiple comparison tests revealed significant differences between academics and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.018$, and between business representatives from the smart city solutions sector (technology and system providers) and business representatives involved in implementing solutions (infrastructure operators, developers, and design firms) $p = 0.010$, indicating that this group rates the importance of cloud services significantly lower than the other expert groups.

Infrastructure

The analysis of expert responses regarding factors from the infrastructure category is presented in Table 2.

In the infrastructure block, very strong and statistically significant differences in assessments between expert groups were found for all analyzed variables. In all cases, the Kruskal–Wallis test indicated clear differentiation of opinions between academics, business representatives from the smart city solutions industry (technology and systems providers), and business representatives implementing solutions (infrastructure operators, developers, design firms).

Table 2. Block 2: Infrastructure (scale 1–5). Source: Own elaboration.

Variables	Group	M	SD	Me	Min	Max	Q1	Q3	Kruskal–Wallis Test
ITS	A	3.89	0.31	4.00	3.00	4.00	4.00	4.00	H(2, *N* = 52) = 33.23 *p* < 0.00001
	B1	2.94	0.83	3.00	2.00	5.00	2.00	3.00	
	B2	5.00	0.00	5.00	5.00	5.00	5.00	5.00	
INFRA_TECH	A	2.93	0.26	3.00	2.00	3.00	3.00	3.00	H(2, *N* = 52) = 45.56 *p* < 0.00001
	B1	4.35	0.49	4.00	4.00	5.00	4.00	5.00	
	B2	4.14	0.38	4.00	4.00	5.00	4.00	4.00	
ENERGY_SMART	A	4.00	0.00	4.00	4.00	4.00	4.00	4.00	H(2, *N* = 52) = 44.16 *p* < 0.00001
	B1	2.71	0.59	3.00	2.00	4.00	2.00	3.00	
	B2	4.71	0.49	5.00	4.00	5.00	4.00	5.00	
CIRC_ECON	A	3.75	0.44	4.00	3.00	4.00	3.50	4.00	H(2, *N* = 52) = 40.55 *p* < 0.00001
	B1	1.94	0.43	2.00	1.00	3.00	2.00	2.00	
	B2	4.29	0.49	4.00	4.00	5.00	4.00	5.00	
DIGITAL_TWIN	A	4.46	0.51	4.00	4.00	5.00	4.00	5.00	H(2, *N* = 52) = 20.52 *p* < 0.00001
	B1	3.53	0.62	3.00	3.00	5.00	3.00	4.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	

Group: A—academics; B1—business representatives from the smart city solutions industry (technology and systems providers); B2—business representatives implementing solutions (infrastructure operators, developers, design firms). M—arithmetic mean; SD—standard deviation; Me—median; Q1—first quartile; Q3—third quartile.

For the variable intelligent transport systems, the Kruskal–Wallis test showed very strong differences, H(2, N = 52) = 33.23, p < 0.00001. The highest ratings were given by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 5.00, Me = 5.00, Q1 = 5.00, Q3 = 5.00. Lower ratings were given by academics, M = 3.89, Me = 4.00, Q1 = 4.00, Q3 = 4.00, while decidedly the lowest ratings were given by business representatives from the smart city solutions industry (technology and systems providers), M = 2.94, Me = 3.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, p = 0.0028, between academics and business representatives implementing solutions, p = 0.0067, and between the two business groups, p = 0.0000, which means that all three groups differed significantly in their assessment of this variable.

For the variable technological infrastructure, the Kruskal–Wallis test showed the strongest differences, H(2, N = 52) = 45.56, p < 0.00001. The lowest ratings were given by academics, M = 2.93, Me = 3.00, Q1 = 3.00, Q3 = 3.00, while significantly higher and similar ratings were given by business representatives from the smart city solutions industry, M = 4.35, Me = 4.00, Q1 = 4.00, Q3 = 5.00, and business representatives implementing solutions, M = 4.14, Me = 4.00, Q1 = 4.00, Q3 = 4.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, p = 0.0000, and between academics and business representatives implementing solutions, p = 0.0005, with no significant differences between the two business groups, p = 1.0000. This means that academics rate the importance of technological infrastructure significantly lower than both business groups.

For the variable smart energy management, the differences were very pronounced, H(2, N = 52) = 44.16, p < 0.00001. The highest ratings were given by business representatives implementing solutions, M = 4.71, Me = 5.00, Q1 = 4.00, Q3 = 5.00, slightly lower by academics, M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, while decidedly the lowest ratings were given by business representatives from the smart city solutions industry, M = 2.71, Me = 3.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, p = 0.000006, and between the two business groups, p = 0.000001, with no significant difference between academics and business representatives implementing solutions, p = 0.134039.

This means that business representatives from the smart city solutions industry rate the importance of smart energy management significantly lower than the other groups.

For the variable circular economy, very strong differences were also recorded, H(2, N = 52) = 40.55, p < 0.00001. The highest ratings were given by business representatives implementing solutions, M = 4.29, Me = 4.00, Q1 = 4.00, Q3 = 5.00, slightly lower by academics, M = 3.75, Me = 4.00, Q1 = 3.50, Q3 = 4.00, while decidedly the lowest ratings were given by business representatives from the smart city solutions industry, M = 1.94, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, p = 0.000001, and between the two business groups, p = 0.000006, with no significant difference between academics and business representatives implementing solutions, p = 0.592980. This means that business representatives from the smart city solutions industry rate the importance of the circular economy significantly lower than the other groups.

For the variable digital twins, the Kruskal–Wallis test showed significant differences, H(2, N = 52) = 20.52, p < 0.00001. The highest ratings were given by academics, M = 4.46, Me = 4.00, Q1 = 4.00, Q3 = 5.00, lower ratings by business representatives implementing solutions, M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and the lowest ratings by business representatives from the smart city solutions industry, M = 3.53, Me = 3.00, Q1 = 3.00, Q3 = 4.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, p = 0.0002, with no significant differences between academics and business representatives implementing solutions, p = 0.3572, and between the two business groups, p = 0.5889. This means that business representatives from the smart city solutions industry rate the importance of digital twins significantly lower than academics.

Smart governance

The analysis of expert responses regarding factors from the smart governance category is presented in Table 3.

Table 3. Block 3: Smart governance (scale 1–5). Source: Own elaboration.

Variables	Group	M	SD	Me	Min	Max	Q1	Q3	Kruskal–Wallis Test
OPEN_DATA	A	4.71	0.46	5.00	4.00	5.00	4.00	5.00	H(2, N = 52) = 40.34 p < 0.00001
	B1	2.18	0.39	2.00	2.00	3.00	2.00	2.00	
	B2	4.14	0.38	4.00	4.00	5.00	4.00	4.00	
EGOV	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	H(2, N = 52) = 41.85 p < 0.00001
	B1	1.94	0.24	2.00	1.00	2.00	2.00	2.00	
	B2	3.86	0.38	4.00	3.00	4.00	4.00	4.00	
E_PARTICIP	A	4.32	0.48	4.00	4.00	5.00	4.00	5.00	H(2, N = 52) = 42.40 p < 0.00001
	B1	1.82	0.39	2.00	1.00	2.00	2.00	2.00	
	B2	3.29	0.49	3.00	3.00	4.00	3.00	4.00	

Group: A—academics; B1—business representatives from the smart city solutions industry (technology and systems providers); B2—business representatives implementing solutions (infrastructure operators, developers, design firms). M—arithmetic mean; SD—standard deviation; Me—median; Q1—first quartile; Q3—third quartile.

In the smart governance block, very strong and statistically significant differences in assessments between expert groups were found for all analyzed variables. In every case, the Kruskal–Wallis test indicated clear differentiation of opinions between academics, business representatives from the smart city solutions industry (technology and systems providers), and business representatives implementing solutions (infrastructure operators, developers, design firms).

For the variable open data, the Kruskal–Wallis test showed significant differences, H(2, N = 52) = 40.34, p < 0.00001. The highest ratings were given by academics, M = 4.71, Me = 5.00, Q1 = 4.00, Q3 = 5.00, slightly lower by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 4.14, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest ratings by business representatives from the smart city solutions industry (technology and systems providers), M = 2.18, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between business representatives from the smart city solutions industry and business representatives implementing solutions, $p = 0.025$, with no significant difference between academics and business representatives implementing solutions, $p = 0.355$. This means that business representatives from the smart city solutions industry rate the importance of open data significantly lower than the other groups.

For the variable E-government services, very strong differences were also found, H(2, N = 52) = 41.85, $p < 0.00001$. The highest ratings were given by academics, M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00, lower by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 3.86, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest ratings by business representatives from the smart city solutions industry (technology and systems providers), M = 1.94, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, $p < 0.0001$, with no significant differences between academics and business representatives implementing solutions, $p = 0.143$, or between the two business groups, $p = 0.059$. This means that business representatives from the smart city solutions industry rate the importance of e-government services significantly lower than academics.

For the variable digital participation tools, the differences were equally strong, H(2, N = 52) = 42.40, $p < 0.00001$. The highest ratings were given by academics, M = 4.32, Me = 4.00, Q1 = 4.00, Q3 = 5.00, lower by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 3.29, Me = 3.00, Q1 = 3.00, Q3 = 4.00, and the lowest ratings by business representatives from the smart city solutions industry (technology and systems providers), M = 1.82, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, $p < 0.0001$, with no significant differences between academics and business representatives implementing solutions, $p = 0.083$, or between the two business groups, $p = 0.092$. This means that business representatives from the smart city solutions industry rate the importance of digital participation tools significantly lower than academics.

Innovation ecosystem and support

The analysis of expert responses regarding factors from the innovation ecosystem and support category is presented in Table 4.

In the innovation ecosystem and support block, in most cases, very strong and statistically significant differences in assessments between expert groups were found. Only for the variable business networking were no significant differences between groups observed. For the variable startup support programs, the Kruskal–Wallis test showed significant differences, H(2, N = 52) = 39.58, $p < 0.00001$. The highest ratings were given by academics, M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00, and by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 4.29, Me = 4.00, Q1 = 4.00, Q3 = 5.00, while significantly lower ratings were given by business representatives from the smart city solutions industry (technology and systems providers), M = 3.00, Me = 3.00, Q1 = 3.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between business representatives from the smart city solutions industry and business representatives implementing solutions, $p = 0.008$, with no significant difference between academics and business representatives implementing solutions, $p = 0.849$.

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Table 4. Block 4: Innovation ecosystem and support (scale 1–5). Source: Own elaboration.

Variables	Group	M	SD	Me	Min	Max	Q1	Q3	Kruskal–Wallis Test
STARTUP_PROG	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 39.58$ $p < 0.00001$
	B1	3.00	0.00	3.00	3.00	3.00	3.00	3.00	
	B2	4.29	0.49	4.00	4.00	5.00	4.00	5.00	
TECH_CLUSTER	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 36.67$ $p < 0.00001$
	B1	3.06	0.24	3.00	3.00	4.00	3.00	3.00	
	B2	4.14	0.69	4.00	3.00	5.00	4.00	5.00	
RND_INV	A	4.71	0.46	5.00	4.00	5.00	4.00	5.00	$H(2, N = 52) = 41.27$ $p < 0.00001$
	B1	2.65	0.49	3.00	2.00	3.00	2.00	3.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	
BUS_NETWORK	A	3.68	0.48	4.00	3.00	4.00	3.00	4.00	$H(2, N = 52) = 4.90$ $p = 0.086$
	B1	3.53	0.51	4.00	3.00	4.00	3.00	4.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	
SC_PROJECTS	A	3.71	0.46	4.00	3.00	4.00	3.00	4.00	$H(2, N = 52) = 14.46$ $p = 0.0007$
	B1	4.24	0.44	4.00	4.00	5.00	4.00	4.00	
	B2	3.43	0.53	3.00	3.00	4.00	3.00	4.00	
TAX_SUBSIDY	A	3.57	0.63	4.00	2.00	4.00	3.00	4.00	$H(2, N = 52) = 35.78$ $p < 0.00001$
	B1	1.35	0.49	1.00	1.00	2.00	1.00	2.00	
	B2	3.43	0.53	3.00	3.00	4.00	3.00	4.00	
PPP	A	3.71	0.46	4.00	3.00	4.00	3.00	4.00	$H(2, N = 52) = 41.05$ $p < 0.00001$
	B1	1.88	0.33	2.00	1.00	2.00	2.00	2.00	
	B2	4.14	0.38	4.00	4.00	5.00	4.00	4.00	
SANDBOX	A	4.00	0.00	4.00	4.00	4.00	4.00	4.00	$H(2, N = 52) = 43.61$ $p < 0.00001$
	B1	3.12	0.33	3.00	3.00	4.00	3.00	3.00	
	B2	2.71	0.49	3.00	2.00	3.00	2.00	3.00	
VC_FUNDS	A	3.68	0.48	4.00	3.00	4.00	3.00	4.00	$H(2, N = 52) = 25.034$ $p < 0.00001$
	B1	4.12	0.33	4.00	4.00	5.00	4.00	4.00	
	B2	2.71	0.49	3.00	2.00	3.00	2.00	3.00	
CROWDFUND	A	2.68	0.48	3.00	2.00	3.00	2.00	3.00	$H(2, N = 52) = 34.27$ $p < 0.00001$
	B1	1.18	0.39	1.00	1.00	2.00	1.00	1.00	
	B2	2.57	0.53	3.00	2.00	3.00	2.00	3.00	

Group: A—academics; B1—business representatives from the smart city solutions industry (technology and systems providers); B2—business representatives implementing solutions (infrastructure operators, developers, design firms). M—arithmetic mean; SD—standard deviation; Me—median; Q1—first quartile; Q3—third quartile.

For the variable technology clusters, significant differences were also found, $H(2, N = 52) = 36.67$, $p < 0.00001$. The highest ratings were given by academics, M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00, lower by business representatives implementing solutions, M = 4.14, Me = 4.00, Q1 = 4.00, Q3 = 5.00, and significantly lower by business representatives from the smart city solutions industry, M = 3.06, Me = 3.00, Q1 = 3.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between business representatives from the smart city solutions industry and business representatives implementing solutions, $p = 0.032$.

For the variable R&D investments, significant differences were recorded, $H(2, N = 52) = 41.27$, $p < 0.00001$. The highest ratings were given by academics, M = 4.71, Me = 5.00, Q1 = 4.00, Q3 = 5.00, lower by business representatives implementing solutions, M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest by business representatives from the smart city solutions industry, M = 2.65, Me = 3.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, $p < 0.0001$.

For the variable business networking, no significant differences between groups were found, $H(2, N = 52) = 4.90$, $p = 0.086$. The ratings of all groups were similar, which indicates a comparable perception of the importance of this variable across all expert categories.

For the variable participation in smart city projects, significant differences were found, $H(2, N = 52) = 14.46$, $p = 0.0007$. The highest ratings were given by business representatives from the smart city solutions industry, M = 4.24, Me = 4.00, Q1 = 4.00, Q3 = 4.00, lower by academics, M = 3.71, Me = 4.00, Q1 = 3.00, Q3 = 4.00, and the lowest by business representatives implementing solutions, M = 3.43, Me = 3.00, Q1 = 3.00, Q3 = 4.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p = 0.039$, and between the two business groups, $p = 0.020$.

For the variable tax reliefs and grants, very strong differences were recorded, H(2, N = 52) = 35.78, $p < 0.00001$. The highest ratings were given by academics, M = 3.57, Me = 4.00, Q1 = 3.00, Q3 = 4.00, and by business representatives implementing solutions, M = 3.43, Me = 3.00, Q1 = 3.00, Q3 = 4.00, while decidedly the lowest ratings were given by business representatives from the smart city solutions industry, M = 1.35, Me = 1.00, Q1 = 1.00, Q3 = 2.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between the two business groups, $p = 0.0019$, with no significant difference between academics and business representatives implementing solutions, $p = 1.0000$.

For the variable Public–Private Partnerships, very strong differences were also found, H(2, N = 52) = 41.05, $p < 0.00001$. The highest ratings were given by business representatives implementing solutions, M = 4.14, Me = 4.00, Q1 = 4.00, Q3 = 4.00, slightly lower by academics, M = 3.71, Me = 4.00, Q1 = 3.00, Q3 = 4.00, and decidedly the lowest by business representatives from the smart city solutions industry, M = 1.88, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between the two business groups, $p < 0.0001$, with no significant difference between academics and business representatives implementing solutions, $p = 0.867984$.

For the variable regulatory sandbox, significant differences were recorded, H(2, N = 52) = 43.61, $p < 0.00001$. The highest ratings were given by academics, M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, lower by business representatives from the smart city solutions industry, M = 3.12, Me = 3.00, Q1 = 3.00, Q3 = 3.00, and the lowest by business representatives implementing solutions, M = 2.71, Me = 3.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between academics and business representatives implementing solutions, $p < 0.0001$, with no significant difference between the two business groups, $p = 1.000000$.

For the variable VC and innovation funds, significant differences were found, H(2, N = 52) = 25.03, $p < 0.00001$. The highest ratings were given by business representatives from the smart city solutions industry, M = 4.12, Me = 4.00, Q1 = 4.00, Q3 = 4.00, lower by academics, M = 3.68, Me = 4.00, Q1 = 3.00, Q3 = 4.00, and the lowest by business representatives implementing solutions, M = 2.71, Me = 3.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives implementing solutions, $p = 0.011$, and between the two business groups, $p < 0.0001$.

For the variable urban crowdfunding platforms, significant differences were also recorded, H(2, N = 52) = 34.27, $p < 0.00001$. The highest ratings were given by academics, M = 2.68, Me = 3.00, Q1 = 2.00, Q3 = 3.00, and by business representatives implementing solutions, M = 2.57, Me = 3.00, Q1 = 2.00, Q3 = 3.00, while decidedly the lowest ratings were given by business representatives from the smart city solutions industry, M = 1.18, Me = 1.00, Q1 = 1.00, Q3 = 1.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between the two business groups, $p = 0.0024$, with no significant difference between academics and business representatives implementing solutions, $p = 1.0000$.

Human capital

The analysis of expert responses regarding factors from the human capital category is presented in Table 5.

Table 5. Block 5: Human capital (scale 1–5). Source: Own elaboration.

Variables	Group	M	SD	Me	Min	Max	Q1	Q3	Kruskal–Wallis Test
TALENT_PROG	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	H(2, *N* = 52) = 40.62 *p* < 0.00001
	B1	2.47	0.51	2.00	2.00	3.00	2.00	3.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	
STEM_DIGLIT	A	4.75	0.44	5.00	4.00	5.00	4.50	5.00	H(2, *N* = 52) = 41.80 *p* < 0.00001
	B1	2.47	0.51	2.00	2.00	3.00	2.00	3.00	
	B2	4.00	0.00	4.00	4.00	4.00	4.00	4.00	
RESKILL	A	4.61	0.50	5.00	4.00	5.00	4.00	5.00	H(2, *N* = 52) = 41.85 *p* < 0.00001
	B1	1.94	0.24	2.00	1.00	2.00	2.00	2.00	
	B2	3.57	0.53	4.00	3.00	4.00	3.00	4.00	
UNIV_COOP	A	4.68	0.48	5.00	4.00	5.00	4.00	5.00	H(2, *N* = 52) = 40.23 *p* < 0.00001
	B1	2.06	0.24	2.00	2.00	3.00	2.00	2.00	
	B2	4.14	0.38	4.00	4.00	5.00	4.00	4.00	

Group: A—academics; B1—business representatives from the smart city solutions industry (technology and systems providers); B2—business representatives implementing solutions (infrastructure operators, developers, design firms). M—arithmetic mean; SD—standard deviation; Me—median; Q1—first quartile; Q3—third quartile.

In the human capital block, very strong and statistically significant differences in assessments between expert groups were found for all analyzed variables. In every case, the Kruskal–Wallis test indicated clear differentiation of opinions between academics, business representatives from the smart city solutions industry (technology and systems providers), and business representatives implementing solutions (infrastructure operators, developers, design firms).

For the variable talent attraction and retention programs, the Kruskal–Wallis test showed significant differences, H(2, N = 52) = 40.62, $p < 0.00001$. The highest ratings were given by academics, M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00, slightly lower by business representatives implementing solutions (infrastructure operators, developers, design firms), M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest by business representatives from the smart city solutions industry (technology and systems providers), M = 2.47, Me = 2.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between business representatives from the smart city solutions industry and business representatives implementing solutions, $p = 0.046$, with no significant difference between academics and business representatives implementing solutions, $p = 0.191$.

For the variable STEM education and digital literacy, significant differences were also found, H(2, N = 52) = 41.80, $p < 0.00001$. The highest ratings were given by academics, M = 4.75, Me = 5.00, Q1 = 4.50, Q3 = 5.00, lower by business representatives implementing solutions, M = 4.00, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest by business representatives from the smart city solutions industry, M = 2.47, Me = 2.00, Q1 = 2.00, Q3 = 3.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, $p < 0.0001$.

For the variable reskilling/upskilling programs, the differences were equally strong, H(2, N = 52) = 41.85, $p < 0.00001$. The highest ratings were given by academics, M = 4.61, Me = 5.00, Q1 = 4.00, Q3 = 5.00, lower by business representatives implementing solutions, M = 3.57, Me = 4.00, Q1 = 3.00, Q3 = 4.00, and the lowest by business representatives from the smart city solutions industry, M = 1.94, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed a significant difference between academics and business representatives from the smart city solutions industry, $p < 0.0001$.

For the variable cooperation with universities, significant differences were also recorded, $H(2, N = 52) = 40.23$, $p < 0.00001$. The highest ratings were given by academics, M = 4.68, Me = 5.00, Q1 = 4.00, Q3 = 5.00, slightly lower by business representatives implementing solutions, M = 4.14, Me = 4.00, Q1 = 4.00, Q3 = 4.00, and decidedly the lowest by business representatives from the smart city solutions industry, M = 2.06, Me = 2.00, Q1 = 2.00, Q3 = 2.00. Multiple comparison tests showed significant differences between academics and business representatives from the smart city solutions industry, $p < 0.0001$, and between business representatives from the smart city solutions industry and business representatives implementing solutions, $p = 0.020$, with no significant difference between academics and business representatives implementing solutions, $p = 0.430$.

In the Spearman rank correlation analysis (summary provided in Appendix B), only the strongest relationships were included, namely those for which the coefficient $\rho \geq 0.80$ or $\rho \leq -0.80$. These relationships form clear groups of links between variables and indicate the existence of coherent thematic areas in the experts' assessments. A very strong positive relationship occurs between AI and Machine Learning and Digital platforms and cloud services, $\rho = 0.85$, which means that as the assessed importance of AI and Machine Learning increases, the assessed importance of cloud services also increases. In the area of infrastructure and environment, a particularly strong relationship is observed between smart energy management and circular economy $\rho = 0.87$, which means that higher ratings of the importance of smart energy management are accompanied by higher ratings of the importance of the circular economy. An equally strong relationship exists between intelligent transport systems and smart energy management, $\rho = 0.80$, indicating that higher ratings of intelligent transport systems are associated with higher ratings of the importance of energy management.

A very distinct cluster of strong positive correlations concerns the area of smart governance, the support ecosystem, and human capital. Open data correlate very strongly with E-government services, $\rho = 0.96$, and with digital participation tools, $\rho = 0.89$, which means that as the assessed importance of open data increases, the assessed importance of e-government and digital participation also rises. E-government services are also very strongly linked with digital participation tools, $\rho = 0.90$. Open data show very strong positive relationships with startup support programs, $\rho = 0.93$, R&D investments, $\rho = 0.97$, talent attraction and retention programs, $\rho = 0.96$, STEM education and digital literacy, $\rho = 0.96$, and cooperation with universities, $\rho = 0.98$. This means that higher ratings of the importance of open data are associated with higher ratings of all these elements of the innovation ecosystem and human capital.

There are also very strong positive relationships between startup support programs and technology clusters, $\rho = 0.98$, which means that as the assessed importance of startup programs increases, the assessed importance of technology clusters also increases. Startup support programs are also very strongly linked with tax reliefs and grants, $\rho = 0.95$, and Public–Private Partnerships, $\rho = 0.92$. R&D investments correlate very strongly with talent attraction and retention programs, $\rho = 0.98$, STEM education and digital literacy, $\rho = 0.98$, and cooperation with universities, $\rho = 0.96$, indicating that higher ratings of the importance of R&D investments are accompanied by higher ratings of the importance of human capital development and cooperation with universities.

In the area of financing and support, very strong relationships occur between tax reliefs and grants and circular economy, $\rho = 0.89$, and also between tax reliefs and grants and urban crowdfunding platforms, $\rho = 0.89$. Public–Private Partnerships correlate very strongly with circular economy, $\rho = 0.93$, and with tax reliefs and grants, $\rho = 0.91$.

There are also very strong negative relationships. Technological infrastructure correlates very strongly and negatively with digital participation tools, $\rho = -0.82$, with R&D investments, $\rho = -0.80$, and with STEM education and digital literacy, $\rho = -0.81$. This means that as the assessed importance of technological infrastructure increases, the assessed importance of these elements of smart governance, the innovation ecosystem, and human capital decreases. A similarly strong negative relationship exists between technological infrastructure and regulatory sandbox, $\rho = -0.81$, indicating that higher ratings of the importance of infrastructure are associated with lower ratings of the importance of the regulatory sandbox.

Effect sizes for all Kruskal–Wallis tests are reported in Table 6.

Table 6. Effect sizes for Kruskal–Wallis tests across all survey blocks. Source: Own elaboration.

Variable	Block	H (df = 2, N = 52)	p	η^2_H	Interpretation
IoT	Technology	8.71	0.013	0.137	moderate
AI/ML	Technology	12.48	0.0019	0.214	large
5G network	Technology	15.65	0.0004	0.279	large
Big data	Technology	12.16	0.0023	0.207	large
Process automation	Technology	23.76	<0.00001	0.444	large
Cloud/digital platforms	Technology	13.02	0.0015	0.225	large
Intelligent transport (ITS)	Infrastructure	33.23	<0.00001	0.637	large
Tech. infrastructure	Infrastructure	45.56	<0.00001	0.889	large
Smart energy management	Infrastructure	44.16	<0.00001	0.860	large
Circular economy	Infrastructure	40.55	<0.00001	0.787	large
Digital twins	Infrastructure	20.52	<0.00001	0.378	large
Open data platforms	Governance	40.34	<0.00001	0.782	large
E-government services	Governance	41.85	<0.00001	0.813	large
Digital participation	Governance	42.40	<0.00001	0.824	large
Startup programs	Ecosystem	39.58	<0.00001	0.767	large
Technology clusters	Ecosystem	36.67	<0.00001	0.708	large
R&D investments	Ecosystem	41.27	<0.00001	0.801	large
Business networking	Ecosystem	4.90	0.086	0.059	small (NS)
SC project participation	Ecosystem	14.46	0.0007	0.254	large
Tax reliefs/grants	Ecosystem	35.78	<0.00001	0.689	large
PPP	Ecosystem	41.05	<0.00001	0.797	large
Regulatory sandbox	Ecosystem	43.61	<0.00001	0.849	large
VC/innovation funds	Ecosystem	25.03	<0.00001	0.470	large
Urban crowdfunding	Ecosystem	34.27	<0.00001	0.659	large
Talent attraction	Human capital	40.62	<0.00001	0.788	large
STEM education	Human capital	41.80	<0.00001	0.812	large
Reskilling/upskilling	Human capital	41.85	<0.00001	0.813	large
Univ. collaboration	Human capital	40.23	<0.00001	0.780	large

Thresholds: small η^2_H < 0.06; moderate $0.06 \leq \eta^2$_H < 0.14; large η^2_H ≥ 0.14. NS = not statistically significant ($p > 0.05$).

Referring to individual hypotheses:

- H1 predicts universal high ratings for technological variables across all groups;
- H2 predicts that infrastructure and sustainability factors will be rated more highly by operators (B2) than by technology providers (B1);
- H3 predicts that academic experts (A) will assign the highest ratings to governance and ecosystem instruments;
- H4 predicts strong positive Spearman correlations between human capital and governance/ecosystem factors.

Based on the analyses carried out, it is possible to develop a conceptual model of the impact of smart cities on the development of enterprises (Figure 3).

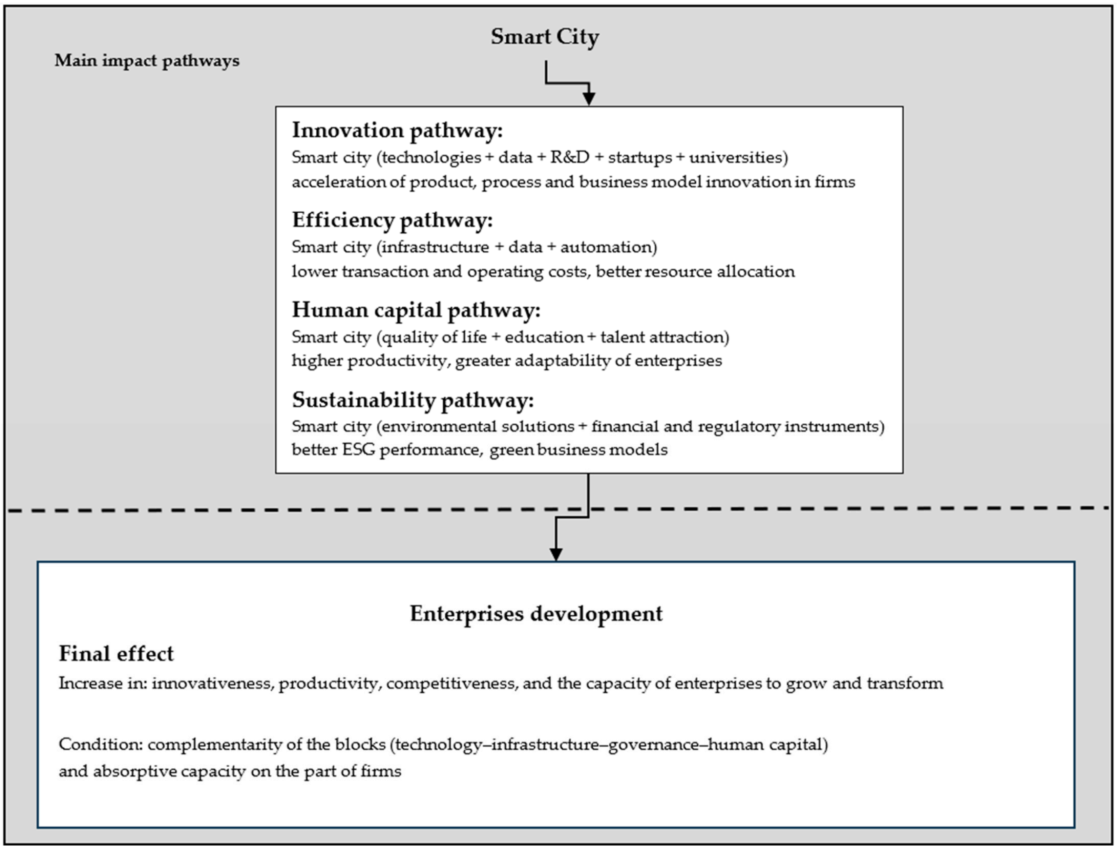

Figure 3. A conceptual model of the impact of smart cities on the development of enterprises. Source: Own study.

5. Discussion

Before interpreting the findings, it is important to clarify the epistemological status of the evidence. The expert survey produces structured professional judgments regarding perceived importance—not causal proof of smart city effects on firm-level outcomes. Causal inference would require longitudinal firm-level panel data with quasi-experimental identification. Therefore, the results should be interpreted in such a way that experts embedded in the smart city ecosystem perceive a specific factor as an important mechanism through which smart cities can influence business development, rather than as a direct reference that smart cities cause a specific outcome. Where external causal evidence is cited, it is explicitly attributed to those secondary-data studies.

The obtained results confirm that the smart city is perceived to act as a complex innovation ecosystem in which technologies, infrastructure, governance, and human capital jointly shape the conditions for enterprise development. This is consistent with ecosystem-based approaches in which a smart city is defined as an environment integrating physical infrastructure, a digital layer, and a capital of knowledge and relationships, constituting a natural context for entrepreneurship and innovation [55,56,85].

First, the high ratings of IoT, AI/ML, big data, and cloud computing by all experts, combined with differences in the perception of the role of infrastructure and governance, fit well with the findings of Jiang et al. [54] and Chen et al. [86], which show that the development of digital infrastructure reduces transaction costs, improves capital allocation, and increases productivity (TFP), particularly in the case of SMEs and private firms.

Second, the very clear differences between expert groups in their assessment of infrastructure (intelligent transport systems, smart energy management, circular economy, digital twins) confirm that infrastructure is perceived as a direct "carrier" of business opportunities—especially by operators and implementation companies. This is consistent with the view of the smart city as a "living laboratory" in which infrastructure becomes a platform for testing new service and product models [87]. At the same time, the lower ratings of some infrastructural and environmental solutions by technology providers suggest a gap between the perspective of entities selling solutions and those bearing the risk of their practical application—which corresponds to the observations of Abbate et al. [62] regarding the differentiated roles of actors in platform-based smart city models.

Third, the results for the smart governance and support ecosystem blocks (open data, e-government, digital participation tools, startup programs, clusters, R&D, PPPs, tax incentives, regulatory sandboxes, VC, crowdfunding) strongly resonate with the literature emphasizing the importance of public policies and institutional instruments for unlocking the potential of smart cities [88,89]. The very high ratings of open data, R&D, and support instruments by academics and operators, and at the same time consistently low ratings of these elements by technology providers, indicate that part of the market still perceives the smart city mainly through the lens of technology, while the literature highlights the key role of data, regulation, and public demand mechanisms in generating entrepreneurial opportunities [58,86].

Fourth, the very strong positive correlations between open data, R&D, startup programs, clusters, and variables related to human capital confirm the findings of studies in which the smart city is interpreted as an environment of intense knowledge spillovers and intergrowth (knowledge spillover theory of entrepreneurship) [58]. Our results indicate that experts see these elements as highly complementary: where the importance of open data and R&D increases, the importance of talent programs, STEM education, and cooperation with universities increases in parallel. This is consistent with the findings of Lv and Gao [62], who show that smart city development leads to higher employment in more productive sectors and increases demand for advanced skills.

Fifth, the results support the thesis about the role of smart cities in the sustainable development of enterprises. High ratings of smart energy management, the circular economy, and the links between these variables and financial instruments (tax incentives, grants, PPPs, crowdfunding) fit well with the findings of Tang et al. [1], who demonstrated a positive impact of pilot smart city programs on firms' ESG performance through green innovation and strengthened internal control systems. Our study suggests that experts—especially from academia and the implementation sector—see these elements not only as a regulatory dimension but also as a real source of competitive advantage and opportunities for cost- and environmentally oriented optimization of business operations.

An important observation is also the heterogeneity of assessments between expert groups, which reflects the differentiated distribution of benefits from smart city development described in the literature. Jiang et al. [54] and Tang et al. [1] show that SMEs and private firms benefit the most; in our study, it is precisely business representatives "close to infrastructure" (operators, developers, design firms) who assign the highest importance to many key factors, while technology providers are significantly more skeptical about the importance of governance instruments, human capital, and sustainability. This can be interpreted as a difference between firms that benefit from long-term urban transformation and entities focused on short-term solution sales.

Finally, the results must be interpreted in light of certain limitations: the expert nature of the sample, the dominance of the Polish perspective, and the lack of direct financial data on enterprises mean that the analysis is primarily perception-based. At the same time, it allows the findings to be situated within the broader body of empirical research [1,44,58,62] and points to specific areas in which further studies—based on firm-level panel data, inter-city comparisons, and sectoral analyses—can deepen our understanding of the mechanisms through which smart cities actually become catalysts for enterprise development.

6. Conclusions

The conducted research confirms that the smart city is perceived by the surveyed experts to act as a catalyst for enterprise development, provided that technology, infrastructure, smart governance, the innovation ecosystem, and human capital develop simultaneously. From a systemic perspective, the smart city creates a multi-dimensional ecosystem in which the digital data layer, advanced technologies (IoT, AI/ML, big data, cloud), spatial infrastructure, public policy instruments, and human competences jointly create an environment conducive to the emergence, growth, and transformation of enterprises.

The four research hypotheses derived from the integrated theoretical framework (Section 2.2.8) received the following empirical support. H1—that advanced digital technologies are universally perceived as high-priority drivers—received partial support: all six technological variables were rated highly overall, but significant between-group differences were recorded for all of them (H range 8.71–23.76; η^2_H 0.137–0.444), confirming that stakeholder position shapes even technology assessments. Notably, the single variable that did not produce significant between-group differences—business networking (H = 4.90, $p = 0.086$, η^2_H = 0.059)—emerged as the only consensual item, suggesting that interpersonal professional networks are perceived as a universally important, position-independent mechanism of enterprise development. H2 was strongly supported: smart energy management (η^2_H = 0.860) and circular economy (η^2_H = 0.787) showed the largest between-group gaps, with operators (B2) systematically exceeding technology providers (B1) by more than two scale points—consistent with the absorptive capacity differential predicted by theory. H3 was supported for all governance and ecosystem variables: academic experts assigned the highest ratings, technology providers the lowest, across the entirety of Blocks 3 and 4 (η^2_H range 0.659–0.849). H4 was very strongly supported: Spearman correlations between governance, R&D, and human capital variables uniformly exceeded *r* = 0.90 (open data–R&D: *r* = 0.97; R&D–talent attraction: *r* = 0.98; startup programs–technology clusters: *r* = 0.98), confirming the theoretical nexus between absorptive capacity and ecosystem quality.

Based on the results, it is possible to propose a synthetic model of the relationships and interactions between the smart city and enterprise development. Its foundation is the technology block (IoT, AI/ML, big data, automation, cloud), which provides the city with a basic capacity to collect, process, and use data in real time. The second block is infrastructure (intelligent transport systems, technological infrastructure, smart energy management, circular economy, digital twins), which is a direct carrier of business opportunities and an environment for testing new service and product models. The third block is smart governance and the support ecosystem (open data, e-public services, digital participation tools, startup programs, clusters, R&D investments, PPPs, tax incentives, regulatory sandboxes, VC funds, crowdfunding), which activate public demand mechanisms, reduce uncertainty, and lower transaction costs for firms. The fourth block is human capital (talent attraction programs, STEM education and digital competences, reskilling/upskilling, cooperation with universities), which conditions enterprises' ability to absorb knowledge and technology and to use the infrastructure and data made available.

In the proposed model, the impacts unfold along at least four main pathways. First, the innovation pathway: the combination of technologies, open data, R&D, startup programs and cooperation with universities leads to accelerated product, process, and business model innovation in enterprises. Second, the efficiency pathway: infrastructure, data, and automation are perceived by experts to support the reduction in transaction and operating costs and the improvement of resource allocation in firms. Third, the human capital development pathway: the smart city, through quality of life, educational programs, and talent attraction, strengthens the competences available to enterprises, which increases their productivity and adaptability. Fourth, the sustainable development pathway: environmental solutions (smart energy, circular economy), combined with financial and regulatory instruments, support improvements in enterprises' ESG performance and the development of green business models.

This model is dynamic and conditional in nature. Strong positive correlations between open data, R&D, startup programs, clusters, and human capital variables indicate that the greatest development potential emerges where these elements co-occur and mutually reinforce one another. At the same time, the observed differentiation of assessments between expert groups (academics, technology providers, operators, and implementation companies) shows that the benefits of smart city development are distributed unevenly and that perceptions of the importance of particular factors are strongly dependent on the actor's role in the ecosystem. The proposed synthetic model (Figure 3) captures the main pathways through which smart city components jointly generate enterprise development outcomes.

The study has four important limitations. First, the expert survey method produces perception-based evidence: conclusions reflect the professional judgements of a purposively selected group of specialists, not objective firm-level performance outcomes. Causal verification requires longitudinal panel data. Second, the Polish and Central and Eastern European perspective limits direct transferability to countries with substantially different institutional frameworks, digitalization levels, or governance models; the generalizability of findings beyond the CEE region is an open empirical question that future comparative studies should address. Third, the unequal group sizes (N = 28, 17, 7) and the exclusion of the administrative subgroup (N = 2) constrain segmentation analyses and reduce multi-stakeholder completeness. Fourth, the cross-sectional design precludes tracking changes in expert perceptions as smart city infrastructure matures—longitudinal replication would substantially strengthen the findings. These limitations notwithstanding, the structured expert survey methodology provides a methodological complement to secondary-data studies and supplies a conceptually grounded, multi-dimensional assessment of smart city drivers from the perspective of actors directly embedded in the ecosystem.

In view of the above, at least three directions for further research are justified. First, quantitative studies based on enterprise-level panel data, enabling the linkage of the level of smart city development (at city or regional level) with objective indicators of firm performance (TFP, revenue dynamics, innovation intensity, ESG performance), using advanced econometric methods. Second, comparative studies between cities and countries that take into account different smart city models, public policy strategiesm and levels of digitalization, which would make it possible to identify configurations of factors particularly conducive to the development of different types of enterprises (SMEs, startups, corporations, private and state-owned firms). Third, in-depth qualitative research (case studies, interviews, process analyses) focusing on cooperation mechanisms within smart city ecosystems, barriers to technology and data absorption by enterprises, and the long-term effects of transformation towards sustainable, knowledge-based development.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: The research results are the property of the authors and may be made available in special cases.

Conflicts of Interest: The authors declare no conflicts of interest.

Appendix A

Summary of factor codes in the expert survey.

Block 1: Technology innovation
IoT—Internet of Things
AI_ML—AI and Machine Learning
5G—5G network
BIGDATA—Big Data
AUTOM—Business process automation
CLOUD—Digital platforms and cloud services
TECH_OTHER—Other (verbal description + optionally a 1–5 rating)
Block 2: Infrastructure
ITS—Intelligent transport systems
INFRA_TECH—Technological infrastructure (broadband, EV charging stations)
ENERGY_SMART—Smart energy management
CIRC_ECON—Circular economy
DIGITAL_TWIN—Digital twins
INFRA_OTHER—Other (verbal description + optionally a 1–5 rating)
Block 3: Smart governance
OPEN_DATA—Open data
EGOV—E-government services
E_PARTICIP—Digital participation tools
GOV_OTHER—Other (verbal description + optionally a 1–5 rating)
Block 4: Innovation Ecosystem and Support
STARTUP_PROG—Startup support programs
TECH_CLUSTER—Technology clusters
RND_INV—R&D investments
BUS_NETWORK—Business networking
SC_PROJECTS—Participation in smart city projects
TAX_SUBSIDY—Tax incentives and subsidies
PPP—Public–Private Partnerships
SANDBOX—Regulatory sandbox
VC_FUNDS—VC and innovation funds
CROWDFUND—Urban crowdfunding platforms
ECO_OTHER—Other (verbal description + optionally a 1–5 rating)
Block 5: Human capital
TALENT_PROG—Talent attraction and retention programs
STEM_DIGLIT—STEM education and digital literacy
RESKILL—Reskilling and upskilling programs
UNIV_COOP—Cooperation with universities
HC_OTHER—Other (verbal description + optionally a 1–5 rating)

Appendix B

Spearman's rank order correlation removed in pairs. Marked correlation coefficients are significant with $p < 0.05000$.

		AI_ML	G5	BIG DATA	AUTOM	CLOUD	ITS	INFRA_TECH	ENERGY_SMART	CIRC_ECON	DIGITAL_TWIN	OPEN_DATA	EGOV	E_PARTICIP	STARTUP_PROG	TECH_CLUSTER	RND_INV	BUS_NETWORK	SC_PROJECTS	TAX_SUBSIDY	PPP	SANDBOX	VC_FUNDS	FUND CROWD	TALENT_PROG	STEM_DIGLIT	RESKILL
IoT	1.00																										
AI_ML	0.78	1.00																									
5G	0.22	0.30	1.00																								
BIGDATA	0.71	0.71	0.04	1.00																							
AUTOM	0.25	0.40	0.40	0.27	1.00																						
CLOUD	0.76	0.85	0.45	0.64	0.45	1.00																					
ITS	−0.29	−0.51	−0.27	−0.27	−0.49	−0.44	1.00																				
INFRA_TECH	−0.23	−0.23	0.60	−0.35	0.17	−0.07	−0.15	1.00																			
ENERGY_SMART	−0.09	−0.31	−0.37	−0.07	−0.63	−0.35	0.80	−0.42	1.00																		
CIRC_ECON	0.18	0.00	−0.32	0.20	−0.48	−0.05	0.68	−0.51	0.87	1.00																	
DIGITAL_TWIN	0.37	0.32	0.04	0.46	−0.07	0.31	0.39	−0.48	0.55	0.64	1.00																
OPEN_DATA	0.32	0.26	−0.33	0.36	−0.26	0.20	0.42	−0.77	0.68	0.84	0.71	1.00															
EGOV	0.40	0.31	−0.33	0.46	−0.17	0.23	0.40	−0.77	0.65	0.81	0.72	0.96	1.00														
E_PARTICIP	0.30	0.21	−0.47	0.38	−0.23	0.09	0.33	−0.82	0.65	0.72	0.65	0.89	0.90	1.00													
STARTUP_PROG	0.36	0.27	−0.30	0.42	−0.21	0.19	0.46	−0.71	0.69	0.87	0.71	0.93	0.97	0.85	1.00												
TECH_CLUSTER	0.42	0.29	−0.26	0.48	−0.18	0.23	0.44	−0.69	0.66	0.85	0.74	0.88	0.94	0.82	0.98	1.00											
RND_INV	0.41	0.33	−0.35	0.43	−0.26	0.25	0.38	−0.80	0.66	0.84	0.73	0.97	0.97	0.89	0.94	0.92	1.00										
BUS_NETWORK	0.22	0.30	0.37	0.17	−0.05	0.38	0.22	0.06	0.28	0.48	0.47	0.44	0.40	0.20	0.46	0.41	0.42	1.00									
SC_PROJECTS	0.51	0.57	0.63	0.41	0.56	0.68	−0.41	0.35	−0.45	−0.24	0.02	−0.18	−0.14	−0.26	−0.14	−0.10	−0.15	0.35	1.00								
TAX_SUBSIDY	0.34	0.25	−0.32	0.34	−0.24	0.16	0.46	−0.66	0.69	0.89	0.63	0.90	0.91	0.81	0.95	0.92	0.91	0.50	−0.10	1.00							
PPP	0.22	0.10	−0.33	0.24	−0.44	0.01	0.60	−0.55	0.83	0.93	0.60	0.86	0.86	0.77	0.92	0.87	0.85	0.47	−0.24	0.91	1.00						
SANDBOX	0.34	0.22	−0.32	0.42	0.04	0.23	0.20	−0.81	0.37	0.42	0.63	0.65	0.72	0.71	0.62	0.68	0.70	−0.04	−0.10	0.52	0.40	1.00					
VC_FUNDS	0.58	0.63	0.57	0.59	0.64	0.82	−0.50	0.18	−0.54	−0.29	0.15	−0.09	−0.02	−0.18	−0.09	−0.00	−0.05	0.26	0.78	−0.13	−0.29	0.15	1.00				
CROWDFUND	0.34	0.20	−0.31	0.33	−0.30	0.11	0.47	−0.59	0.70	0.85	0.65	0.84	0.87	0.77	0.88	0.86	0.87	0.47	−0.15	0.89	0.90	0.53	−0.13	1.00			
TALENT_PROG	0.40	0.32	−0.30	0.43	−0.20	0.26	0.39	−0.77	0.66	0.83	0.73	0.96	0.98	0.89	0.96	0.94	0.98	0.44	−0.12	0.93	0.87	0.70	−0.02	0.89	1.00		
STEM_DIGLIT	0.35	0.28	−0.33	0.39	−0.23	0.21	0.39	−0.81	0.66	0.82	0.71	0.96	0.95	0.88	0.93	0.91	0.98	0.37	−0.14	0.90	0.83	0.72	−0.07	0.85	0.97	1.00	
RESKILL	0.38	0.28	−0.35	0.44	−0.19	0.20	0.39	−0.79	0.65	0.81	0.72	0.92	0.96	0.90	0.95	0.93	0.95	0.37	−0.13	0.92	0.83	0.73	−0.05	0.84	0.95	0.94	1.00
UNIV_COOP	0.38	0.28	−0.29	0.40	−0.21	0.22	0.43	−0.73	0.69	0.84	0.72	0.98	0.98	0.89	0.95	0.90	0.96	0.46	−0.14	0.91	0.88	0.65	−0.07	0.87	0.97	0.94	0.94

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