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Gender-Inclusive Smart Cities: A Systematic Review, Case Studies and Practical Recommendations

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Abstract

Today, urbanisation is changing the face of cities, making them smarter. However, smart cities often overlook gender equality. This paper aims to explore the links between the implementation of smart city strategies and gender equality indicators, as well as to analyse the consequences of underestimating the importance of this aspect during city planning. This study conducted an interdisciplinary analysis of 25 academic publications and official reports (ITU, UN Women, UN-Habitat), which includes thematic coding, comparative analysis of regional indicators, and visualisation of statistics. The source data consisted of ITU statistics on the digital gender gap (2019–2024) and case studies of four cities: Barcelona, Amsterdam, Seoul, and Dhaka/Chennai. The results show that the global gender parity index for internet access has increased from 0.91 to 0.94, and the gap in the number of users has narrowed from 277 million to 189 million, but in the least developed countries, the indicator has declined (from 0.74 to 0.70). Case studies demonstrate that a combination of physical infrastructure (safe lighting, inclusive transportation) and digital solutions (mobile applications, gender-disaggregated data) improves women's safety and mobility. The analysis identified barriers such as the digital divide, algorithmic bias, surveillance risks, and lack of women's participation in planning. The discussion highlights the issues of algorithmic bias and surveillance, underscores the importance of women's participation in planning, and provides recommendations for the development of truly inclusive smart cities.

Keywords: Gender, Gender Gap, Economic Sustainability, Smart City, Region, Regional Strategy, Urban Development, Urban Planning

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1. INTRODUCTION

Urban population growth and globalisation pose new challenges for urban planning, from environmental degradation to the exacerbation of social inequalities. By 2050, more than 68% of the world's population is expected to reside in cities (United Nations, 2018), underscoring the need for innovative solutions to support their sustainable development. The concept of a smart city involves the use of information and communication technologies (ICT) to optimise public services, save energy, and improve the quality of life. The European Commission defines a smart city as a combination of sustainable and economic development, and quality of life achieved by integrating physical, human, and social capital with digital infrastructure (Kotnala & Ghosh, 2018). However, the technological approach is often detached from social realities: women and vulnerable groups continue to face urban violence and limited access to services and transportation, highlighting the link between gender equality and sustainable urbanisation (Puttkamer, 2023). The Sustainable Development Goals (SDGs) emphasise the need for synergy between SDG 5 (gender equality) and SDG 11 (sustainable cities) (Ababneh et al., 2025).

Despite recognising the importance of gender, many innovative initiatives focus on technology and economic efficiency while ignoring differences in residents' needs. The literature emphasises that cities are cultural and economic centres where development implies improving the quality of life, and sustainability implies intergenerational justice (Ababneh et al., 2025). Gender shapes access to resources and opportunities, but the same research shows that the participation of women and marginalized groups in smart city planning remains low (Ababneh et al., 2025). In the context of accelerating urbanization and climate change, the inclusion of a gender perspective is becoming an integral part of sustainable development (Ababneh et al., 2025).

This study aims to fill the gap in contemporary reviews, where the gender perspective is often treated as merely an add-on to the technological agenda. The focus is on the question: how can smart cities be designed to enhance gender equality rather than reproduce inequalities? Given the scarcity of empirical research on gender in smart cities, this paper presents a comprehensive analysis that combines statistics, case studies, and policy recommendations.

The article sets out the following objectives: (1) to analyze the literature on gender aspects of smart cities and identify research gaps; (2) to assess the scale and dynamics of the digital gender gap based on ITU data; (3) to study case studies of gender-oriented projects and derive performance metrics; (4) to formulate testable hypotheses and recommendations for inclusive urban policies.

This study aims to connect two seemingly disparate fields: technological development and gender studies. Despite the rapid growth of interest in smart initiatives, there is still no comprehensive assessment of how digital transformation affects the daily lives of women and other marginalised groups. Modern cities are complex socio-technical systems; their effectiveness is determined not only by the introduction of sensors and algorithms, but also by the quality of public institutions, cultural norms, and the level of trust. Women have historically faced systemic barriers to accessing resources, opportunities, and spaces, and the digital transition risks perpetuating these inequalities if gender is considered only after the fact (Chant, 2013; Yellen, 2021; Ababneh et al., 2025).

It is important to emphasize that technologies are not neutral. They are created and implemented in specific political, economic, and cultural contexts and can therefore reproduce existing hierarchies. Recent research has shown that algorithms trained on historical data often inherit hidden biases (Criado Perez, 2019), which can potentially limit women's access to resources or employment unfairly, as artificial intelligence (AI) is used (Smith & Rustagi,

2021; Soria Sotelo, 2025). In this light, smart city approaches should be seen as part of a broader social contract: the effectiveness of digital technologies will depend on how deeply they are rooted in the values of equality, transparency, and openness. As urbanization increases the impact on ecosystems, the smart city concept must also include climate sustainability: gender-sensitive infrastructure planning (e.g., lighting, sanitation, cooling points during heat waves) simultaneously addresses environmental adaptation and the protection of women and girls (Puttkamer, 2023).

Another important perspective is an intersectional and cross-sectoral approach. Gender experiences intersect with class, ethnicity, age, and physical ability, so digital strategies must consider the diversity of user scenarios. For migrant women, women with disabilities, and older women, barriers may be related not only to economic resources but also to language and cultural constraints. International organisations emphasise that access to the internet and digital services has become an integral part of human rights; denial of such access limits women's participation in the economy, education, and politics (Singh & Sauter, 2024). Consequently, the smart city ideology should not be limited to optimising traffic or energy. However, it should include the creation of safe spaces, care facilities, and support services that promote social interaction and solidarity. Only such a socially oriented vector will enable digital cities to work in the interests of all their residents truly.

Our analysis is based on the idea that existing power structures shape technologies and can either transform or reinforce inequality. This paper explores how technology can contribute to inclusive development by ensuring accessibility and safety for all. Research begins with the hypothesis that integrating gender principles into the early stages of smart city planning enhances program effectiveness, reduces crime, and improves perceptions of safety, which will be tested through a case study analysis.

2. LITERATURE REVIEW

Smart cities are often positioned as a universal solution for sustainable development, but critics point out that the technological focus can lead to a “technology-centric” approach. Research emphasises the need to consider social factors when implementing ICT. Women, residents of poor neighbourhoods, the elderly, and people with disabilities have different mobility patterns and service needs than the “average” user. Therefore, standard smart systems may be ineffective for them (Puttkamer, 2023). Gender-sensitive planning involves creating safe streets, well-lit bus stops, caregiving infrastructure (playgrounds, toilets), and tools for residents to participate in decision-making (Puttkamer, 2023).

International studies show that women often face harassment and violence in urban spaces, even in wealthy European cities, where 25-45% of female respondents reported incidents of harassment (Puttkamer, 2023). The level of safety and comfort is determined not only by infrastructure, but also by behavioural and cultural norms (Whitzman et al., 2013; Jalalkamali & Doratli, 2022), which is why gender mainstreaming is becoming a key principle of sustainable urbanism. The Frontiers review emphasizes that the link between SDG 5 and SDG 11 lies in the use of smart technologies to solve social problems, promote sustainability principles, and improve transportation for women (Ababneh et al., 2025).

The tendency to rely on cameras, sensors, and analytics to ensure safety is often accompanied by an underestimation of privacy rights. As UN Women notes, video surveillance systems without institutional support from social services can only create an illusion of safety, leaving the root causes of violence unaddressed (Kotnala & Ghosh, 2018). In addition, digital harassment is becoming an increasingly serious problem, especially in countries with poor legal protection. Ultimately, the underrepresentation of women in planning means that many decisions are made without considering

women's experiences. Women are underrepresented among architects, transportation engineers, and ICT developers (Puttkamer, 2023; Sánchez de Madariaga & Roberts, 2013; U.S. Bureau of Labor Statistics, 2017), which reduces cities' ability to take into account the needs of mothers, older people, and people with disabilities. As a result, infrastructure is geared toward the "average" user, who is most often a middle-aged man.

Another most apparent manifestation of inequality is the digital gender gap, the difference between men and women in access to the internet, digital devices, and the ability to use them. In Asia and the Pacific, only 54% of women have access to the internet. Women are 36% less likely to use the internet than men (Singh & Sauter, 2024). Reasons include low digital literacy, high device costs, cultural constraints, and inadequate infrastructure (Singh & Sauter, 2024). The inaccessibility of digital services exacerbates economic inequality and limits opportunities for distance learning and medicine (Singh & Sauter, 2024).

An additional challenge is algorithmic bias. Studies have shown that 44% of AI systems implemented in various fields demonstrate gender bias (Berkeley Haas Center for Equity, Gender and Leadership, 2021; Soria Sotelo, 2025). Bias arises from training on incomplete data and the lack of gender-disaggregated statistics (Soria Sotelo, 2025), leading to unequal distribution of resources (e.g., recommendation algorithms focused on male routes).

Based on the above, it can be observed that existing research in the field of smart cities primarily focuses on a technology-centric discourse, prioritising the implementation of digital solutions, enhancing the efficiency of urban infrastructure, and stimulating economic growth. Social aspects, including gender equality issues, often remain unexplored. In addition, a review of the literature reveals that the gender perspective in urban planning is closely tied to the accessibility of transportation systems, the safety of public spaces, the availability of care and support infrastructure, and the level of women's participation in decision-making processes. The lack of attention to these issues leads to the reproduction of inequalities in access to resources and services, as well as the exclusion of the needs of significant population groups from planning decisions (World Bank, 2020).

In low-income countries, this lack of attention hinders women's access to the internet, digital services, educational resources, and remote forms of employment. This gap is exacerbated by algorithmic bias, where digital systems trained on incomplete or unrepresentative data reproduce gender stereotypes and unevenly distribute access to services. Therefore, it is necessary to include gender-disaggregated data in planning processes, develop technologies that take into account user diversity, and ensure a balance between security and the protection of individual rights. A review of the literature showed that only with this approach can digital and infrastructure solutions help reduce existing inequalities rather than exacerbate them, creating more equitable and sustainable cities.

3. METHODOLOGY

The sources used in this paper were the academic databases Scopus, Web of Science, and Google Scholar, as well as the official portals of international organizations (ITU, UN Women, UN Habitat, UNESCAP). The search covered the period 2015–2024 and was conducted in Russian and English. The following key queries were used: "smart city" AND "gender", "women" AND "smart cities", "digital divide" AND 'gender', "safety app" AND city name. Additional sources (dissertations, city council reports) were searched for through city administration websites.

In the first stage, a pool of 120 documents was formed. Duplicates and irrelevant types of publications (e.g., blog posts, commercial press releases) were removed; after this operation, 110 unique records remained. Next, the titles and abstracts were reviewed, and 70 works were selected based on the inclusion

criteria (peer-reviewed, official statistics, and content related to gender and smart cities). At the final stage of full reading, 25 publications were left, which formed the basis of the analysis. Exclusion criteria: lack of gender data, technological descriptions without a social component, materials prior to 2015 (excluding historical references). The selection scheme is presented in Figure 1.

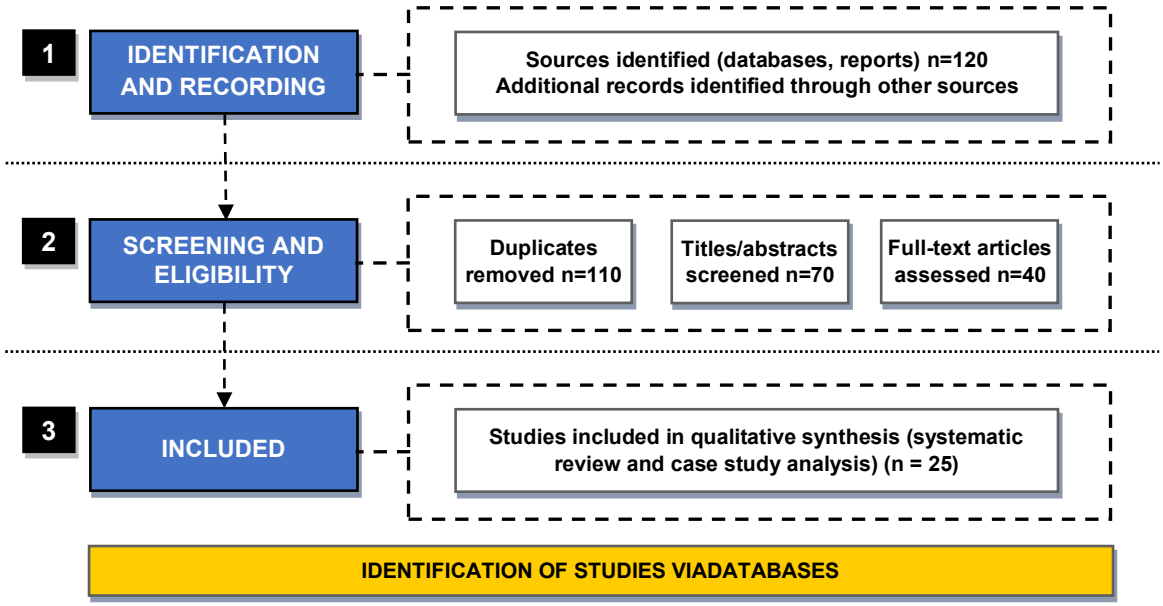


Figure 1. Literature selection scheme (modified PRISMA)

The statistical part is based on ITU data from the report Facts and Figures 2024 – the gender digital divide (ITU, 2024) and updated indicators of the gender parity index by region (ITU, 2024). For visualization purposes, graphs and tables were constructed showing the share of Internet users by gender, the dynamics of the GPS index, and the difference in the number of users.

The qualitative analysis included thematic coding of texts, identification of categories (digital divide, data bias, security, participation), and cross-referencing of these categories with case study data. Four cities were selected for the case studies—Barcelona, Amsterdam, Seoul, and Dhaka/Chennai—based on the following criteria: (1) the presence of a documented gender agenda in smart programs; (2) the availability of official reports and accessible metrics; (3) geographical diversity and level of digitalisation. Data on initiatives were collected from official municipal reports, scientific journal publications, and international organisation portals.

The analytical tools included: (1) thematic coding to identify problems and solutions; (2) comparative analysis of regional indicators, including comparative GPS indicators and improvement rates; (3) visualization of statistical data using diagrams and tables; (4) development of recommendations grouped by level (municipalities, transport and communications operators, developers, NGOs) with an indication of possible metrics for success.

The selection and screening scheme for publications is shown in Figure 1. It shows the process from the initial search to the final set of works used in the analysis.

Qualitative analysis was conducted using thematic coding. Based on the selected articles, five categories were identified: (1) digital divide; (2) algorithmic bias; (3) security and

privacy; (4) participation and representation; (5) infrastructure and maintenance. Two researchers independently coded the texts (using NVivo software) and discussed ambiguous passages. To assess the consistency of the coders, Cohen's κ was calculated, which was 0.83, corresponding to a high level of reliability. Controversial passages were discussed until consensus was reached, and the coding framework was revised as necessary. This approach ensures the replicability and transparency of analytical conclusions.

4. RESULTS

ITU data show that in 2024, 70% of men and 65% of women worldwide had access to the internet, representing an improvement in gender parity compared to 2019 (0.91 → 0.94). The gap in the number of users has also narrowed: while in 2021 there were 277 million more men than women online, by 2024 this difference had decreased to 189 million (ITU, 2024).

The visualisation shows not only the percentage ratio, but also the absolute gap in the number of internet users. The improvement in indicators between 2021 and 2024 may be due to several factors: the spread of inexpensive smartphones, the expansion of mobile broadband access, and targeted digital literacy programs aimed at women and girls (GSMA, 2023, UN Women, 2025). Thus, Figure 2 shows the proportion of men and women with internet access, as well as the number of users in millions worldwide.

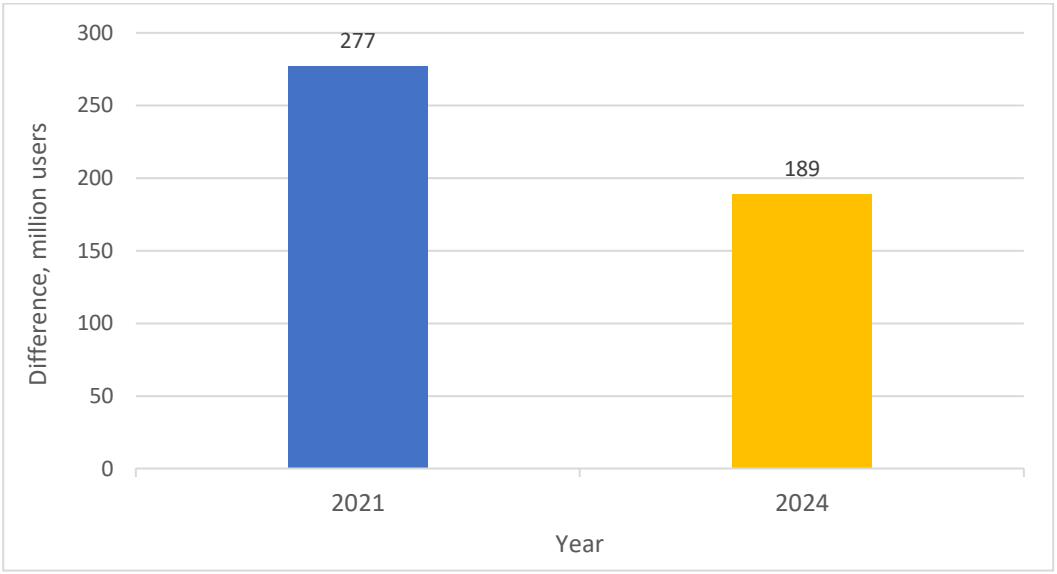


Figure 2. Proportion of men and women with internet access and difference in the number of users for 2021 and 2024

However, even with the gap narrowing in absolute terms, 189 million women still lack internet access compared to men, reflecting persistent inequality. Such differences are particularly prevalent in rural areas, where infrastructure is underdeveloped and cultural norms may limit women's access to technology. An analysis of the reasons for this gap reveals that high tariffs, low digital literacy, and weak connections between ICT policies and gender mainstreaming remain key barriers (Singh & Sauter, 2024).

Further analysis shows that the digital divide has distinct intergenerational and spatial characteristics. Young women in cities tend to be quicker to adopt digital services and utilise messaging apps, mobile banking, and learning platforms. In contrast, older women and those

in rural areas are more likely to remain outside the digital economy. The reasons for this include low levels of general education, a lack of trust in technology, and security concerns. In several countries, girls are often denied their own smartphones or access to computers, as these devices are controlled by men, turning technology into a tool of control. These aspects underscore the need for programs targeting specific age groups and local communities, as well as campaigns that change cultural norms and persuade families of the benefits of digital education (Singh & Sauter, 2024).

It is equally important to understand that access to digital technologies does not guarantee their practical use. Women often face a "secondary" gap, where connectivity does not lead to full participation in the economy and politics. For example, online entrepreneurship and remote work require skills in financial management, marketing, and data analytics. Without digital literacy courses and support, such opportunities remain unrealised. In addition, digital platforms can expose women to cyberaggression and unwanted attention, which reduces their motivation to use the internet. In this context, governments and NGOs must not only provide access but also create safe online spaces, support mentoring programs, and develop services to protect against digital violence (Kotnala & Ghosh, 2018).

Finally, reducing the user gap should be seen as part of a broader picture that includes connection quality and service costs. In some regions, connections are unstable and expensive, limiting opportunities for streaming education or telemedicine. Gender-sensitive policies should consist of subsidising connectivity, developing public Wi-Fi zones, and encouraging competition among operators. Such measures, as successful examples from the Asia-Pacific region demonstrate, enable women to participate more actively in the digital economy and lay the groundwork for poverty reduction (Singh & Sauter, 2024).

The Gender Parity Score (GPS) shows the ratio of women to men among Internet users. Figure 3 illustrates the global change in this index between 2019 and 2024, where the index approaches 1 as the gap between the two values narrows.

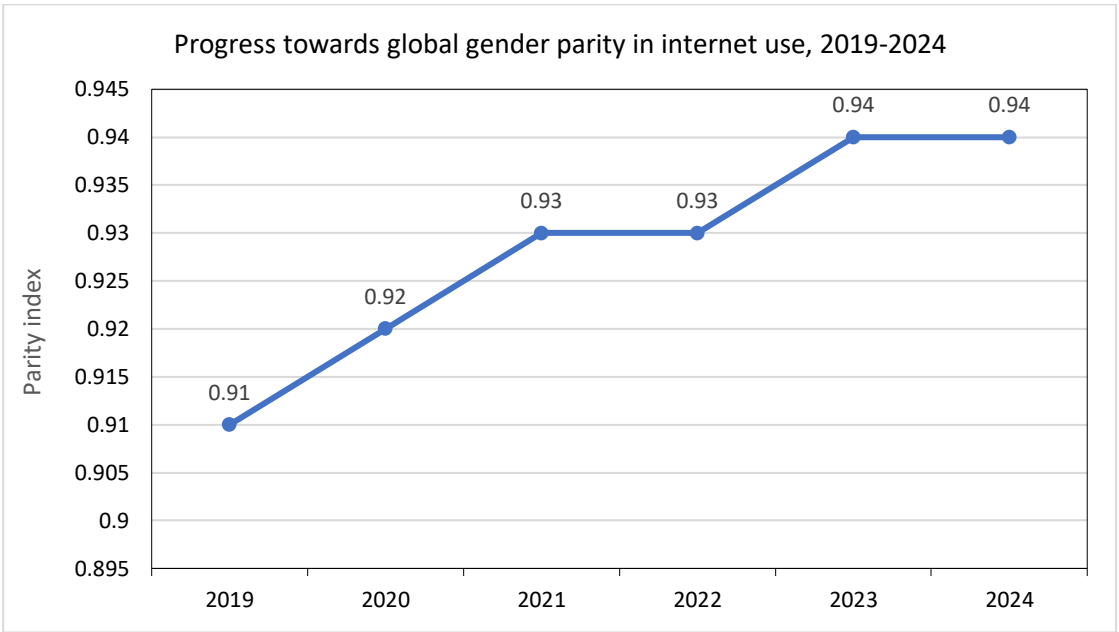


Figure 3. Dynamics of the global Gender Parity Index for 2019–2024

Note: compiled by the authors based on data ITU (2024)

The growth of the global GPS index from 0.91 to 0.94 reflects a gradual narrowing of the gap; however, the graph shows that the pace is slowing. After an increase in 2020–2021 (0.92 → 0.93), progress stalled, and by 2024, the value remained at 0.94. This suggests that the initial successes were probably achieved at the expense of "easily accessible" groups, while achieving parity (1.0) will require complex structural changes in education, employment, and legal regulation. An important conclusion is that even a slight improvement in the index has a significant impact on the lives of millions of women; a 0.01 increase in the GPS means that a significant number of women are connecting to the network. Therefore, national strategies should focus not only on expanding infrastructure but also on removing social and cultural barriers that affect Internet use (Singh & Sauter, 2024). Regions exhibit different dynamics.

Table 1 summarises the change in GPS by region between 2019 and 2024.

Table 1. Change in the Gender Parity Score (GPS) by region for 2019–2024

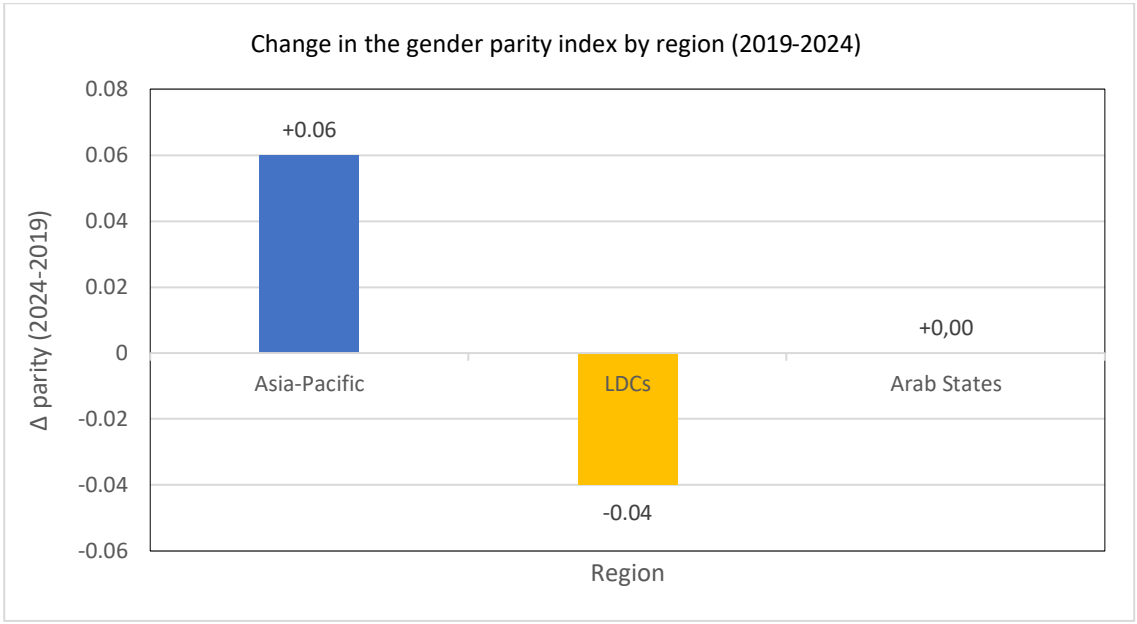
Region	Index 2019	Index 2024	Trend	Comment
Global level	0,91	0,94	improvement (+0.03)	the world is gradually moving towards gender parity (ITU, 2024)
Asia-Pacific	0,89	0,95	improvement (+0.06)	the region is showing significant progress (ITU, 2024)
Arab States	0,86	0,86	Stagnation (0)	The gap is not narrowing (ITU, 2024)
LDCs (Least Developed Countries)	0,74	0,70	Decline (-0.04)	The gap has widened, requiring intervention (ITU, 2024)
SIDS (Small Island Developing States)	>1,00	1,00	slight decrease	value fell but remained at parity (ITU, 2024)
Americas / Europe / CIS	–	≥0,98-1,02	parity achieved	parity achieved, baseline data for 2019 not provided (ITU, 2024)
Africa	–	–	improvement indicated	indicated region lags behind but is progressing (ITU, 2024)

Note: compiled by the authors based on data ITU (2024)

Table 1 and Figure 4 show that the Asia-Pacific region has made the most significant progress, with the GPS index rising from 0.89 to 0.95 (+0.06), while the global level increased from 0.91 to 0.94 (+0.03). At the same time, LDCs lost ground (a decline of -0.04), while Arab states showed stagnation, remaining at 0.86. These differences underscore the need for regional strategies to take into account local conditions and opportunities.

A more detailed analysis shows that successful regions, such as Asia-Pacific, combined government investment in infrastructure with market competition and civil society initiatives. There, government programs subsidised the cost of smartphones, promoted mobile applications in local languages, and developed campaigns to increase digital literacy among women. In Arab states, despite high GDP per capita, women's access to technology remains restricted by cultural barriers and low policy transparency (Singh & Sauter, 2024). A comparison of regions highlights that economic prosperity alone does not guarantee digital equality: a regulatory framework that supports women's rights and targeted programs to remove cultural barriers play a key role.

Figure 4 shows the change in the GPS index for several regions.



The distribution of the GPS index by region shows that SIDS (small island developing states) and the Americas/Europe/CIS have reached or even exceeded parity (values ≥ 1). Still, this success should be interpreted in light of the overall share of users: in SIDS, less than two-thirds of the population uses the internet (ITU, 2024), which means that small changes in absolute numbers can have a significant impact on the index.

Additional visualisation in Figure 5 shows GPS index values by region in 2024. A value above one means that the share of female users exceeds the share of male users (parity and above).

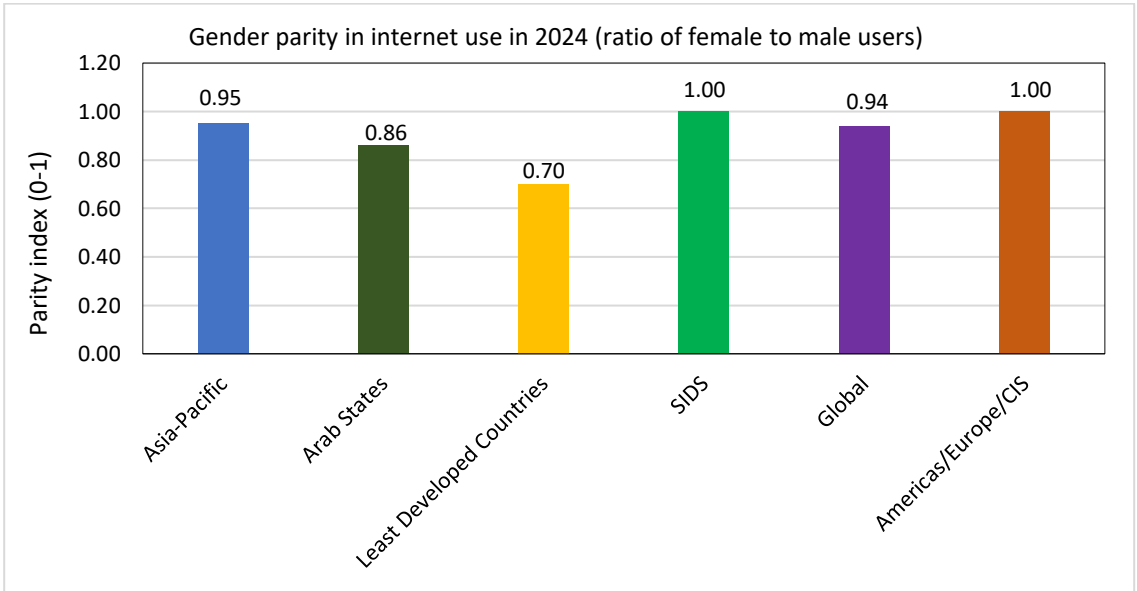


Figure 5. Gender Parity Index (GPS) by region in 2024

In the Americas/ Europe/ CIS regions, a high level of digital infrastructure is combined with high education indicators and gender equality policies, which contribute to achieving parity. The global level (0.94) and Asia-Pacific (0.95) show progress but have not yet achieved full equality. LDCs (0.70) lag significantly behind, underscoring the need for prioritised investment in women's digital literacy and access to communication services. Thus, the parity index should be analysed in conjunction with the overall share of users and context: high GPS values do not always mean high coverage, as can be seen in the example of SIDS.

Further analysis highlights that regional differences in GPS are closely linked to economic and cultural factors. Countries with high per capita income may show stagnation or even decline if traditional gender roles limit women's participation in the economy, as observed in some Arab states (ITU, 2024). In contrast, in the Asia-Pacific region, positive dynamics have been driven by government smartphone subsidy programs, the mandatory introduction of gender analysis in service design, and the active role of women's NGOs. This shows that economic prosperity alone does not guarantee digital equality; it is achieved through a combination of political will, civic engagement, and cultural change (Singh & Sauter, 2024). In LDCs, the decline in the GPS from 0.74 to 0.70 indicates that infrastructure deficiencies, low levels of education, and gender norms are widening the gap, and simply building basic networks will not solve the problem.

In this regard, it is essential to note that the GPS index does not accurately reflect the quality and depth of digital participation. Women may be among the users, but they may use the internet exclusively for basic communications. At the same time, men are more likely to acquire professional skills and access high-income areas such as programming and fintech. Differences in connection speed, network security, and the availability of content in local languages also affect the quality of participation. Therefore, expanding access must be accompanied by initiatives to improve digital literacy, develop content for women and girls, and combat online violence (Kotnala & Ghosh, 2018). The GPS Index is a “first step” but not a comprehensive measure of digital equality.

Finally, the link between the digital divide and socio-economic resilience is becoming clear in light of climate and health crises. The COVID-19 pandemic has demonstrated that access to high-quality internet is crucial for education, telemedicine, and remote work. Offline women were deprived of these opportunities, which exacerbated economic and educational gaps. In the future, as cities face extreme weather events and population displacement, digital inclusion could become a factor in survival: from disseminating information about disasters to managing resource distribution. Therefore, regional and global strategies must consider digital equality as an element of climate resilience and support it on par with physical infrastructure.

Practical examples show how integrating a gender approach improves women's quality of life. Table 2 lists initiatives in Barcelona, Amsterdam, Seoul, and Dhaka/Chennai.

As part of the Lighting Masterplan program, approximately 1,100 smart streetlights were installed, resulting in 30% energy savings and approximately €4.5 million in annual savings (Maçon-Dauxerre, 2020). The IoT infrastructure includes 19,500 smart meters and 670 Wi-Fi hotspots; the program has saved $58 million in water supply and created approximately 47,000 jobs (Adler, 2016).

A number of sources also note a reduction in street crime of approximately 20% thanks to smart lighting (Welsh et al., 2022). For Amsterdam, Seoul, and Dhaka/ Chennai, significantly less quantitative data is available: indicators for bicycle lane coverage, security app usage are not published in open sources, as highlighted in the limitations section. A comparison of cases shows that the effectiveness of gender-oriented smart initiatives depends not only on the technology itself, but also on the economic context.

Table 2. Gender-inclusive initiatives and metrics in smart cities

City	Initiative/ technology	Description	Quantitative indicators (KPIs)
Barcelona	Smart lighting, IoT, and Wi-Fi	The city has installed smart streetlights, sensors, mobile apps, and deployed an IoT infrastructure with 19,500 smart meters and 670 Wi-Fi hotspots (Fortune, 2015). These solutions enhance visibility, enable women to plan their routes in real-time, increase energy efficiency, and provide free access to the network (Ababneh et al., 2025).	1,100 smart streetlights, 30% energy savings, and €4.5 million in savings per year; 19,500 smart meters; 25% water savings and $58 million in water supply savings; 670 Wi-Fi hotspots; 47,000 new jobs; €50 million in additional parking revenue; a reduction in street crime of approximately 20% (Adler, 2016; Maçon-Dauxerre, 2020; Welsh et al., 2022).
Amsterdam	Gender-sensitive transport design	The authorities and women's NGOs are designing bicycle and pedestrian routes that take into account the needs of women, mothers, and people with disabilities; route data is used to adapt infrastructure (Ababneh et al., 2025).	Quantitative data on the impact of the initiative has not been published; metrics (e.g., number of lit bike paths or proportion of female users) are not available — this uncertainty is noted in the limitations section.
Seoul	Ansimi app and safety programs	Seoul developed the Ansimi mobile app for sending distress signals and tracking routes, created video surveillance zones and women's parking lots, and organized digital literacy courses for women (Singh & Sauter, 2024).	The Ansimi app has been downloaded more than 100,000 times; there are no official reports on crime reduction or parking lot usage.
Dhaka / Chennai	Digital security audit and crowdsourcing	The apps allow women to mark dangerous locations on a map; the data collected is used by municipalities to improve lighting, organize patrols, and manage roads (Soria Sotelo, 2025).	There is no available data on the quantitative effects (e.g., the number of dangerous areas marked or the reduction in incidents).

Note: compiled by the authors based on literature and official reports (Ababneh et al., 2025; Soria Sotelo, 2025; Adler, 2016; Maçon-Dauxerre, 2020)

Thanks to a long-term strategy (since the early 2010s) and investment in IoT infrastructure, Barcelona has achieved measurable effects, including energy savings, employment growth, and crime reduction. At the same time, the programs initially included an assessment of the impact on vulnerable groups. In Amsterdam and Seoul, initiatives are developing in parallel with participation policies: the authorities actively cooperate with women's organisations, conducting public consultations and providing data in an open format. However, quantitative indicators are still rarely published, which indicates insufficient evaluation of programs and the complexity of measuring social effects. Dhaka/Chennai, despite limited resources, demonstrate an innovative approach—the use of crowdsourcing applications to map dangerous areas. However, the success of these initiatives is limited by the availability of smartphones and the literacy level of the population. These differences underscore the necessity of tailoring technologies to local conditions and developing indicators to evaluate the impact of programs on women's safety and mobility.

Additionally, case studies demonstrate that combining physical infrastructure (such as lighting, well-maintained sidewalks, and video surveillance) with digital services (including mobile apps and feedback platforms) has a synergistic effect. For example, smart lighting in Barcelona not only reduces energy costs but also creates a sense of security, allowing women and girls to move freely at night. Similarly, women's parking lots and escort apps in Seoul increase comfort and can stimulate economic activity, as women use public transport more frequently and attend

cultural events. Such solutions must be complemented by social programs, including digital skills training, information about rights and opportunities, and support for women's entrepreneurship.

The potential for scaling up the initiatives studied depends on financial and regulatory conditions. Barcelona was able to finance its plan through the municipal budget and private partnerships, whereas cities in the Global South often rely on international grants and pilot projects. Nevertheless, even low-budget programs such as collecting data on dangerous areas through free apps can yield quick results if accompanied by political will and community participation. For countries with limited resources, projects related to lighting and improving public transportation infrastructure may be a priority, as they directly impact the sense of safety and access to education and employment.

A more detailed examination of the cases reveals the specific features of each initiative and provides lessons for scaling up. Back in 2012, Barcelona began deploying an integrated fiber-optic network and thousands of sensors to track traffic, water consumption, and noise (Bakıcı et al., 2013). This infrastructure formed the basis of the Lighting Masterplan, which allows real-time brightness control and reduces energy consumption by 30%. An important aspect of the program was that the city collected feedback from residents through mobile apps and women's councils, which enabled the identification of dangerous areas and the rapid adjustment of lighting scenarios. Thus, the technological solution is linked to the ongoing participation of users and tied to a broader sustainability plan that includes water conservation, parking modernization, and job creation (Adler, 2016; Maçon-Dauxerre, 2020)

In Amsterdam, gender-sensitive transport design has manifested itself in specific practices: the city has adapted bike lanes for strollers and applied ergonomic design for people with disabilities; additional public transport stops were introduced near kindergartens and care centres, and tram schedules were adjusted to take into account the time when women return home from work. These changes resulted from an extended dialogue among the municipality, women's organisations, and the academic community. Although quantitative indicators have not yet been published, qualitative data indicate an increase in women's satisfaction with transport and a decrease in incidents of harassment at stations. Amsterdam is also investing in IT platforms for consultation, allowing residents to vote on priority changes, which increases transparency and accountability (Ababneh et al., 2025).

The example of Seoul shows how a digital safety ecosystem can be integrated into urban infrastructure. The Ansimi app connects users with the police, allowing them to track their route in real-time. At the same time, surveillance cameras and designated parking spaces for women ensure physical safety, while digital literacy courses help women utilise the services effectively. Seoul also runs campaigns to raise awareness of gender-based violence and has set up hotlines to support victims. Despite the lack of official data on the decline in crime, the app's popularity (over 100,000 downloads) suggests that residents trust this approach. The government continues to update the service, adding language and inclusive features (Singh & Sauter, 2024).

In the cities of Dhaka and Chennai, digital safety audits are based on crowdsourcing platforms where women report dangerous streets, inadequate lighting, or a lack of transportation. This data is sent to municipal authorities, who develop plans to improve infrastructure, including installing streetlights, creating safe routes to schools and markets, and establishing patrols. Experience shows that the effectiveness of such programs depends on the availability of smartphones, literacy levels, and the responsiveness of authorities. In some areas, the creation of women's self-help groups has been key to success: they help other women download the app, teach safety, and accompany them on their journeys. Thus, digital solutions work when they are accompanied by a strong community and support from NGOs (Soria Sotelo, 2025).

Taken together, these examples demonstrate that the success of gender-focused initiatives depends on the symbiosis of technology, institutional support, and public participation. Technology only amplifies the effects if local authorities are willing to invest in infrastructure and listen to residents. Women's NGOs and activist groups act as intermediaries between the community and municipalities, providing feedback and oversight. The key conclusion is that each city requires an individualised strategy that considers its unique cultural and economic characteristics; solutions cannot be copied without adaptation. At the same time, the general principles are clear: quality data, transparency and accountability, joint planning, and consideration of the needs of marginalised groups.

A review of the literature revealed several key obstacles. Table 3 summarizes the main barriers, their causes, and consequences.

Table 3. Main barriers and risks to gender-inclusive smart cities

Barrier/problem	Causes and manifestations	Consequences
Digital gender gap	Low digital literacy; high prices for devices and connectivity; cultural norms; limited infrastructure (Singh & Sauter, 2024).	Limited access for women to education, healthcare, e-commerce, and civic participation; women with disabilities and residents of poor areas are most vulnerable (Singh & Sauter, 2024).
Algorithmic bias	Training AI on historical data where women are underrepresented; lack of gender-disaggregated data (Soria Sotelo, 2025).	Algorithms repeat gender stereotypes and reinforce the uneven distribution of resources.
Risk of surveillance and privacy violations	Reliance on video surveillance without legal protection; increase in digital violence and dissemination of personal data (Kotnala & Ghosh, 2018).	Violation of women's privacy; decreased trust in digital services and authorities.
Lack of participation and representation	Low representation of women among urban planners and ICT developers; limited access to digital platforms (Puttkamer, 2023).	Services are geared toward the “average” (male) user; infrastructure does not take into account the needs of mothers and people with disabilities.

Note: compiled by the authors based on literature (Singh & Sauter, 2024; Soria Sotelo, 2025; Puttkamer, 2023).

The barriers presented in Table 3 are closely interrelated. The digital gender gap is the foundation on which the other problems are built: lack of access to the internet prevents women from participating in online education, leaving them out of the high-tech employment market. Algorithmic bias exacerbates the gap, as recommendation systems based on historical data often invisibly exclude women from decision-making processes. Solving these problems requires a comprehensive strategy: governments should subsidise the cost of connectivity, and companies should publish data on algorithmic risks and involve ethics and gender experts in AI development. The danger of surveillance underscores that security cannot be built solely on total surveillance; a legal framework regulating data processing and storage is crucial, as is the existence of independent control and feedback mechanisms. Lack of participation is a cross-cutting issue: without women in design teams and politics, the results will be geared towards male needs and therefore incomplete. Removing these barriers requires both structural changes (e.g., representation quotas) and cultural transformation aimed at revising gender stereotypes in society.

5. CONCLUSION

Smart cities have the potential to be a powerful tool for gender equality. However, this potential can only be realised through a comprehensive approach that combines technology with social innovation and policy reform. According to ITU data, the global digital divide is narrowing, but remains significant, especially in LDCs and Arab states, requiring flexible, context-sensitive strategies. Case studies from Barcelona, Amsterdam, Seoul, and Dhaka/Chennai demonstrate that integrating physical infrastructure (such as lighting and transportation) with digital services (including mobile apps and gender-disaggregated data) enhances women's safety and engagement. However, without gender mainstreaming, data ethics, and real civic participation, smart systems risk reinforcing existing inequalities. This study contributes to the interdisciplinary field of "smart cities, gender, and sustainability" (Bibri & Krogstie, 2017) by proposing a methodology that combines quantitative analysis, thematic coding, and case studies, allowing for the simultaneous identification of structural barriers and the scaling up of successful practices. The results underscore the need to shift from a technology-centric to a human-centric approach: digital infrastructure must be complemented by measures to expand women's rights, increase their economic independence, and enhance their participation in decision-making processes. A promising direction is the development of a regulatory framework for assessing gender inclusiveness with indicators of access (the proportion of women using the internet and digital services), safety (the level of crime and harassment in "smart" neighborhoods), participation (the representation of women in the management of transport and technology companies), and impact (income and employment growth). International coalitions such as UN Women and ITU can play a key role in standardisation and data exchange.

Future research should focus on refining indicators, assessing the long-term effects of emerging technologies on women's daily lives, and developing legal mechanisms to protect digital rights. Finally, an intersectional approach is critical: women's experiences intersect with class, ethnicity, age, and disability, so without taking into account the needs of migrant women, women with disabilities, and older women, "smart" projects risk becoming solutions for the privileged. Based on the principles of participation, transparency, and social justice, smart city innovations can become part of the global movement for gender equality and truly serve everyone.

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