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Research Article

Mathematical Insights into Framework Design for Ethical and Cyber-Secure Smart Cities

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ABSTRACT

As urban populations worldwide continue to rise, smart city initiatives are increasingly harnessing the Internet of Things (IoT) to create smarter, more efficient, and cost-effective solutions, addressing challenges such as pollution, accidents, insecurity, and environmental degradation. This study integrates key research and develops interactive models for smart cities, focusing on mobile device privacy, infrastructure, energy management, healthcare, and frameworks to enhance security and public engagement with smart services, alongside the roles of blockchain and social media. It emphasizes the need for sustainable and intelligent city projects, evaluating their effectiveness through advanced techniques. The research employs the Intuitive Fuzzy Decision-Making Experiment and Evaluation Laboratory (IF-DEMATEL) and the Intuitive Fuzzy Analytical Hierarchy Process (IF-AHP) within a Multiple Criteria Decision-Making (MCDM) model. Findings reveal that among 23 critical elements impacting Smart City Development (SCD), Smart Living and Governance (SLG) stands out as the most significant dimension, with SLG and Smart Life and Management (SGL) showing the strongest interrelations. Ultimately, the study underscores the potential economic and social benefits of smart city initiatives, particularly in nations like India, the UAE, and Morocco, while providing strategies for practitioners to enhance the implementation of sustainable smart city models, with IoT being pivotal in delivering effective smart services.

Keywords: Internet of Things (IoT), Smart City Development, Multi-Criteria Decision Making (MCDM), Analytical Hierarchy Process(AHP)

INTRODUCTION

The global population has experienced significant growth over the past three decades [1], leading to a pressing need for advancements in housing, transportation, employment, healthcare, and education. In many developing countries, a shortage of housing in rural areas has driven a substantial migration to urban centers. Projections indicate that by 2030, around 60% of the population will reside in cities, a figure expected to rise to 75% by 2050 [2, 3]. Economic expansion, urbanization, and international development are recognized as pivotal factors for the continuation of human civilization. The surge in global population has contributed to rapid urban growth and migration in recent years, resulting in challenges such as inadequate public transportation, compromised security, pollution, insecurity, and economic stagnation. Addressing these issues necessitates urban resource planning aimed at resolving these problems and enhancing citizens' quality of life. To tackle these challenges, urban planning and environments require innovative solutions and advanced technologies [4]. Smart city development has emerged as a strategic solution for urban progress, gaining widespread traction. The implementation of technology is integral to achieving smart cities, with conversational technology being integrated into nearly every product to enhance service quality and citizens' overall quality of life.

The smart concept is viewed as a promising catalyst for national growth and advancement [5]. Over the past two years, the smart city concept has garnered significant attention, with numerous perspectives in the literature defining what constitutes a smart city [6]. IBM's unveiling of its smart city vision in 2009 garnered global interest in the transformation of traditional cities into smart cities. Consequently, nearly 100 smart cities were being planned and built by China in 2010 [7]. For Smart City Development (SCD), the Indian government has unveiled the "100 Smart Cities Mission" in 2015 [8]. To cope with rapid urban expansion and enhance citizen services, Taiwan embraced a new SCD approach and established a smart city in Taipei [9].

The Korea Research Institute of Human Settlements (KRIHS), in collaboration with the Inter-American Development Bank (IDB), introduced a project to construct a new smart city near Seoul, with aspirations of becoming South Korea's Silicon Valley [10]. Developing countries are striving to adopt effective and efficient SCD strategies from more developed counterparts [11]. However, this transition is challenging due to the social, economic, and technological resources required to accomplish this feat. Therefore, developing nations need to establish mechanisms that support and promote smart city development. Various studies [12, 13] have identified multiple dimensions crucial to supporting SCD, including business acumen, financial resources, sustainability, technology, governance, and collaboration between business and government. Additionally, authors have outlined India's endeavors to enhance sustainable development through smart city initiatives [14], Smart education based on IoT is that pledges to upgrade the basic education system into smart education environment [15]. While Ibrahim et al. have emphasized key elements of smart cities that bolster sustainable development [16]. The primary subjects covered by SCD include a number of important domains, such as service management, which is concerned with planning and coordinating the provision of services. The improvement of quality also prioritizes raising benchmarks and yields in several industries. Another important component is digital governance, which deals with the policies and plans for integrating digital technology into public administration. While intelligent transportation looks at creative ways to enhance mobility and transportation systems, connected living investigates how technology may be integrated into daily life to boost efficiency and convenience. ICT, or information and communication technology, is crucial to these activities because it facilitates efficient information sharing and communication, which advances the cause. Safeguarding is also a critical concern, ensuring the protection of individuals and communities, alongside the concept of empowered citizens, which highlights the importance of engaging and enabling individuals to participate actively in society.

The COVID-19 pandemic has underscored the global significance of preserving cultural heritage. Author has given figure of affected cases due to COVID-19[17]. Both developed and developing cities are seeking data and tools to gather critical information and implement interventions to save lives during crises. A key step in realizing the long-held vision of "smart cities" is the effective use of digital resources. However, the pandemic has also brought to light policy, regulatory, and operational challenges that have emerged since the inception of the smart city concept. These issues pertain to information security, personal privacy protection, secure and rapid information sharing between institutions and organizations. As we contemplate recovery from the pandemic and invest in building resilience for future disasters, it's crucial for governments to address responses to the inequitable policies that impact us. In its first study on urban governance, the World Economic Forum recently highlighted the G20 Global Smart Cities Alliance. This coalition promotes the ethical and responsible application of smart city technologies and comprises over 200,000 cities, local governments, established businesses, startups, research centers, and non-governmental organizations.

The COVID-19 pandemic has had a major impact on communities, businesses, and governments across the globe since 2019. As of April 2020, the economies of almost all nations are in trouble. One of the worst economic and health crises in history is currently plaguing cities, which have historically been engines of economic progress. In this context, smart city technologies can play a role in enhancing cities' response and resilience to current and future shocks while also promoting employment and improving livelihoods. Cities like Melbourne are utilizing foot traffic data to analyze economic activity, while Seoul and Singapore are providing rapid services due to investments in data infrastructure. However, as demonstrated by the incident in Singapore, the rapid adoption of technology can lead to public backlash. Cities may struggle to pursue stable policies during a crisis while seeking solutions. Future investments in new technologies may be influenced by the need for efficient and effective operations. It's essential to ensure that regulations are in places that embed ethical and responsible governance as city leaders begin to explore technologies like chatbots and facial recognition for operational efficiencies and new services. This will ensure that communities can swiftly implement innovative solutions without compromising sustainability, privacy, or cybersecurity.

OBJECTIVES

The idea of a "smart city" has gained popularity in recent years, a number of studies describing various facets of the

Smart City Development concept have been published in the literature. Consequently, the aim of this paper is to present the applications, benefits, and approaches of SCD.

The paper "Governing Smart Cities" acts as a guide for municipalities aiming to establish regulations for the ethical and accountable management of their smart city initiatives. It examines current practices in relation to five fundamental principles:

Open data, privacy impact analysis, cyber accountability, and ICT accessibility. The conclusions are based on surveys and interviews with policy experts and local government representatives from the 36 "Pioneer Cities" of the Alliance. Rather than relying solely on high-level indicators, the paper's insights are derived from an analysis of specific policy components. The analysis in this report exposes substantial discrepancies among cities of all sizes, in all geographies, and at all stages of economic development using model policies created by international experts as a framework. Our Pioneer Cities include:

- Because of how quickly the pandemic has accelerated digital transformation and the adoption of municipal services, having accessible digital city services is critical for an inclusive city. However, fewer than half of cities have policies in place to incorporate fundamental accessibility standards into ICT procurement, and fewer than half have provided proof that these requirements are met as described in Figure 1.

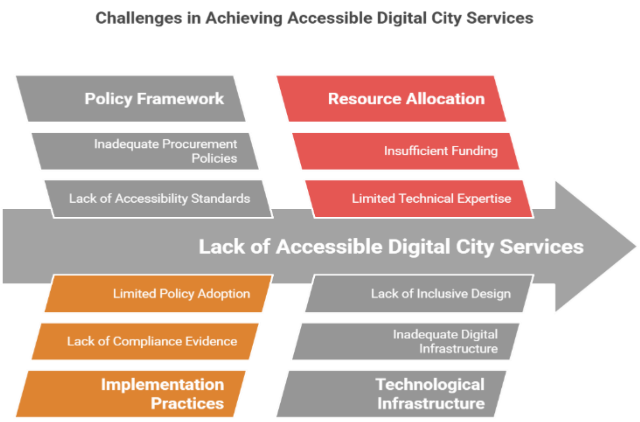


Figure 1: Digital City Services

- 80% of cities recognize their legal responsibility to protect citizens' privacy and personal information, yet only 25% actually do privacy effect analyses before implementing new technologies as represented in Figure 2.

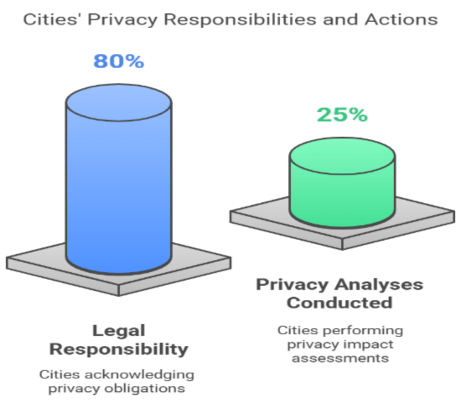


Figure 2: Cities Privacy Responsibilites and Actions

- There seems to have been a rise in cyberattacks against local governments and services during the pandemic shown in Figure 3. Despite this, few cities have a dedicated person in charge of cybersecurity or a plan that is routinely examined by senior officials.

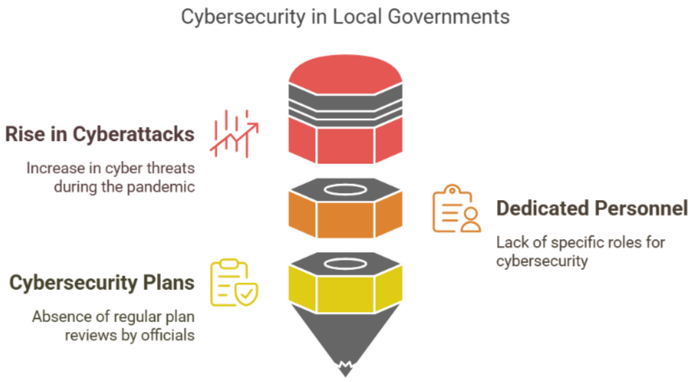


Figure 3: Cyber Attacks in Local Governments

- The epidemic has been characterized by home schooling and online learning. The digital infrastructure required to facilitate or sustain this transformation as in Figure 4, however, is lacking in many places.

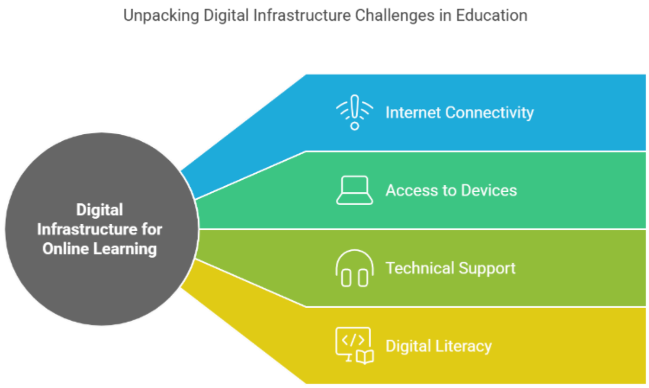


Figure 4: Digital Infrastructure for Online Learning

Today, software forms the basis of many modern devices, such as PCs, smart phones, tablets and navigation systems that we have come to rely on so heavily in our everyday lives [18]. Less than half of the Pioneer Cities have a "Dig Once" policy in place to guarantee that digital infrastructure is installed during street excavations and construction projects. In addition to lessening interruption, this would hasten the deployment of connectivity infrastructure. Furthermore, less than one-third of cities have the governance structures required to implement a Dig Once policy and accelerate connection roll-out. Perhaps the only area where most of the cities in our study have attained a degree of fundamental implementation is open data policy. Even here, just 15% of the Pioneer Cities have done what is required to make a city "open by default"—integrated their open data portals with their larger city data infrastructure. These findings show that today's cities do not have buildings designed to protect their interests and ensure the sustainability of their smart cities. The main purpose of this study is to understand SCD rules. SCD research and analysis, especially in developing countries, is still in its infancy and more analysis is needed to understand the concept. Therefore, this study proposed a framework to assist policymakers in planning sustainable development in Morocco. This study presents a new method based on multidimensional decision making (MCDM) to examine the relationship and degree of impact of smart city variables/models. All previous studies focusing on the development and/or measurement of size in SCD have used various MCDM methods [19-27].

OVERVIEW OF CYBER ATTACKS

A security attack refers to any action that undermines an organization's information security while using a method meant to detect it. There are various types of attacks, but the following are the most common:

- Denial of Service Attacks: These are commonly used to render resources, such as a web server, inaccessible to users. They overload the system with fraudulent service requests, causing the resource to slow down or crash due to the sheer volume of inquiries.
- Brute Force Attacks: These attacks aim to breach the system's password protection through a trial-and-error approach. They account for a significant portion of network attacks, with automated software guessing hundreds or thousands of password combinations.
- Browser Attacks: Targeting internet users, these attacks lead to unwittingly downloading malware through fake software upgrades or applications. Keeping web browsers updated is a key strategy for mitigating these risks.
- Shellshock Attacks: Exploiting vulnerabilities in the widely used Bash command-line shell on Linux and UNIX systems, these attacks persist due to many systems not being updated. Their widespread nature makes Shellshock a common target for network attacks.
- SSL Attacks: In these attacks, data transmitted over an encrypted connection is intercepted, allowing access to unencrypted data. They remain prevalent in the present day.
- Backdoor Attacks: These attacks create a means for remote access bypassing standard authentication, often through intentional software design or modification. Backdoors are less common but still pose a threat.
- Botnet Attacks: Perpetrators use botnets to carry out malicious activities, and these networks can be rented for nefarious purposes. A botnet can ensnare millions of devices, making it a potent tool for attackers.

CYBER SECURITY APPLICATION CHALLENGES AND GAPS

The primary goal of security is to prioritize the identification of security risks within the software and conduct thorough testing to ensure the effectiveness of implemented security measures. Research indicates that implementing security techniques is crucial for securing data communication among systems and devices with varying capabilities.

- Facilitating secure and seamless communication across diverse devices.
- Ensuring comprehensive protection of sensitive data throughout its lifecycle.
- Utilizing a unified representation of diverse collected data.
- Offering remote bulk update and system recovery solutions in case of cyber attacks or intrusions.

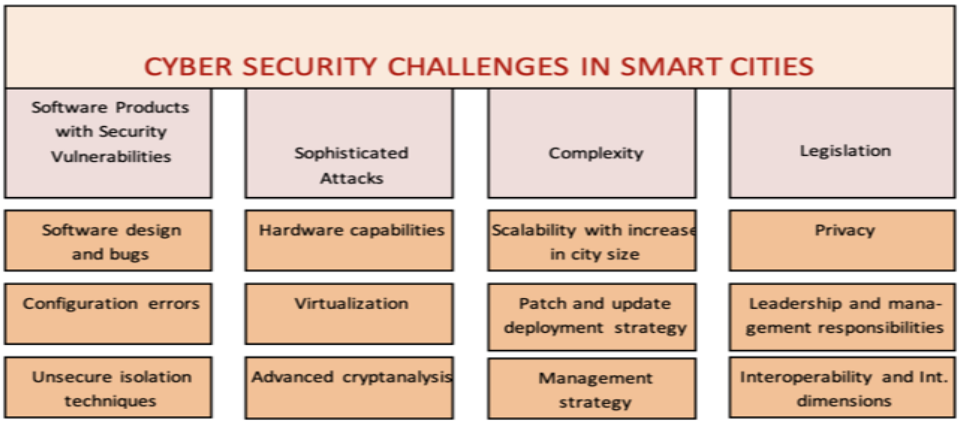


Figure 5: Cyber Security challenges in smart city

Moreover, as advanced nations aim to be at the forefront of embracing new technologies, it is important to take into account the differing levels of social and technological progress across societies to expand the potential of these applications for the benefit of a wider population. For instance, existing research on smart transportation has primarily focused on fully digitalized urban societies. While traffic congestion and road safety are equally important in developing countries, they are less able to contribute to a more favorable perception of smart transportation due to inadequate road and telecommunication infrastructure, as well as ineffective traffic monitoring systems. The main discoveries from the research gap are outlined below:

- 41% of the cities included in the survey have established policies mandating that ICT procurement must adhere to minimum accessibility standards.
- When new technologies are introduced, 25% of cities conduct privacy impact analyses.
- 40% of cities have implemented a "dig once" policy to ensure that digital infrastructure is incorporated during street excavations and construction projects.
- 15% of respondents have integrated their open data portals with the broader city data infrastructure to make the city open by default

METHODS

MCDM Approaches for smart city development: Multi-Criteria Decision Making (MCDM) can address complex problems with multiple criteria and has been applied to various issues related to SCD (Smart City Development). Certain studies have shown a preference for using AHP and ANP to calculate weights and determine valuesover other MCDM methods. MCDM, employing mathematical process (MP) or artificial intelligence (AI) technology, is also employed to address diverse smart city challenges. Mathematical process (MP) are utilized for information gathering and service design in smart city projects [28].

Energy measurement and optimization [29, 30], as well as geospatial data planning [31, 32], can also benefit from the MP method. Additionally, AI models can solve complex problems. Problems and desired results influence the choice of MCDM methods [33]. These criteria include weights, rankings, goals and more. The weight of the selected size/pattern must be calculated. Finally, biases and uncertainties in decision making must be considered and taken into account. Considering the purpose of this study, the DEMATEL method seems to be the best option in solving problems where there is a relationship between various dimensions/processes [34]. Conversely, the AHP method is regarded as a significant choice for determining the weight of each dimension/measurement. Moreover, Intuitive Fuzzy Set Theory (IFS) serves as a potent tool for addressing ambiguity in data. To achieve the objective, a hybrid heuristic fuzzy AHP-DEMATEL method was employed.

Proposed research methodology: Initially, a thorough review of literature was undertaken to identify the key factors and processes that drive SCD leaders. The research data on SCD sizes was then selected and compiled into an Excel sheet. This list was then forwarded to the expert panel, comprising professionals from various fields such as environmental science, information technology, and elected officials. These experts were tasked with evaluating the validity and strength of the relationships between the chosen models. Subsequently, the IF-AHP method was systematically employed to calculate the importance or intensity of influence (weight) of the shortlisted dimensions/criteria. Additionally, an IF-DEMATEL analysis was conducted to ascertain the driving force and magnitude within the framework. The DEMATEL method was utilized to establish a correlation system for the MCDM method, enabling the examination of direct and indirect relationships between system dimensions and system type and complexity as shown in Figure 6.

IF-AHP and IF-DEMATEL Methods:

I. Intuitive Fuzzy Set Theory: In 1965, Zadeh proposed fuzzy set theory, which was inspired by Atanassov's intuitive fuzzy set theory introduced in 1986 [35, 36]. Expanding on the concept of intuitional triangular fuzzy numbers (ITFN) as suggested by Nehi and Maleki [37], trapezoidal intuitionistic fuzzy numbers (TrIFN) can be created. This involves a generalization of intuitionistic fuzzy collapse [38], which generates a continuous set of non-parallel problems represented by two intuitionistic fuzzy numbers (triangle and trapezoid). There are two types of functions in intuitionistic fuzzy set (IFS) theory- membership and non-membership. IFSs have demonstrated definite benefits in managing ambiguity and uncertainty, in contrast to fuzzy sets theory, which does not take decision-makers' reluctance into consideration [39]. The primary benefits of IFSs are as follows [40–43].

- IFS can use different levels of uncertainty to model uncertain data. Therefore, the IFS should be selected using fuzzy techniques to capture the actual perception when the decision maker doubts the outcome.

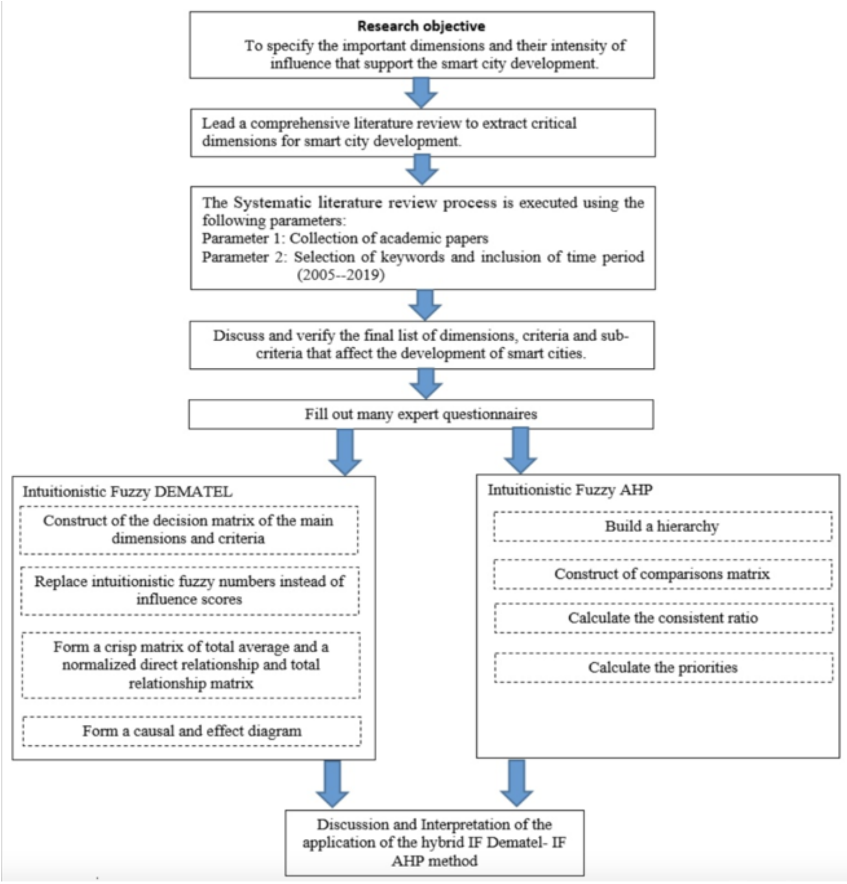


Figure 6: Architecture of the proposed methodology

- IFS can consist of three types of membership: non-interest-bearing, member and non-member. Therefore, it is similar to the second type of fuzzy set. However, each fuzzy number represents only one membership level, which is an integer in the range [0,1].
- No uncertainty can reflect expert “agreement.” It merely expresses the ambiguity of “consensus.” IFS often analyze decisions or preferences from our perspective to provide with a more accurate description.

The following discussion [44] presents concepts and ideas from a surprising perspective that is important for understanding the topic.

Definition 1. Let F be a fixed set, then an IFS A in F is defined as:

$$A = \{(f, \mu_A(f), v_A(f)) \mid f \in F\} \qquad (1)$$

where $\mu_A(f) : (F) \rightarrow [0, 1]$ and $v_A(f) : (F) \rightarrow [0, 1]$ are defined such that $0 \leq \mu_A(f) + v_A(f) \leq$, $f \in F$. The number $\mu_A(f)$ indicates membership degree and $v_A(f)$ denotes non-membership degree of element $f \in F$ to set A. The $\pi_A(f)$ is hesitance level of $f \in F$ to A and $0 \leq \pi_A(f) \leq 1$, $f \in F$ which are calculated according using Equation (1), can be calculated using Equation (2) [35]:

$$\pi_A(f) = 1 - \mu_A(f) - v_A(f), \qquad f \in F \qquad (2)$$

II. Sensationalist IF-DEMATEL, or fuzzy DEMATEL: The process of constructing a model based on the interrelationships between components is known as DEMATEL. The Battelle Memorial Institute in Geneva developed the DEMATEL method for researching and studying human connections in order to tackle intricate and related issues. In DEMATEL, each factor is grouped into cause and effect categories, which are established by aggregating the influence values of the different elements. This categorization facilitates a deeper understanding of the constituent parts of the system to identify issues and propose solutions [45]. The IF-DEMATEL method involves the following phases [46].

Establishing a relationship matrix: Experts use the scale presented in Table 1 to compare the models and create a relationship matrix A (n × n), where n represents all the models. The numbers Aij, which indicate the extent to which criterion i impacts j, are used to represent each element of the matrix A(n×n). The n × n average is calculated for each expert judgmentmatrices. A is calculated as follows:

$$a_{ij} = \frac{\sum_{k=1}^{H} F_{ij}^{k}}{H}$$

where H represents all experts

Use the following equation to calculate the normalized matrix of the initial correlation:

$$F = k.A$$

$$k = \frac{1}{\max \sum_{j=1}^{n} aij}$$

Create the entire T correlation matrix using the equation below. The number matrix is represented by I.

$$T = F(I - F) - 1$$

Create a logic diagram. D and R represent all lines and all lines respectively, including the following equation:

$$T = [t_{ij}]_{n\times n} \; i,j = 1,2,\dots,n$$

$$R = [\sum_{i=1}^{n} t_{ij}]_{1\times n}^{t} = [t_j]_{1\times n}$$

$$D = [\sum_{i=1}^{n} t_{ij}]_{n\times 1} = [t_i]_{1\times n}$$

The total value and importance of each measurement (horizontal axis) are denoted by (D + R), while the outcome of each measurement (vertical axis) is represented by (D - R). Typically, if (D - R) is positive, the index is presented in the working group, and if it is negative, the index is divided by the group's results.

Table 1: Representation value of trapezoidal fuzzy number for word content

Linguistic Expressions	Acronyms	Influence Score	Trapezoidal IF Numbers Expected	Crisp Value
Absolutely Low Influence	ALI	0	((0; 0; 0; 0); (0; 0; 0; 0))	0
Low Influence	LI	1	((0; 0,1; 0,2; 0,3); (0; 0,1; 0,2; 0,3))	0,15
Fairly Low Influence	FLI	2	((0,1; 0,2; 0,3; 0,4); (0; 0,2; 0,3; 0,5))	0,25
Medium Influence	MI	3	((0,3; 0,4; 0,5; 0,6); (0,2; 0,4; 0,5; 0,7))	0,45
Fairly High Influence	FHI	4	((0,5; 0,6; 0,7; 0,8); (0,4; 0,6; 0,7; 0,9))	0,65
High Influence	HI	5	((0,7; 0,8; 0,9; 1) ; (0,7; 0,8; 0,9; 1))	0,85
Absolutely High Influence	AHI	6	((1; 1; 1; 1); (1; 1; 1; 1))	1

III. Intuitionistic Fuzzy Analytic Hierarchy Process (IFAHP)Technique:

Hierarchy is a valuable and effective method for organizing knowledge or insights derived from information. By examining the order and distribution of numerical values, hierarchies provide a means to comprehend the complexity of the world around us [47]. In this research, the combination of IFS with the AHP model is explored, encompassing its limitations in decision-making and precise guidance. The advantage lies in the representation of both members and non-members. The following are the steps of the IF-AHP approach described in [48]:

- When constructing a hierarchical problem model, an IFS matrix is created to determine k experts and n dimensions/scales. Table 2 illustrates the evaluation values provided by the expert. The decision matrix of the kth expert is expressed by the following equation:

$$R^{(k)} = (r_{ij}^{(k)})n \times n = \begin{pmatrix} r_{11}^{(k)} & r_{12}^{(k)} \cdots & r_{1n}^{(k)} \\ \vdots & & \vdots \\ r_{n1}^{(k)} & r_{n2}^{(k)} \cdots & r_{nn}^{(k)} \end{pmatrix}$$

$$\text{Where } r_{ij}^{(k)} = (\mu_{ij}^{(k)}, \upsilon_{ij}^{(k)}, \pi_{ij}^{(k)})$$

Table 2: Comparison between Intuitive fuzzy numbers and communication terms

Linguistic Expressions	Acronyms	IFNs
Extreme low	EL	(0.05, 0.95, 0.0)
Very low	VL	(0.15, 0.8, 0.05)
Low	L	(0.25, 0.65, 0.1)
Medium low	ML	(0.35, 0.55, 0.1)
Medium	M	(0.5, 0.4, 0.1)
Medium high	MH	(0.65, 0.25, 0.1)
High	H	(0.75, 0.15, 0.1)
Very high	VH	(0.85, 0.1, 0.05)
Extreme high	EH	(0.95, 0.05, 0)

- If we denote Ek as [uk ,vk , πk], representing an intuitionistic fuzzy number for the evaluation of the k expert (refer to Table 4), and λk as the importance weights of the experts, the weight of the k expert can be computed using the following Equation:

$$\lambda k = \frac{\mu k + \pi k\left(\frac{\mu k}{\mu k + \upsilon k}\right)}{\sum_{k=1}^{t} \left(\mu k + \pi k\left(\frac{\mu k}{\mu k} + \upsilon k\right)\right)}$$

Where $\sum_{k=1}^{t} \lambda k = 1, \lambda k \in [0,1]$

- Formulate an integrated IFS matrix by incorporating the thoughts and input from all experts. To accomplish this objective, the following equation employs the intuitive fuzzy weighted average (IFWA) operator introduced by [50]. If the decision of the IFS of experts is denoted as ij k, then let R(k) = (r(k)).

$$r_{ij} = \text{IFWA}_{\lambda}(r_{ij}^{(1)}, (r_{ij}^{(2)}, \ldots, (r_{ij}^{(t)}) = \lambda_1 (r_{ij}^{(1)} \oplus \lambda_2 (r_{ij}^{(2)} \oplus \ldots \lambda_t (r_{ij}^{(t)})$$
$$= \left[1 - \prod_{k=1}^{t} (1 - \mu_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^{t} (1 - \upsilon_{ij}^{(k)})^{\lambda_k}, \prod_{k=1}^{t} (1 - \mu_{ij}^{(k)})^{\lambda_k} - \prod_{k=1}^{t} (1 - \upsilon_{ij}^{(k)})^{\lambda_k}\right]$$

The aggregate IF decision matrix can be expressed by the following equation:

$$R = \begin{pmatrix} r_{11} & r_{12} \cdots & r_{1n} \\ \vdots & & \vdots \\ r_{n1} & r_{n2} \cdots & r_{nn} \end{pmatrix}$$

- Calculate the IF entropy weight of length/scale according to the following equation

$$H_j = -\frac{1}{n\ln 2} \sum_{i=1}^{n} [\mu_{ij}\ln\mu_{ij} + \upsilon_{ij}\ln\upsilon_{ij} - (1 - \pi_{ij})\ln(1 - \pi_{ij}) - \pi_{ij}\ln 2]$$

Then W can be computed as below

$$Wj = \frac{1 - Hj}{n - \sum_{j=1}^{n} Hj}$$

Table 3: Explanations regarding the weighting of experts

Linguistic Expressions	IFNs (μ, υ, π)
Very important	(0.9, 0.05, 0.05)
Important	(0.75, 0.2, 0.05)
Medium	(0.5, 0.4, 0.1)
Unimportant	(0.25, 0.6, 0.15)
Very unimportant	(0.1, 0.8, 0.1)

APPLICATION OF THE PROPOSED METODOLOGY

Thisresearch framework was executed in three phases to accomplish the objectives of evaluating SCD in the Moroccan context. The subsequent sections present a detailed account of each phase.

Stage I: The initial step involves utilizing existing data and gathering new data to identify aspects and processes associated with SCD. This study scrutinizes the literature on smart city development to establish the viability of current plans. The government and decision-makers are assiduously attempting to identify and comprehend the most important SCD-related concerns. Strategic planning decisions are imperative to ensure the sustainability of Morocco's smart city initiatives. A panel of four experts was assembled for this study, and surveys were used to gather feedback from these experts. Privacy Preserving Data Mining (PPDM), which uses various techniques, statistical, cryptographic and others, to facilitate cooperative data mining while protecting the privacy of the organizations or individuals involved[49].The experts' task is to assess the strength of interaction between measured parameters/methods and compare the outcomes of the variables/methods. The survey aimed to gather experts' opinions on SCD and collect data, including a list of parameters identified through a qualitative literature review. Prior to data collection, experts were provided with a detailed explanation of the study's purpose and rationale.

Figure7 illustrates the organization of smart city dimensions/structures (5 dimensions and 23 structures) for calculating importance (weights) using IF-AHP. These relationships between dimensions and processes serve as the foundation for collaborative work.

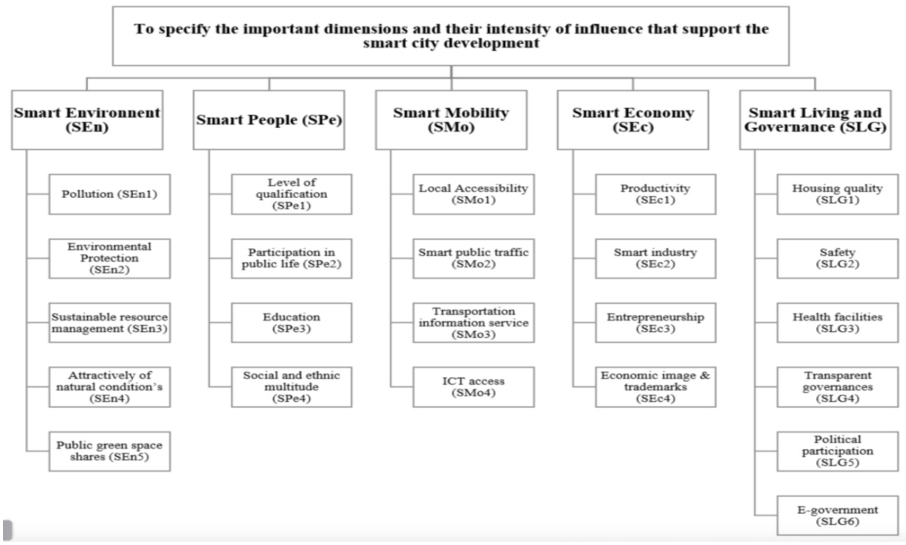


Figure 7: Hierarchy of SCD dimensions/rules

Stage II: IF-AHP assesses the relative significance of the measured length/scale.The hierarchy process is utilized to evaluate the problem, which is divided into three levels, as depicted in Figure 7: statement of purpose (Level I), size (Level II), and structure (Level III).

Stage III: IF-DEMATEL provides a range of size/model combinations. Expert opinions are integrated into studies involving their participation. To gather the input of all experts, a direct correlation matrix was utilized, demonstrating the assessment of the relationship between elements using evaluation control words. This matrix illustrates the autonomy and impact of the primary dimension.

REVIEW OF SOME EXISTING FRAMEWORKS FOR CYBER SECURED SMART CITIES

A Smart City Framework serves as a simple decision-making tool, facilitating more effective planning and implementation of Smart City initiatives by the public and commercial sectors.Instead of following a rational, systematic procedure, many cities usually go through this process spontaneously. Infrastructure efficiency and transparency in city operations will both improve with a systematic approach.

Figure 8: Smart City Framework Layers (from bottom to top) [Source: Cisco IBSG, 2012]

The framework's four levels establish a coherent progression that allows stakeholders to advance projects and put them to the test. For example, Let us examine an example where a local government representative is committed to advancing sustainability, and this becomes a top priority within Layer 1. Now, suppose the city identifies that its bus system's travel times rank poorly in international transportation indices (Layer 2). With this information in hand, stakeholders can then deliberate on a city initiative for a "connected bus fleet" (Layer 3) and discuss the specifics of creating and implementing such a system. Subsequently, city officials can look for best practices from initiatives of a similar nature across the globe, focusing on their operations, financing, and the legal and regulatory frameworks required for the project to succeed (Layer 4).

The feedback loop created by the Smart City Framework's circular information flow enables stakeholders to understand the best practices of other Smart City initiatives. To enhance understanding of the framework, the elements of each layer are further detailed.

Layer 1:- City Objectives - Enhancing the Social, Environmental, and Economic Foundations: In general, discussions about cities often revolve around policy matters such as "How will investing in transportation enhance the city?" or "What strategies can we employ to stimulate economic growth and attract employment opportunities?" Although these questions are commonly posed by city officials and other stakeholders globally, they are frequently challenging to address using quantitative data and can change based on the function and viewpoint of the individual. A framework that finally connects the city's goals to its programs, projects, and policies is necessary to comprehend a city's operations completely.

Layer 2:- City Indicators - Correlating Indicators to City Objectives: City objectives are broad and transient, so it's critical to link them to already-publicized "city indicators," which evaluate and compare cities according to certain, pre-established criteria. Many indicators, such as the Green City Index, both the Global City Indicators Facility (GCIF) and the Mercer Quality of Living Survey have distinct foundations and procedures that make use of a variety of quantitative and qualitative techniques. Other cities could need a different set of metrics. The Green City Index wouldn't be suitable, for instance, if a city put its economy above all else. If a community wishes to promote sustainability, comparable surveys like the Green Community Index or the Mercer Quality of Living Survey may be helpful. There should only be one set of city indicators in a perfect world. Owing to the complexity of cities and the differences in their objectives and priorities, cities could inadvertentlyfavor a city index whose indicator methodology closely resembles their own, and then evaluate themselves in relation to that index.

Layer 3:- City Components - Detailing City Assets: Most Smart City efforts are implemented in the commercial and physical sectors of a city, such transport and train stations. This layer connects the goals,measurements, and contents of the city to the physical elements of a city, such as utilities, real estate, transportation, and services.

The components are at the top level, and the hierarchy allows us to dive down to each sublevel. For example, the subject of transportation is divided into four divisions: air, train, road, and logistics (see Figure 9). The hierarchy has more levels, but these are the only four that are shown here. These levels' main subsections are merely included for clarification and to spark conversation.

Utilities	Transportation	Real Estate	City Services
Power	Rail	Residential	Healthcare
Water	Road	Commercial	Education
Waste	Air	Retail / Hotels	Fire / Police / Defense
N/A	Logistics	Public Buildings	Municipal Services

Figure 9: Hierarchy of City Components. [Source: Cisco IBSG, 2012]

Layer 4:- City Content—Mapping Objectives to Best Practices and Policies: This layer addresses the "how"—the process via which Smart City solutions are implemented. Before going on to Layer 1, it relates directly to Layer 3 since it provides information and makes it possible to find essential information for Layer 1 (city objectives). Many extensive literatures on cities describes innovative approaches and ideas that have already been put into practice, however the material's writing and documentation styles differ greatly and don't provide a solid framework for comprehending and duplicating Smart City deployments or for information sharing. For example, conducting web searches with just "keywords" does not produce relevant results. Specifically, the information is presented in an erratic and ambiguous way. It becomes difficult to replicate efficient rules and procedures in other places as a result. The uneven reporting of advantageous Smart City ideas and case studies slows down installations and results in confusion and a lot of labor that is not very efficient. For instance, botany's classification scheme dates back more than a century. Over the past ten years, environmental sustainability requirements and related norms have greatly improved. For municipal data, there isn't, however, a similar recognised categorization. With the use of an organised framework for best practices and regulations, cities will be able to find and reuse data on the responsibilities of stakeholders, needs for policies, and business models related to Smart City initiatives.

Since stakeholders have the biggest influence on municipal activities and operations, it is imperative to emphasise that responsibilities for stakeholders must be established before developing any Smart City plans. Figure 10 displays the relationships between five significant stakeholders.

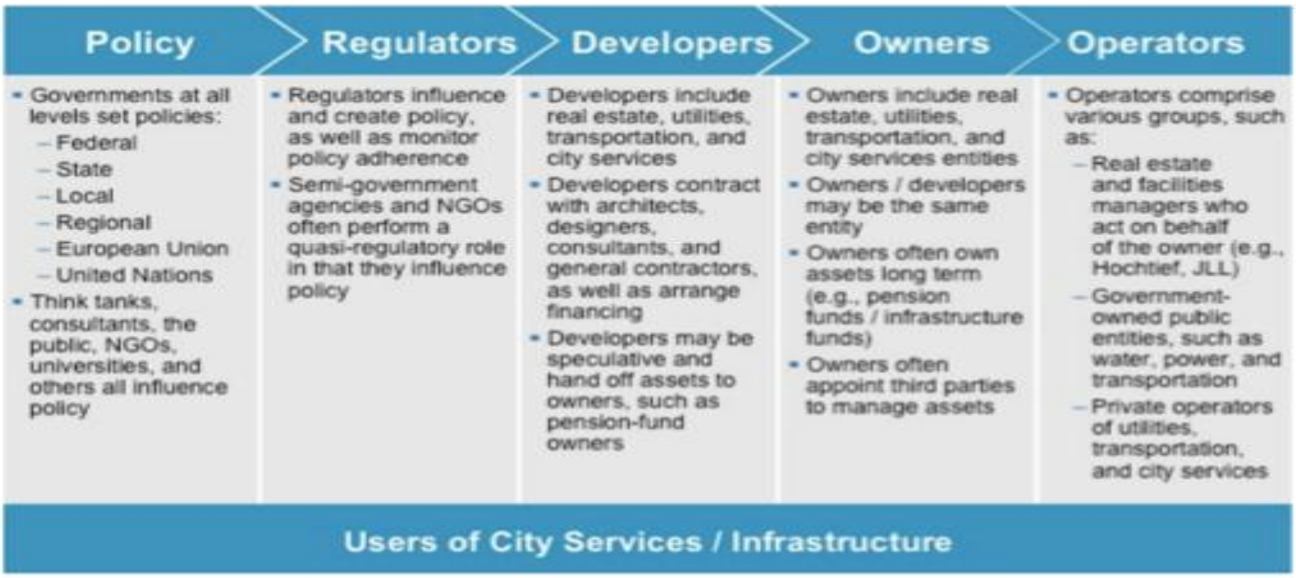


Figure 10: Stakeholder Roles and Responsibilities [Source: Cisco IBSG, 2012]

Cyber Secured Smart city framework model 1: This is one of the existing framework model given as below in Figure 11:

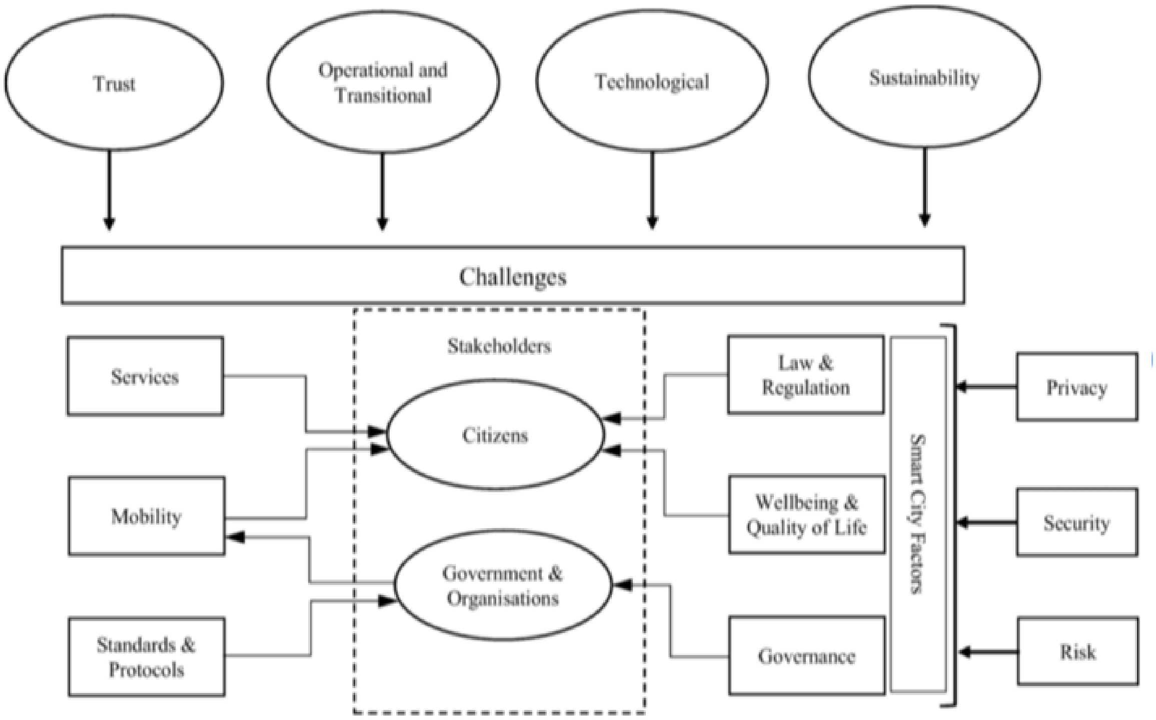


Figure 11: Smart cities security & privacy framework [50]

The framework contextualises how important components like services and mobility interact from the perspective of the various stakeholders and explains how the major concerns have an impact on the countless operational activities inside the smart city. The model takes into account every aspect of the complexity that comes with risk, security, and privacy in smart cities. These components are essential to the functioning of smart cities and necessitate effective protocols and procedures anywhere there are interactions and transactions with the infrastructure.

The framework lists the main issues that smart city designers and integrators must keep in mind while creating these kinds of cities: trust, operational and transitional issues, technology and sustainability. The foundation for the selected smart city framework factors—services, mobility, standards and protocols, law and regulation, wellness, quality of life, and governance—is laid by the identified themes and literature review. Each one serves as an example of the range of requirements that must be met for the smart city to function effectively. The primary stakeholders in smart city operations are individuals, governments and organisations, highlighting the critical role that human factors and interactions play in these operations (Kitchin 2015; Scuotto et al. 2016).

Cyber Secured Smart city framework model 2: This is another existing framework model with some enhanced data protection feature like using clouds given in below in Figure12:

Open Data Cloud: a virtual data cloud where anyone with permission can view any data and add to it without affecting the original data source.
Public Cloud: This is a subscription service available to anyone wishing to use certain services.
Private Multi cloud: a multi-cloud strategy comprising multiple cloud services from multiple cloud private vendors.
Application clouds: These clouds offer enhanced performance and efficiency, greater flexibility and dependability, and a reduction in IT expenses. Formerly used Microsoft Office 365.

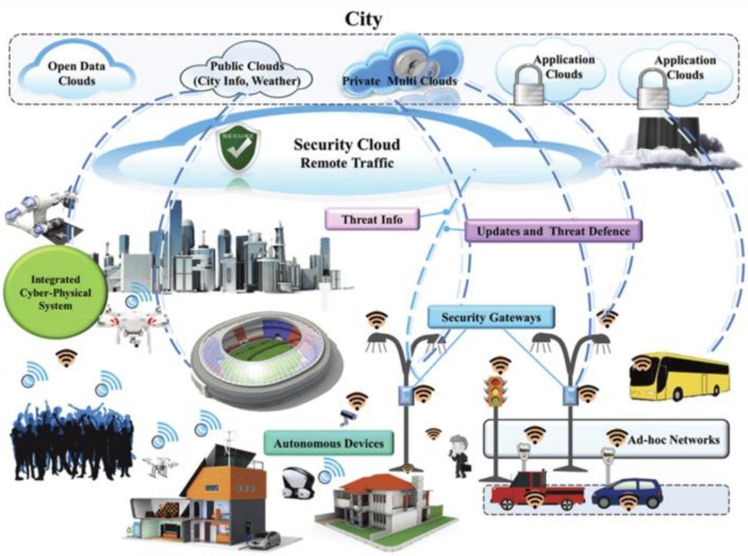
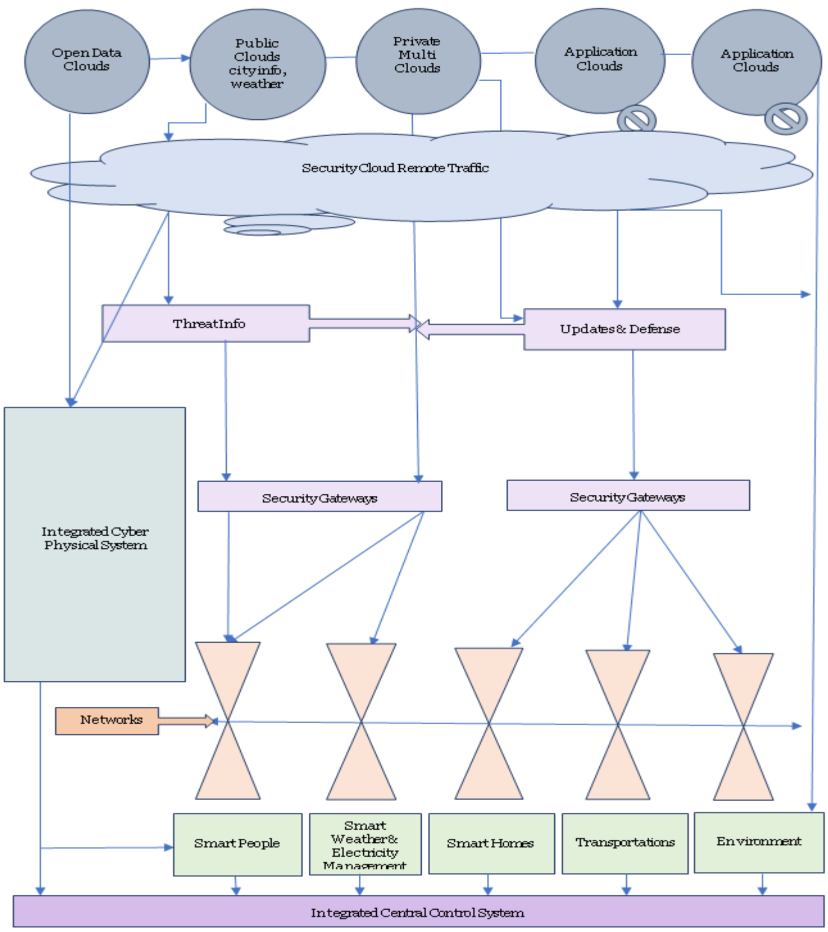


Figure 12: Smart City-Multi-layer security framework [51]

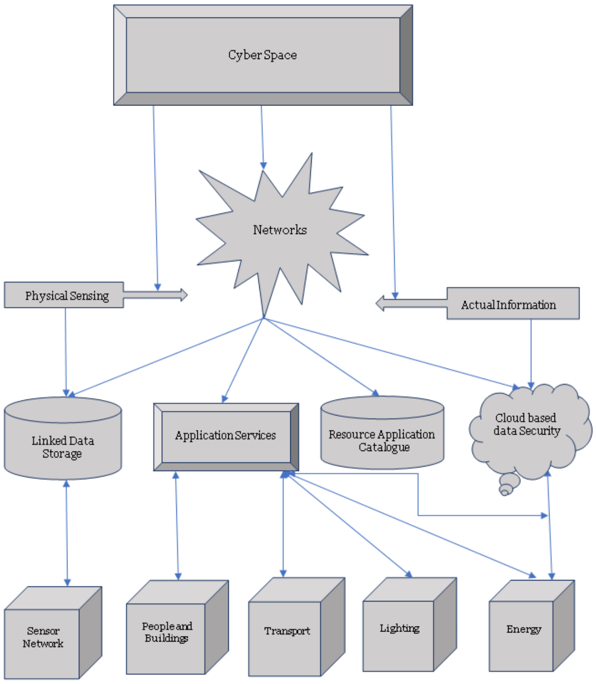
PROPOSED CYBER SECURED FRAMEWORK MODEL FOR SMART CITIES

The Enhanced Cybersecure Smart City Framework Model is a comprehensive approach that integrates advanced cybersecurity measures into the infrastructure and operations of smart cities. Central to this model are the **Integrated Cyber Physical System** and the **Integrated Central Control System**, which work together to enhance the efficiency and sustainability of urban environments.

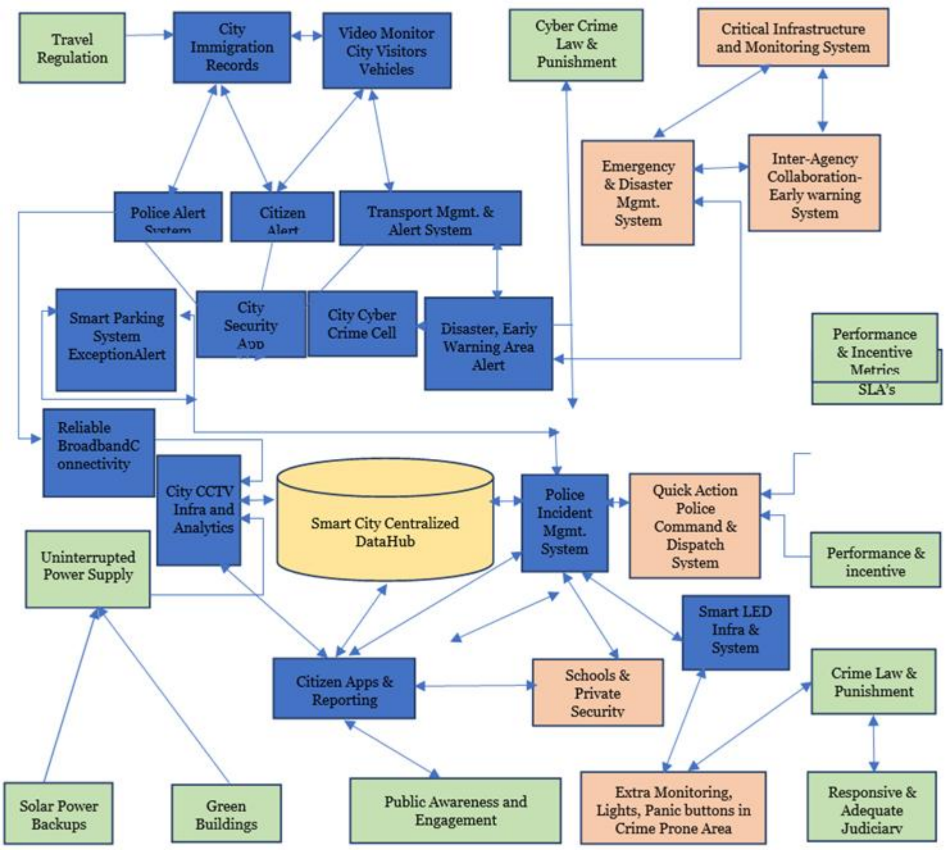
Enhanced cybersecure smart city framework model



Integrated Cyber Physical System



Integrated Central Control System



Security Cloud Remote Traffic in enhanced smart city framework refers to a cloud-based system designed to optimize traffic management while ensuring robust security measures. This innovative approach utilizes real-time data from various sources, including traffic cameras, sensors, and vehicles, to monitor and analyze traffic patterns across the urban environment. By processing this data in the cloud, the system can efficiently manage traffic flow, reduce congestion, and enhance overall transportation safety. Additionally, the cloud infrastructure facilitates remote access for city officials and traffic management agencies, enabling them to respond swiftly to incidents, adjust traffic signals, and implement emergency protocols as needed. Security is a paramount concern, with advanced encryption, authentication, and access control mechanisms in place to protect sensitive traffic data from cyber threats. This integration of security measures within the cloud architecture ensures that the traffic management system is resilient against potential attacks, making the smart city framework not only more efficient but also more secure. Overall, the Security Cloud Remote Traffic system exemplifies how intelligent data management and cybersecurity can work together to create safer and more optimized urban mobility solutions.

An **Integrated Cyber-Physical System (ICPS)** is a sophisticated framework that seamlessly combines physical processes with cyber capabilities, enabling enhanced interaction between the digital and physical worlds. In this system, physical components, such as machinery, sensors, and actuators, are interconnected with computational resources, data analytics, and communication technologies through the Internet of Things (IoT). This integration allows for real-time monitoring and control of physical systems, such as transportation networks, smart grids, and industrial operations, facilitating improved efficiency, responsiveness, and decision-making. By leveraging advanced technologies like artificial intelligence and machine learning, an ICPS can analyze vast amounts of data to optimize performance, predict maintenance needs, and enhance safety measures. Furthermore, the inherent connectivity of an ICPS enables remote operation and management, allowing for innovative services and applications that improve the quality of urban life. Overall, the Integrated Cyber-Physical System represents a transformative approach to managing complex systems, promoting smarter, more sustainable cities and industries while addressing the challenges of a rapidly evolving technological landscape.

The **Integrated Central Control System (ICCS)** in a cyber-secured smart city framework refers to a centralized platform that manages and coordinates various urban systems and services while ensuring robust cybersecurity measures. Here's a breakdown of its key components and functions.The Integrated Central Control System (ICCS) in a cyber-secured smart city framework consists of several key components that work together to enhance urban management and security. First, a **Centralized Data Hub** collects data from multiple sources, such as IoT devices, sensors, and databases across the city, ensuring data interoperability and real-time access for stakeholders. Second, the **Cybersecurity Infrastructure** implements advanced security protocols to protect data integrity, confidentiality, and availability, incorporating firewalls, intrusion detection systems, and encryption mechanisms to safeguard against cyber threats. Third, the system facilitates **Control and Monitoring**, enabling real-time oversight of city services like traffic management, energy consumption, waste management, and public safety, while utilizing analytics and AI to optimize resource allocation and improve service delivery. Additionally, the ICCS establishes **Incident Response Coordination** protocols for rapid responses to cyber incidents or failures in city services, integrating with emergency services to ensure a coordinated response during crises. Finally, it features a **User Interface and Access Management** system that provides dashboards for city officials, security personnel, and other stakeholders to visualize data and monitor systems efficiently, while implementing access control measures to restrict system access based on user roles. Together, these components create a robust framework for managing the complexities of a smart city while prioritizing cybersecurity.

BLOCKCHAIN UTILIZATION IN SMART CITIES

Blockchain technology has shown promise in addressing some of the privacy and security concerns that smart cities confront (Mora et al. 2019, Noh and Kwon 2019, Ramos and Silva 2019). According to Mora et al. (2019), smart cities should implement blockchain-based solutions to help reduce privacy exposure. Benefits include better data control and reliable transactions. The study conducted tests to evaluate privacy risk and calculate cloud resource requirements for IoT technology integration with blockchain smart contracts for identity, operation, and privacy confirmation. The authors contend that because of barriers relating to legislation and social norms, the adoption curve for adopting blockchain in large-scale applications will take some time. Many issues, including user factors, technical system aspects, legal concerns, and institutional considerations, can impact the implementation of blockchain technology in smart cities (Noh and Kwon 2019). Ramos and Silva (2019) assert that understanding how governments function within a political and legal context is essential for adopting blockchain technologies. The article argues that utilising blockchain technology for data processing might not always be the best course of action and that it's critical to lessen some of the risks that data subjects may encounter while using blockchain.

IOT IN SMART CITIES

The internet of things (IoT) is a key component of smart city initiatives since it is the enabling technology that has enabled ubiquitous digitization and given rise to the idea of smart cities. The ubiquitous internet connection of gadgets, which enables them to transmit data to the cloud and maybe receive commands for executing actions, is referred to as the "internet of things." In order to extract information to support decision- and policy-making, IoT requires collecting data and carrying out data analytics operations. By 2025, it is anticipated that over 75 billion devices will be online, which will encourage the development of even more applications. As per the author, the propagation of IoT devices and their appliances in various fields, namely, smart homes, smart cities, smart health etc[52].IoT makes it possible for sensors to gather and share environmental data in SC. IoT includes data detection, transmission/reception, processing, and storage through the usage of cloud services. As illustrated in Figure13, the technology claims that the universal IoT architecture is composed of five levels, each of which functions on data from the layer before it. Additionally, it outlines three alternative IoT system topologies.

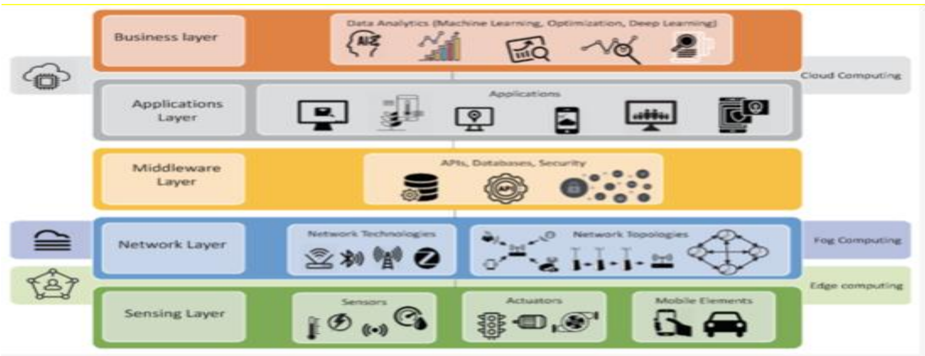


Figure13: IoT Architecture

The Sensing layer, or Perception layer is generally called, is made up of sensors that can collect information on physical quantities relevant to any given application and actuators that may act on physical objects, such as RFID readers for reading RFID tags and other similar devices. Data read by the sensing layer is sent to the middleware layer via Bluetooth, Wi-Fi, cellular internet, Zigbee, and other wireless network technologies. The middleware layer provides a general interface that connects the hardware of the sensing layer with the application layer, which leverages data to give services to users via various APIs and database management services. Plans and policies that support system management are produced at the business layer, which is connected to the application layer.

IoT architectures are generally categorised according to the kinds of operations that are delegated to different IoT system components; data processing duties serve as the primary basis for this classification. Based on the IoT framework level at which data processing might occur, there are three different IoT system architectures: Cloud, Fog, and Edge Models.

- Through the network, cloud computing provides remote access to ongoing shared resources (storage, computation, and services).
- Fog computing assigns some of the work to network devices, which allows for a different kind of responsibility distribution than what cloud computing design demands. In Internet of Things networks, cloud computing often refers to data processing performed by routers and other network devices.
- Data processing at the "thing" level, or from sensors and devices in other IOT systems, is referred to as edge computing [53]. Another edge analysis concept addressed in [54] describes a layer between the fog and "things" (sensors) rather than the edge itself.

RESULTS AND DISCUSSION

This section discusses the benefits of using the recommended framework. There is also a discussion of the managerial details and the consequences of these findings:

IF-AHP Results: By accounting for ambiguity in the problem formulation, the IFAHP method is intended to assist policy makers in making quick judgements. Set criteria by ranking the dimensions and processes that have an impact on SCD. There are a total of 23 elements that specialists claim are associated to SCD in the initial round of the investigation. IF-AHP and IF-DEMATEL were used to analyse the effects of the five groups of rules on SCD activities. The results indicate that SLG has the largest weight. This clarifies the reason behind specialists' increased focus on the consequences of big SLG. Furthermore, the outcomes align with, who deemed the pertinent SLG model crucial for the advancement of smart city development.

IF-DEMATEL Findings:

The IF-DEMATEL approach can be used to track the degree of influence and relationship between dimensions/processes, as the IF-AHP method just computes the weight of SCD-related dimensions/processes. According to IF-DEMATEL results, intelligence (SMo) and smart man (SPe) were categorised as impacts associated with other dimensions. This is due to the fact that their power (R) exceeds their power (D) since the factor (D – R) is negative. Subjects covered include Smart Environment (SEn), Smart Economy (SEc), and Smart Living and Governance (SLG); as they are all related to SCD, they should all be given more thought. The set of causes' (D) influence is greater than the effect of the result (R). The score (D + R) indicates the dimension's relative importance. The SCD priority should be Smart Living and Governance (SLG), which has the greatest (D+R) value (2.89995).The top spot in the ranking (D+R) goes to Smart Life and Management (SGL), which is followed by Smart Environment (SEn), Smart Mobility (SMo), and Smart People (SPe).Furthermore, SLG is ranked first (D-R) in the ranking, followed by Environment (SEn) and Intelligence (SEc), in that order. In general, we ought to take into account both (D+R) and (D-R) ordering. The size of SLG has a major impact on how smart home cities evolve. SMo is associated with other dimensions, though, as it has the lowest D-R score (0.40269) of any dimension. We assess the new concerns to determine which three are the most crucial. The findings indicated that SLG held the most significance.

MANAGERIAL IMPLICATIONS

The study's findings have significant management ramifications. The analysis's findings provide managerial advice in the following areas:

Primary aspects

- Identify differences or patterns affecting SCD in new countries. This study presents 23 models and 5 dimensions from the SCD perspective derived from the literature. In this study we try to identify some features or mechanisms associated with SCD in developing countries. Research and experts argue about five dimensions: SMo, SPe, SLG, SEn and SEc. These factors are all strategies to improve SCD assessment.
- Provide a solid foundation for new countries to measure the development of smart cities. Policy makers are constantly dealing with many issues related to urban planning. This article provides a good basis for evaluating smart cities in developing countries. Analysis of dimensions and parameters related to SCD is performed by a combination of IF-AHP and IF-DEMATEL methods. A reliable method to determine the relative importance and significance of each dimension and pattern is IF-AHP. Also on a large scale/process, use the IF-DEMATEL method to show effects and causes. To ensure that Morocco's smart city initiative works effectively, policymakers should use this framework to develop dimensions/systems to identify and understand the most important SCD-related changes. Policymakers should be aware that research results may vary based on research data. The results of this research may not be applicable to other situations, but decision makers will find that the proposed approach allows for accounting for uncertainty

FUTURE WORK AND CONCLUSION

Despite the aforementioned perks and services, there is an infinite supply of work. To begin with, authors can gather information from different specialists for upcoming studies and contrast the findings with earlier studies. The AHP-IF DEMATEL hybrid IF approach is theoretically grounded as well. To further enhance practical knowledge, further MCDM techniques including ANP, preference vector approach, skill modelling, and PPROMTHEE can be employed in subsequent studies. Neutron technology was just released by Smarandash with a fresh wave of blurring. A useful tool for simulating ambiguity and uncertainty. Consequently, it is possible to resolve the measurement/measurement dilemma in fuzzy environments in Neutrosophics in the future. Although it can be used to other developing nations as well, this planning approach is concentrated on smart city development in emerging nations like Morocco. In a similar vein, we might broaden our research by consulting specialists in relevant subjects.

Important ramifications of this study for practitioners and researchers indicate that smart city initiatives have an immediate impact on the national economy. Due of the immediate financial and social benefits that smart city initiatives can provide, some growing economies, such as, India and UAE, are starting to put them into practice. This research offers a thorough inventory of the 23 elements/procedures that affect how well smart city development proceeds in nations like Morocco. This study's combination of the IF-AHP and IF-DEMATEL approaches offers numerous benefits and opportunities for practitioners and researchers. By using expert judgment and data analysis, the use of IF-AHP facilitates the evaluation of the weights of dimensions and measures. Similarly, use IF-DEMATEL to analyze interactions between different levels and dimensions. IF-AHP and IF-DEMATEL, which are used to analyze the impact and model of smart city development were used to construct a strategy to help practitioners understand the relationship between the model and comprehending the implementation of smart city/urban models. Through the development of smart cities, a sustainable design approach can contribute to the creation of sustainable development and better social health. Furthermore, the implementation of smart cities will contribute to improving the standard of living for city dwellers.It talks about different smart city architectures and the difficulties in implementing them, viewing the Internet of Things as a crucial part of smart city services. Finally examine the technological expertise and connection of these applications, as well as the use of intelligence in smart cities.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

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