Preliminaries on the State-of-the-Practice on Smart Cities Projects in Brazil

David Antônio Teixeira de Moraes Barros[1], **Edison Andrade Martins Morais**[1], **Mohamad Kassab**[2,3], **Valdemar Vicente Graciano Neto**[1]

[1]Instituto de Informática – Universidade Federal de Goiás (UFG)
Goiânia – GO – Brazil

[2]Penn State University – Malvern – PA - United States

[3]The New York University at Abu Dhabi – Abu Dhabi – Arabi Emirates

davidbarros@discente.ufg.br, {valdemarneto,eammorais}@ufg.br, muk36@psu.edu

Abstract. *Smart cities emerge as a response to build the city of the future, where the well-being and rights of citizens are ensured under a sustainable perspective. Understanding the current state of smart cities in Brazil becomes essential to assess how technology is impacting urban dynamics in the country. In that sense, the main contribution of this paper is to present preliminary results of a survey research on smart city projects in Brazil. 21 professionals from 7 states and different areas responded to the survey. Results reveal that (i) there is a range of smart cities projects in different regions of Brazil; (ii) several technologies are already deployed in Brazilian cities, but (iii) infrastructure is one of the main challenges to make smart cities a full reality.*

1. Introduction

The accelerated urbanization has led to a significant increase in the urban population, with projections of reaching 70% by 2050 [5, 12, 15]. Information and Communication Technologies (ICTs) have driven technological advancement in urban environments, enabling solutions to optimize the various dimensions of urban life, such as transport, health and mobility, culminating in what is so-called as **smart cities**. Understanding the current state of smart cities in Brazil becomes essential to assess how ICTs are being implemented and impacting urban dynamics in the country. However, despite the existence of literature reviews [4], case studies [8] and non-academic rankings of smart cities in Brazil[1], the authors are unaware of a survey research study that provides an overview of smart city project initiatives in Brazil.

In this sense, the main contribution of this paper is to present preliminary results of a survey research on smart city projects in Brazil. 21 professionals, who come from seven different Brazilian states, from different areas, and who participated in ICT development projects for smart cities in Brazil responded to a questionnaire. Preliminary results reveal that (i) there is an equitable distribution of smart cities projects in different regions of Brazil; (ii) several technologies are already deployed in Brazilian cities, such as smart buildings, urban monitoring systems and smart traffic systems; (iii) infrastructure is one

[1]Brazilian Institute of Human, Smart, Creative and Sustainable Cities: https://www.ibrachics.org.br/

of the main challenges to make smart cities a full reality in Brazil; however, other several challenges exist in several areas, such as financial support, sustainability, education and management. The paper is structured as follows: Section 2 brings background; Section 3 presents the survey protocol and results; and Section 4 brings final remarks.

2. A Brief Overview of Smart Cities

Smart cities emerged initially focused on the importance of ICTs for cities infrastructure. Then, the rise and popularization of the Internet of Things (IoT) supported novel smart city experiences, incorporating systems for environmental monitoring, traffic and security [13]. Finally, in the last decade, the advancement of Big Data and Artificial Intelligence (AI) has further fostered the dissemination of solutions, with consolidated initiatives around the world, such as Barcelona, Singapore and Seoul. In short, a city can be considered smart when investments in human and social capital, as well as in traditional (such as transport) and modern infrastructure (ICT) drive sustainable economic growth and result in a high quality of life for citizens. This *smartness* is manifested through efficient management of natural resources and the promotion of a participatory governance model. Smart cities are often analyzed under determined dimensions [14], which include smart (i) economy, (ii) people, (iii) governance, (iv) mobility, (v) environment, (vi) living and all other dimensions of the urban life that can be enhanced by the use of ICT or other smart solutions. In Brazil, there is a growing adoption of smart technologies. According to the Brazilian Institute of Geography and Statistics (IBGE) [7], 14.3% of Brazilian households have smart devices, and 93% of the number of homes have internet access. Projects such as Porto Maravilha, in Rio de Janeiro, public transport in Curitiba, and the Água Branca Consortium Urban Operation, in São Paulo, are examples of innovative interventions [3, 16].

Related Work. Lazzaretti (2018) identified the network of Brazilian researchers dedicated to the study of smart cities [9]. The results of their study revealed that 58 public and private universities in Brazil host research groups in different areas focused on smart cities. Weiss et al. (2017) [16] addresses the implementation of smart cities in Brazil, reflecting on the specific challenges of the Brazilian context in creating smart cities, considering the predominance of social and political issues. In our study, we update part of the results of Weiss et al. (2017), reporting up-to-date results 7 years after their study was published. A search in Google Scholar in February, 2024 using the string ``survey smart cities Brazil'' reveals that hundreds of studies are retrieved. However, although there exist studies in Portuguese and English, literature reviews, case studies, and maturity models, including a Brazilian one [1], we are not aware of other survey research results, as ours.

3. Survey Research

For this research, a protocol was developed inspired by *guidelines* for conducting survey research [11], in addition to prior experiences with this type of study [10]. The conduction method was composed of four steps: **Step 1) Planning, Step 2) Execution, Step 3) Analysis** and **Step 4) Reporting**, as follows.

Step 1) Planning. Due to space restriction, a web page with supplementary material is available, with the complete protocol, justifications for the research questions,

copy of the form and answers, following the principles of Open Science[2]. The **objective of this research** was *to explore the scenario of technologies related to Smart Cities in Brazil from the perspective of technology professionals*. From the objective, the following research questions (**RQ**) were derived: ***RQ1) What is the geographic coverage of Smart Cities distributed across the Brazilian territory? RQ2) Which implementations of technologies related to the smart city concept are predominant in Brazil? RQ3) What are the potential challenges and difficulties that technology professionals may face when implementing Smart Cities technologies in Brazil?***

Identification of the target audience. The study population is made up of professionals actively involved in technology, specifically those who work on projects or research related to Smart Cities in industry or academia in Brazil.

Ethical issues. The questionnaire was designed with a Free and Informed Consent Form (TCLE), exempting approval from an Ethics Committee, as it falls into the category *Public opinion research with non-identifiable participants*, according to Circular Letter No. 17/2022 /CONEP/SECNS/MS, July 2022 and CIRCULAR LETTER No. 12/2023/CONEP/SECNS/DGIP/SE/MS[3].

Sampling planning. The sampling plan employs a combination of incidental sampling, where invitations are extended to a broad group of participants, and snowball sampling, encouraging participants to invite colleagues or partners from their professional networks. This approach is adopted to ensure a diverse and representative sample of technology professionals involved in initiatives related to Smart Cities in Brazil.

Step 2) Execution. Data collection took place between December 15, 2023 and January 21, 2024. Invitations to participate in the survey were made per convenience to research groups and R&D teams that work with smart cities, in addition to posts on LinkedIn. It is not possible to estimate the response rate accurately.

Step 3) Analysis. After the responses were received, the data was accordingly normalized to anonymize the respondents. The data was synthesized so that the RQ could be answered, as follows.

Demographics. The survey received responses from 21 participants. All respondents have academic degree and a significant majority, 14 (66.66%), has extensive development, holding a doctorate or master's degree. In this regard, participants are distributed as follows: Completed Doctorate (23.80%), Doctorate in progress (4.76%), Complete Master's degree (38.09%), MBA or *Lato sensu* (14.28%), Undergraduation (14.28%) and Undergraduation in Progress (4.76%). The survey included a detailed analysis of participants' academic career, providing valuable insights into educational diversity within the group. Among the 21 participants, the distribution in regards to the academic area is as follows: Technology Courses (61.90%), Management (14.29%),

[2]https://ww2.inf.ufg.br/~valdemarneto/projects/surveySmartCities.html

[3]https://conselho.saude.gov.br/images/comissoes/conep/documentos/CARTAS/SEI_MS_0035011614_Oficio_Circular.pdf

Electrical Engineering (4.76%), International Relations (4. 76%), Mathematics (4.76%), Civil Engineering (4.76%), Physical Education (4.76%). These data reveal the diverse and interdisciplinary nature that Smart Cities demand.

When analyzing the participants from the perspective of their professional profile, as can be seen in the graph, it is clear that 12 of them (57.14%) are involved in academic activities, while 7 (33.33%) perform roles in Public Administration and 4 (19.04%) work in Private Institutions. This scenario reflects an equitable distribution between the academic and non-academic sectors. Furthermore, it is important to note that 3 participants are students, and another 3 work in both spheres, highlighting a diversity of perspectives in the data collected. The average age of the participants was 33 years old, with the youngest being 22 years old and the oldest being 50 years old, allowing us to infer a predominance of young people when we approach the topic. Regarding gender identification, 4 (19.04%) identified themselves as women, and 17 (80.96%) as men, highlighting the male predominance in the sample.

Step 4) Reporting. In this section, we answer the research questions, as follows.

RQ1 - What is the geographic coverage of Smart Cities distributed across the Brazilian territory? The geographic distribution of participants is remarkably diverse, reflecting an equitable representation of different regions of Brazil, although there is a gap in relation to the North region due to the absence of participants from this region. The survey received responses from Goiás (3), Rio de Janeiro (2), Rio Grande do Sul (6), Maranhão (5), São Paulo (2), Paraná (2) and Rio Grande do Norte (1). We could not state that this is the real distribution, since we do not have data from the entire country. Then, we partially answer this question by covering regions and states from where we received answers.

RQ2 - Which implementations of technologies related to the smart city concept are predominant in Brazil? Seven participants (33.3%) highlighted the presence of smart buildings, while 7 (33.3%) identified smart homes. Smart grids were mentioned by 4 participants (19%). 42.9% of them highlighted the implementation of smart traffic systems, and 3 (14.3%) mentioned smart management systems. Smart health was mentioned by 5 participants (23.8%), as was smart governance. Electric vehicles were indicated by 4 participants (19%), while autonomous vehicles were not mentioned by any participant. Smart campuses were identified by 2 participants (9.5%), and 1 (4.8%) of the participants mentioned the lack of implementations, lack of knowledge or the use of urban video surveillance. Urban monitoring systems was mentioned by 12 (57.1%), renewable energies, smart mobility technologies and big data and data analysis were also mentioned, each with 8 respondents (38.1%).

Concerning the technologies that underpin those solutions, IoT is predominant, being mentioned by 11 participants (52.4%). Sensor networks were mentioned by 6 participants (28.6%), while 1 (4.8%) indicated that they did not identify any of these technologies. With regard to devices, smartphones were highlighted by 20 participants (95.2%), tablets by 5 (23.8%), personal computers by 4 (19%), video devices by 8 (38.1%), wearable devices by 5 (23.8%), and in-vehicle navigation systems by 7 (33.3%).

RQ3 - What are the potential challenges and difficulties that technology profes-

sionals may face when implementing Smart Cities technologies in Brazil?

A plethora of challenges and difficulties when implementing Smart Cities technologies in Brazil were reported. In the scope of infrastructure and connectivity, 11 participants (52.4%) highlighted challenges related to infrastructure, while 8 participants (38.1%) highlighted the scarce coverage of communication networks as an obstacle. Limitations in electrical grid infrastructure were mentioned by 7 participants (33.3%). One participant (4.8%) was unable to provide details. Regarding finantial challenges, 19 participants (90.5%) indicated budget limitations as a significant barrier. The difficulty in accessing financing for smart city projects was mentioned by 7 participants (33.3%), while 10 participants (47.6%) pointed out the high cost of maintaining the implemented technologies. One participant (4.8%) mentioned cultural change as a challenge in accepting new technologies. About challenges for sustainable energy, 13 participants (61.9%) pointed to a lack of awareness about sustainable practices. Limitations in accessing renewable energy sources were mentioned by 2 participants (9.5%), while 12 participants (57.1%) highlighted the difficulty in implementing clean energy solutions. One participant (4.8%) suggested the region's high potential for sustainable energy projects, particularly in solar energy. In education and training, 13 participants (61.9%) highlighted the lack of educational programs on modern technologies. The difficulty in training local professionals was mentioned by 11 participants (52.4%). Two participants (9.5%) indicated that they did not face challenges in this aspect, while two others were unable to provide details. The modernization of culture within public management was cited by 1 participant (4.8%). In data management and privacy, the main concerns highlighted by 14 participants (66.7%) refer to data security and privacy. The difficulty in ensuring the application of privacy policies was highlighted by 13 participants (61.9%), while 11 participants (52.4%) mentioned the lack of professionals specialized in data analysis and management as a challenge[4].

4. Final Remarks

The main contribution of this paper was to present preliminary results of a survey research on the infrastructure of smart cities in Brazil. 21 people involved in ICT projects on smart cities from 7 states and 4 different regions participated. The results reveal that (i) smart cities projects are relatively well spread in the Brazilian territory (considering the modest numbers and sample of the study); (ii) several technologies are already deployed in Brazilian cities; and (iii) infrastructure is still the main challenge. The lack of awareness about sustainable practices by citizens is a strong challenge, since solutions need to be realand it is essential to rely on citizens in the maintenance and evolution of a smart city (government, academia, industry, but also citizens). The identified challenges can serve as an agenda to guide efforts for the sustainable advancement of Smart Cities in Brazil. Smart Cities are Systems-of-Systems [6] and one of the Grand Challenges in Information Systems for the Decade 2016-2026 [2]. This work contributes for advancing this grand challenge with updated data on the state of practice in smart city projects in Brazil. Future work include a systematic review and further methodological procedures.

[4]Due to the space restrictions, discussion is not presented herein. It can be consulted in the external supplementary document at `https://ww2.inf.ufg.br/~valdemarneto/projects/surveySmartCities.html`

References

[1] Afonso, R. A., dos Santos Brito, K., do Nascimento, C. H., Garcia, V. C., and Álvaro, A. (2015). Brazilian smart cities: using a maturity model to measure and compare inequality in cities. In *Proceedings of the 16th annual international conference on digital government research*, pages 230–238.

[2] Bernardini, F. C., Viterbo, J., Vianna, D. S., Martins, C. B., de Medeiros, A. P., Meza, E. B. M., Moratori, P. B., and Bastos, C. A. M. (2017). General Features of Smart City Approaches from Information Systems Perspective and Its Challenges. In Araujo, R., Maciel, R., and Boscarioli, C., editors, *Grand Challenges in Information Systems for the Next 10 years*, pages 25–40. Brazilian Computer Society, Porto Alegre, Brazil.

[3] Bichueti, R. S., Gomes, C. M., Kneipp, J. M., Motke, F. D., and Da Costa, C. R. R. (2019). Cidades sustentáveis no contexto brasileiro: A importância do planejamento para o desenvolvimento urbano sustentável. *XIX ENGEMA*, pages 1–16.

[4] de Paula, I., Viana, F. D. F., Rodrigues, L. F., Rocha, S. A. S., and Silva, A. L. (2022). Cidades inteligentes no Brasil: uma revisão sistemática da literatura. In *Anais do Encontro Nacional de Engenharia de Produção*, pages 1–13, Foz do Iguaçu, Brazil.

[5] Graciano Neto, V. V. and Kassab, M. (2023). *What Every Engineer Should Know About Smart Cities*. CRC Press - Taylor & Francis. 1st Edition. 254 p.

[6] Graciano Neto, V. V., Oquendo, F., and Nakagawa, E. Y. (2017). Smart Systems-of-Information Systems: Foundations and an Assessment Model for Research Development. In Araujo, R., Maciel, R., and Boscarioli, C., editors, *Grand Challenges in Information Systems for the Next 10 years*, pages 1–12. Brazilian Computer Society, Porto Alegre, Brazil.

[7] IBGE (2022). Pnade contínua. *https://agenciadenoticias.ibge.gov.br/agencia-noticias/2012-agencia-de-noticias/noticias/38306-em-2022-streaming-estava-presente-em-43-4-dos-domicilios-com-tv*.

[8] Júnior, L. A. F., de Almeida Guimarães, L. G., El-Aouar, W. A., and da Silva, B. A. M. (2023). Cidades inteligentes: mapeando pesquisas, projetos, iniciativas e grupos nas capitais brasileiras. *Revista Tecnologia e Sociedade*, 19(55):149–175.

[9] K.Lazzaretti, e. a. (2018). Cidades inteligentes: insights e contribuições das pesquisas brasileiras. *urbe. Revista Brasileira de Gestão Urbana*.

[10] Lebtag, B. G. A., Teixeira, P. G., dos Santos, R. P., Viana, D., and Neto, V. V. G. (2022). Strategies to evolve exm notations extracted from a survey with software engineering professionals perspective. *J. Softw. Eng. Res. Dev.*, 10:2:1–2:24.

[11] Molléri, J. S., Petersen, K., and Mendes, E. (2016). Survey guidelines in software engineering: An annotated review. ESEM '16, pages 58:1–58:6, Ciudad Real, Spain.

[12] Rocha, V., Alves, L., Graciano Neto, V. V., and Kassab, M. (2019). A review on the adoption of agile methods in the technology development for smart cities. In *Anais do II Workshop Brasileiro de Cidades Inteligentes*, Belém. SBC.

[13] Schönfelder, S. and Axhausen, K. W. (2016). *Urban rhythms and travel behaviour: spatial and temporal phenomena of daily travel*. Routledge.

[14] Song, H., Srinivasan, R., Sookoor, T., and Jeschke, S. (2017). *Smart cities: foundations, principles, and applications*. John Wiley & Sons.

[15] UN, U. N. (2015). Agenda 2030 para desenvolvimento sustentável. *brasil.un.org/pt-br/91863-agenda-2030-para-o-desenvolvimento-sustentável*.

[16] Weiss, M. C., Bernardes, R. C., and Consoni, F. L. (2017). Cidades inteligentes: casos e perspectivas para as cidades brasileiras. *Revista tecnológica da Fatec americana*, 5(1):01–13.