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# Exploring Engineers' Experiences in Tackling IoT Implementation Challenges in Smart Cities

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**ABSTRACT**

The integration of Internet of Things (IoT) technologies into smart cities is a rapidly evolving field that aims to optimize urban systems through interconnected devices. Despite significant advancements in IoT solutions, little research has explored the subjective experiences of engineers who implement these technologies in smart city projects. While technical performance and public adoption have been well-documented, the personal and social challenges faced by engineers remain underexplored. This study seeks to answer the question: How do engineers experience and interpret the challenges of implementing IoT solutions in smart cities? We employed an interpretative phenomenological analysis (IPA) approach to delve into the lived experiences of engineers, focusing on both technical and social aspects. Through semi-structured interviews with 12 engineers involved in IoT smart city projects, we identified key themes related to system integration, scalability, and community acceptance. Our findings indicate that engineers struggle with integrating diverse IoT systems and ensuring scalability, while also encountering resistance and trust issues from local communities. These intertwined technical and social challenges emphasize the importance of adopting a holistic strategy that balances technological efficiency with community engagement. These findings contribute to a deeper understanding of smart city development and provide insights for future research on human-centered technology integration.



## INTRODUCTION

The phenomenon of integrating Internet of Things (IoT) technologies into smart city projects has emerged as a critical area of focus in urban development (Semary et al., 2024). Smart cities, which leverage digital technologies to enhance urban living, represent the confluence of technology, infrastructure, and human experience (Ferreira et al., 2022). As cities continue to grow, the need for efficient, sustainable, and interconnected urban environments becomes increasingly urgent (Arsene et al., 2022). The implementation of IoT technologies in these contexts aims to improve various aspects of urban life, including traffic management, public safety, and resource optimization. However, the integration of these technologies into existing urban infrastructures is not without its challenges.

The relevance of this phenomenon lies not only in its technological implications but also in its social and cultural impact (Akhmetzhanov et al., 2024). Engineers involved in these projects encounter a complex web of technical, social, and ethical issues as they strive to develop systems that are not only functional but also accepted by the communities they serve (Assumpção et al., 2022). The integration of IoT technologies touches upon the core of daily life for city dwellers, influencing how they interact with public services and experience urban spaces (Suresh et al., 2025). As such, the subjective experiences of engineers working on these projects are essential for understanding both the challenges of implementation and the broader societal implications of these technologies. Their perceptions and experiences provide valuable insights into the lived realities of transforming urban spaces into smart cities.

Given the intricate and multifaceted nature of this transformation, there is a pressing need to explore the meanings and personal experiences that underpin the process of IoT implementation in smart cities (Marzouk & Atef, 2022; Phua et al., 2020). While the technical aspects of IoT integration are often well-documented, less attention has been given to understanding the human experience of engineers tasked with its realization (Chui et al., 2019). Most existing studies focus on performance metrics, cost-benefit analyses, or citizen adoption, thereby overlooking the voices of engineers who translate these systems into practice. Only limited research has examined how engineers perceive system integration difficulties, scalability concerns, or interactions with local communities, leaving an underdeveloped understanding of the professional and social dimensions of IoT implementation. This study seeks to bridge this gap by delving into the subjective experiences of engineers, providing a deeper understanding of how they navigate the challenges, opportunities, and societal impacts inherent in smart city projects. Such an exploration is crucial for comprehending the broader implications of these technologies, particularly in terms of their social acceptance, usability, and long-term sustainability.

Research on the subjective experiences of individuals involved in complex technological projects, such as IoT integration in smart cities, has become an increasingly important area of study (Luna-Navarro et al., 2021). The ability to understand the personal, lived experiences of engineers working on these projects is crucial to capturing the full complexity of IoT implementation (Tzerakis et al., 2023). Despite the technological advancements in smart city systems, much of the existing research focuses on quantitative data, such as system performance, cost-efficiency, or user adoption rates (Rababah & Eskicioglu, 2021). However, these metrics fail to address the human experiences, perceptions, and challenges encountered by engineers, who are at the forefront of this transformation. This gap underscores the need to investigate how engineers interpret their roles, make decisions under technological and social constraints, and negotiate the balance between innovation and community trust.

One of the primary challenges in researching the subjective experiences of individuals is the methodological limitations of traditional quantitative approaches (Rasool et al., 2020). These methods, while effective at measuring outcomes, are unable to capture the nuanced, in-depth understanding of personal experiences and perceptions. In the context of IoT in smart cities, quantitative data often falls short of providing insights into the emotional, social, and cognitive processes that engineers navigate as they engage with complex urban technologies (Kotovs et al., 2025). As a result, existing research lacks a comprehensive understanding of how these professionals interpret and make sense of their roles in these projects.

This gap in the literature underscores the need for a more qualitative approach that can explore the rich, multifaceted experiences of engineers (Kuo et al., 2024). Phenomenological research, with its emphasis on deep, contextualized understanding, offers a more effective framework for exploring these personal experiences (Åkerlund & Nylén, 2021). By focusing on how engineers make meaning of their work in the context of IoT implementation, this research aims to provide a more complete and human-centered perspective on the challenges, successes, and implications of smart city projects. Without such an approach, the true essence of this technological evolution remains incomplete and underexplored.

In addressing the challenges and opportunities of IoT integration in smart cities, much of the current research relies on practical, technically-oriented approaches, such as performance metrics, cost-benefit analyses, and user adoption studies (Brodén et al., 2025; Moradi, 2021). These approaches provide valuable insights into the effectiveness of IoT systems but fall short of capturing the deeper, subjective experiences of engineers who are directly involved in these projects (Yang et al., 2022). While they offer practical solutions for implementation and scalability, they do not explore the nuanced, human side of the integration process particularly the personal and emotional challenges that engineers face, nor the meanings they attach to these experiences. The limitations of these methods result in a shallow understanding of the full impact of IoT technologies on both the professionals involved and the communities they serve.

To overcome these limitations, an alternative solution lies in adopting a phenomenological approach to research (Nguyen et al., 2025). By focusing on the lived experiences of engineers, this approach allows for a more holistic understanding of the phenomenon. Phenomenology goes beyond technical details and captures the essence of the personal experiences, interpretations, and emotional journeys of individuals. This shift in perspective is necessary to uncover how engineers interpret their roles, the challenges they face, and the broader societal implications of their work (Rossetti et al., 2022). Without this deeper, experiential insight, our understanding of the integration of IoT technologies in smart cities remains incomplete. Thus, this study aims to fill the gap by exploring the subjective experiences of engineers, providing a richer, more comprehensive view of the impact of IoT on smart city development.

Previous studies have examined the technical and operational aspects of IoT integration in smart cities, but there is a significant gap in the exploration of engineers' personal experiences in this context (König et al., 2024). Literature on the subject typically focuses on quantitative measures of system performance and public acceptance, often overlooking the emotional, cognitive, and social dimensions of the engineers involved in the implementation. A few studies have applied phenomenological methods to understand user experiences with smart technologies, yet there remains a lack of research that specifically focuses on engineers' lived experiences in the smart city ecosystem. These gaps highlight the need for a more in-depth qualitative approach to understand how engineers perceive and navigate the challenges of implementing IoT in urban spaces, particularly from a phenomenological standpoint.

To address this gap, we propose using an interpretative phenomenological analysis (IPA) approach (McNett et al., 2024). This method is ideal for uncovering the nuanced and subjective meanings that engineers assign to their experiences in smart city projects. IPA enables the exploration of how participants interpret their roles and the challenges they face, providing rich, first-hand insights into the complexities of IoT implementation that are not captured through traditional quantitative methods. By focusing on the essence of engineers' experiences, this approach facilitates a deeper understanding of the personal, emotional, and social factors at play in the technological transformation of urban environments. This methodology answers the knowledge gap by shifting the focus from technical outcomes to the human side of the smart city revolution.

The article is structured to first introduce the broader context of IoT and smart cities, followed by a detailed explanation of the phenomenological approach and its relevance to the study (Yasuoka et al., 2023). The methodology section outlines the data collection process, including semi-structured interviews and thematic analysis, which were used to explore engineers' experiences (Vodă et al., 2021). Next, the findings are presented in terms of major themes that emerged from the data, followed by a discussion of the implications of these findings for both theory and practice. The conclusion ties together the key insights, offering recommendations for future research and practical applications in smart city development.

## RESEARCH METHODS

### Study Design

This research employed a phenomenological approach to explore the lived experiences of engineers involved in the implementation of Internet of Things (IoT) technologies in smart city projects (Fife, 2020). The choice of phenomenology as the design was driven by the need to understand the subjective perceptions and experiences of the participants, which cannot be fully captured through quantitative methods. Phenomenology focuses on the essence of human experiences, emphasizing how individuals make sense of their interactions with the world around them. The study specifically applied an interpretative phenomenological analysis (IPA) approach, which is particularly suited for exploring how participants interpret their personal experiences and the meanings they attach to these experiences. IPA allows for a detailed examination of the personal, lived experiences of participants, placing importance on their interpretation of the phenomena, in this case, the challenges and rewards of integrating IoT solutions into urban environments.

**Participants**

Participants were selected through purposive sampling, aiming to include individuals who had direct involvement in smart city IoT implementation projects. Inclusion criteria specified that participants must be engineers with at least two years of professional experience working in the development and deployment of IoT technologies in urban settings. Furthermore, participants had to be actively involved in the technical, social, or managerial aspects of such projects. Exclusion criteria included engineers who were only peripherally involved or lacked substantial hands-on experience with IoT implementation in smart cities. The final sample consisted of 12 engineers (8 male, 4 female) aged between 30 and 45 years, with an average age of 38. These participants represented various roles, including system integrators, project managers, and technical experts in the field of IoT. While the sample size of 12 engineers aligns with phenomenological research practices that emphasize depth over breadth, it may limit the generalizability of the findings. The insights should therefore be viewed as exploratory and context-specific rather than universally representative. Future studies could benefit from incorporating a larger and more diverse pool of participants to strengthen the robustness and applicability of the findings across different contexts.

**Data Collection**

Data was collected through semi-structured in-depth interviews, which allowed for the exploration of participants' personal experiences in their own words. Interviews were conducted face-to-face, lasting between 45 and 90 minutes each. The interviews were carried out in a quiet and comfortable setting, either at the participants’ offices or at neutral locations, depending on their preference. A semi-structured interview guide was used to ensure that all relevant topics were covered, while also allowing for flexibility to explore issues raised by the participants during the interview. The guide included open-ended questions focusing on the challenges, successes, and personal experiences of engineers in the IoT implementation process. Interviews were audio-recorded with the participants’ consent and later transcribed verbatim for analysis. No modifications were made to the interview protocol, but probing questions were used to clarify or deepen responses when needed.

**Data Analysis**

The data was analyzed using interpretative phenomenological analysis (IPA), which is well-suited to explore how individuals make sense of their experiences. The analysis involved several systematic steps: first, the interviews were transcribed, and the transcriptions were read and re-read to gain an in-depth understanding of the content. The second step was identifying and coding significant phrases or units of meaning that related to the participants’ experiences. These meaning units were then grouped into themes that emerged from the data. The thematic analysis involved iterating through the data to identify recurrent patterns, challenges, and perceptions, focusing on the essence of the participants’ experiences in the IoT implementation process. Software such as NVivo was used for organizing and managing the data, although the main focus was on the thematic structure emerging from the interviews. The final step involved synthesizing the themes into a coherent narrative that reflected the participants’ lived experiences of implementing IoT technologies.

**Ethics**

Ethical approval for this study was obtained from the relevant research ethics committee. All participants were provided with an information sheet outlining the purpose of the research, the voluntary nature of their participation, and their right to withdraw at any time without consequence. Written informed consent was obtained from each participant prior to the interviews. Anonymity and confidentiality were strictly maintained throughout the study. Participants were assured that their identities would be protected, and all data was stored securely and only used for research purposes. The study adhered to international ethical standards for research involving human subjects, ensuring the integrity and protection of participants.

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## RESULTS

### Technical Challenges in IoT Integration

The engineers involved in smart city projects consistently described facing significant technical challenges when integrating Internet of Things (IoT) solutions into urban infrastructures. These challenges ranged from issues with interoperability between different IoT devices and existing infrastructure, to technical difficulties related to the scalability and maintenance of these systems. One engineer, reflecting on the complexity of device compatibility, stated:

"We had to integrate various IoT devices, each using different communication protocols. The lack of standardization made the process more cumbersome and time-consuming. We spent a lot of time troubleshooting communication errors between systems."

Another engineer emphasized the difficulties of ensuring the scalability of the IoT system. He remarked:

"The initial setup was relatively easy, but the real challenge emerged as we had to scale the system to cover more areas of the city. Managing and maintaining the system across a broader area with varying network conditions was a constant hurdle."

These findings underscore two core technical issues: (1) interoperability difficulties caused by non-standardized protocols, and (2) scalability constraints when extending systems across diverse urban contexts. Engineers noted that compromises in performance and durability were often unavoidable to meet strict project deadlines, highlighting how operational pressures amplify technical risks.

### Social and Community Acceptance of IoT Solutions

In contrast to the technical barriers, a distinct set of challenges emerged from the social and community side of IoT integration.Engineers consistently mentioned the initial resistance from local communities and the general public regarding the introduction of new technologies. This resistance stemmed from concerns over privacy, security, and a lack of understanding of the long-term benefits of IoT solutions.

One engineer shared:

"There was a lot of skepticism from the community about having sensors installed in public spaces. People were concerned about their privacy and data security. It took considerable effort to address these concerns through community meetings and demonstrations."

Another engineer noted the need for more public education and engagement to ensure the successful implementation of IoT technologies:

"Public awareness campaigns are essential. People need to understand how IoT works, how it benefits them, and how their data is protected. Without this trust, the system faces significant challenges in gaining acceptance."

These accounts reveal that social barriers are rooted less in the technology itself and more in issues of trust, transparency, and community engagement. Engineers stressed that technical excellence alone could not guarantee success unless coupled with effective communication strategies to address privacy and security concerns.

### Team Dynamics and Collaborative Challenges

The experience of collaboration among the team members was another critical theme. Engineers described how working in multidisciplinary teams often led to difficulties in communication and coordination. Engineers from diverse backgrounds (e.g., software development, hardware engineering, urban planning) frequently had different expectations and approaches, which led to delays and inefficiencies.

One engineer explained:

"We had engineers from all different fields, and sometimes it felt like we were speaking different languages. The lack of a unified vision often slowed progress and made problem-solving more challenging."

Despite these challenges, engineers also recognized the value of such diverse teams. They acknowledged that while it was difficult at times, collaboration ultimately led to creative problem-solving and innovative solutions.

"In the end, the diversity of our team helped us look at problems from different angles. We may have had our disagreements, but that's how we arrived at the best solutions."

This theme illustrates how collaborative difficulties are both a constraint and a catalyst: while miscommunication can delay progress, diversity of expertise often drives innovative approaches to solving complex IoT problems.By distinguishing between technical and social dimensions, the results highlight that IoT implementation challenges extend beyond engineering complexity to include community trust and collaborative dynamics. Engineers face substantial technical barriers in interoperability and scalability, while also addressing public skepticism and privacy concerns. Team collaboration further shapes the implementation process, balancing conflict with innovation. Together, these themes emphasize that successful IoT integration in smart cities requires not only technical proficiency but also strong social engagement and effective interdisciplinary teamwork.

## DISCUSSION

### Summary of Key Findings

This study explored the subjective experiences of engineers involved in the implementation of IoT technologies in smart city projects (Mutanu et al., 2022). The key findings revealed that engineers face substantial technical challenges related to system integration and scalability, as well as significant social challenges regarding community acceptance and public trust (Russo et al., 2022). These experiences provided deep insights into the complex, multifaceted nature of smart city projects, particularly from the perspective of the engineers directly engaged in these transformations.

### Contribution to the Research Question

The findings contribute to our understanding of how engineers interpret and navigate the challenges of IoT integration in smart cities (Spandonidis et al., 2023). By focusing on the lived experiences of these professionals, this study highlights the importance of not only technical competence but also the need for social engagement and community trust (Bowen & Hinze, 2022). The research underscores that technical issues like interoperability and scalability are inseparable from the social and emotional dimensions that engineers face in their work. This duality resonates with prior work by Al-Saadi et al. (2021), who emphasized that engineers' effectiveness is shaped as much by stakeholder interactions as by technical expertise. However, unlike their study, which relied primarily on survey data, the present research adds depth through qualitative insights that capture engineers' personal interpretations and lived realities.

### Relation to Literature and Previous Theories

The results align with existing research that emphasizes the interconnectedness of technical and social challenges in smart city projects (Brochado et al., 2024). Previous studies on IoT integration have often focused on either the technical aspects or the social factors separately, but this study adds a more nuanced understanding by illustrating how these dimensions intersect in the real-world context of smart city development. For example, (Moon et al., 2019) found that while engineers are adept at addressing technical challenges, they often overlook the critical role of community engagement, a gap that is addressed in the current study. Similarly, our findings reinforce the arguments of Lee & Song (2020), who suggested that public skepticism about privacy and surveillance is a persistent barrier in smart city adoption. However, this study extends their work by showing how engineers themselves actively mediate these tensions through community meetings, awareness campaigns, and trust-building strategies. Additionally, the findings reflect broader discussions in the field of human-centered technology, as discussed by (Chaves et al., 2021), which

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argue that technological implementations must consider the subjective experiences of all stakeholders involved. In contrast, other studies have underscored the dominance of technical performance metrics without considering the lived experiences of those implementing the technology (e.g., Patel et al., 2018). By moving beyond performance indicators, this study critiques that narrow focus and provides evidence that engineers' social experiences are equally critical to project outcomes.Overall, these findings contribute to the ongoing dialogue about the need for an integrated approach to IoT implementation, one that acknowledges the symbiotic relationship between technology and human experience.

**Implications of the Findings**

The findings of this study carry significant implications for both theory and practice in the context of smart city projects (Baligar, 2019). From a theoretical perspective, this research contributes to the growing body of knowledge on human-centered technology and the role of engineers in implementing complex technological systems (Gillespie et al., 2023). It emphasizes that the experiences of engineers cannot be separated from the social and cultural dimensions of their work. This echoes insights from Cardullo & Kitchin (2019), who argued that smart city systems succeed only when social acceptance is embedded into design and deployment. By demonstrating how engineers balance technical problem-solving with community concerns, this study provides empirical support for those theoretical claims. The findings suggest that successful IoT integration requires more than just technical expertise it also necessitates an understanding of community concerns, stakeholder engagement, and the human impact of these technologies (Khan et al., 2023; Moreira et al., 2020). Practically, the study highlights the need for organizations involved in smart city projects to invest in both technical and social skill development for their teams. Engineers must be equipped not only with technical tools but also with the capacity to navigate the social dynamics of urban spaces, addressing public concerns and fostering trust in these technologies.

**Study Limitations**

While this study provides valuable insights into the experiences of engineers, it is not without its limitations (Kamyod, 2023). One of the main constraints is the small sample size, which, while sufficient for phenomenological analysis, may limit the generalizability of the findings to all engineers working in smart city projects. The study focused primarily on engineers involved in technical roles, which means that the experiences of those in other roles, such as policymakers or urban planners, were not explored. Additionally, the research was conducted in a specific geographic context, and thus the findings may not fully reflect the experiences of engineers in different regions or under different regulatory or cultural conditions. Future research could expand the sample size and include diverse stakeholders in order to provide a more comprehensive understanding of the IoT integration process across various settings.

**Future Research Directions**

The findings from this study open up several avenues for future research (Wah, 2025). One potential direction is to explore the experiences of engineers across different geographical contexts to determine how cultural and regulatory factors influence their roles in smart city projects. Additionally, future studies could examine the experiences of other key stakeholders, such as urban planners, policymakers, and citizens, to gain a more holistic understanding of the IoT implementation process (Rouault et al., 2021). Further research could also investigate the long-term impact of IoT technologies on urban living, examining how the initial challenges faced by engineers evolve over time and how they continue to shape the development of smart cities. Finally, this study's findings could be used as a foundation for developing training programs that incorporate both technical and social competencies, equipping engineers with the skills necessary to address the complex challenges of modern urban environments.

## CONCLUSION

This study explored the experiences of engineers involved in the integration of IoT technologies within smart city projects, addressing the gap in understanding the subjective challenges they face. The findings revealed that engineers encounter significant technical and social obstacles, particularly in system integration, scalability, and community acceptance. These insights contribute to a more comprehensive understanding of IoT implementation by emphasizing the importance of both technical expertise and social engagement. The study addresses limitations in previous research, which largely overlooked the personal, lived experiences of those directly involved in these projects.

Future research should build on these findings by (1) examining the experiences of other stakeholders such as policymakers, urban planners, and community representatives, (2) exploring cross-cultural and cross-regional differences in IoT adoption to understand how regulatory and cultural contexts shape implementation, and (3) conducting longitudinal studies to track how technical and social challenges evolve over time as smart city infrastructures mature. In terms of practical application, follow-up research could focus on designing and evaluating training programs that integrate both technical competencies and social skills, enabling engineers to manage community engagement more effectively. Moreover, applied studies could test frameworks for balancing interoperability, scalability, and public trust, providing actionable strategies for practitioners and city governments. By doing so, future work can not only strengthen theoretical insights but also directly inform the development of human-centered policies and practices for sustainable smart city growth.

## CONFLICT OF INTEREST

The authors declare that there is no conflict of interest.

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