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A Study on Determinants of the Emergence of Sustainable Smart Cities

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Abstract - **The urbanization is the moment of people from the countryside to city seeking employment and other basic amenities to improve their life better. As per the World Bank data, today about 4.4 billion (56%) inhabitants live in big cities and the numbers are rising steadily. The city life has been posting major challenges to the city-planners and governments to meet the expectation of city life. The concept of smart city is basically how the big cities are governed by using newer and smarter technologies in every sphere of city life ranging from connectivity to financial transaction. The digital technologies and data collected by the cities through various ICT like IoT may considerably raise the efficiency bar to deliver improved services to its dwellers. This exploratory study examines the determinants and sub-determinants and their rankings through statistical analysis by using Technology-Organization-Environment framework model.**
Keywords: **Smart City, Determinants of Smart City, Technology-Organization-Environment (TOE) Framework, Urban Governance**

I. INTRODUCTION

Urbanization is impacting the life of common people and it also influencing the social economic systems of the countries where such urbanization is happening at fast pace. Urbanization also affects the quality of life of the city dwellers besides big corporate firms and the local city governance. It also brought visible social changes among the citizens in terms of demand, their routines, and value system.

Today, countries are facing challenges in creating adequate healthcare, energy and maintaining ecological balance in urban areas. Managing urban areas in a country need to network with several basic services of citizens such as health care, education, power supply, public transport system while keeping the ecological needs. Such networking of services not only provides employment generation for the local population but also generate some revenue to sustain the services by the local governments.

There has been a shift in policy by the local governments towards regulatory framework to govern the cities. Emergence of digital technologies and high speed internet connectivity though open platforms by government and private companies have made it possible to remove complexities in urban governance. Digital intervention of city eco-system is slowly shaping the engagement of people and externalities across the vertical markets (Komninos *et al.,* 2011).

Digitization can result in reduced consumption of resources, but the opposite may also be true. Digital technologies have been playing significant role in playing triple factors viz. environment, economy and social. There is an increasing trend by major cities inviting big tech corporations to set up a base to create more revenue and employment for them. Such initiatives are seen by public for boosting their incomes and improving their lives. On the one hand ICT companies are seeing a business opportunities in a smart city project, on the other hand cities are facing challenges in integrating technologies connecting difference services to the citizens. The risk for engaging big tech companies to provide a technical solution to the smart cities nevertheless the ICT companies will always get profits. This is a major imbalance in smart city projects.

II. LITERATURE REVIEW

According to Soderstrom, the smart city is a trade mark registered by IBM Company in 2011 and traces the path to the Smarter Planet Campaign undertaken by the IBM. Therefore, it is a commercial in nature in origin and it has been considered a technical push or vendor driven demand (Mona Treude, 2021). Experts have criticized the smart city projects on the grounds of being overrating with various technologies without providing any value addition to the citizens as promised at the time of their entry (Marsal-Llacuna *et al.,* 2016).

The area of research studies towards smart cities are diverse in nature involving engineering and data sciences as well as social sciences for effectively managing the efficiently the smart cities projects (Lytras *et al.,* 2020; Colding and Barthel, 2017; Quijano-Sanchez *et al.,* 2020; Lim *et al.,* 2019). Caragliu's arguments towards the smart city is based

on investments in human and social capital which ultimately drive the sustainable economic growth, an improved quality of life, protection of natural environment through responsive governance mechanism (Caragliu *et al.,* 2009). The foundation of a smart city is stemming from the availability of a good transport connectivity with ICT infrastructure with an eye on business opportunities (Harrison *et al.,* 2010). The smart city technologies were instrumental in accelerating the sustainable growth with objectivity by bring overall improvements in environment with proactive behavior with the help of big data and smart technologies (Kitchin, 2014).

The notion of smart city has always been seen as knowledge economy but restricted to big cities (Kourtit *et al.,* 2012). By advancing this argument, one can safely assume that the economy and governance of a smart city is supposedly driven by innovation, creativity, entrepreneurial activities by smart people living there. Here the ICT with data analytics are given innermost importance to realize the potentials of a smart city with innovative ideas generated for various professional services. Embedding the ICT in urban infrastructure along cannot make the city smart rather the broad objectives could be achieved in combination with human and social capital with a liberal economic policy to leverage the growth and development (Hollands, 2008; Caragliu *et al.,* 2009).

The ever increasing of population densities of cities not only led to increased consumption and environment pollution but it has created social issues too (Albino *et al.,* 2015). The government machineries are struggling and to juggle with multiple priorities in terms of quality of citizens, development, improved infrastructure facilities, poverty alleviation and social problems because of increased labour migration from rural to urban cities. Availability of limited resources had forced the local urban government bodies into exploring suitable solutions to a better monitoring and governance systems to satisfy the voters. Smart city is the solution to the increasing challenges faced by the government and converting the traditional cities into smart cities.

Smart cities stand outs from the traditional cities because of its over reliance on technology for its operational and city governance (Washburn *et al.,* 2010; Walravens, 2012; Lee *et al.,* 2013). Smart people prefers to live in smart cities (Meijer and Bolivar, 2016) where a large number of its well educated population contributes for the development of cities (Lambardi *et al.,* 2012).

According to United Nations estimate, urban population of the world would grow from 4.2 billion to 9.7 billion with an increase of 9% (UN/DESA, 2018, 2017). It has been consistent past practice by the policy makers to prioritize the economic dimensions of sustainability by overlooking smart city components which is resulting in draining of profits by ICT providers (Hollands, 2008). According to World Bank report nearly 56% of the inhabitants live in big cities and it may increase to 70% by 2050. Cities contribute 80% of global GDP and if these cities are innovatively managed well urbanization could contribute for improved productivity and sustainable growth (World Bank, 2022).

The World Economic Forum (WEF) identified five ways to make our cities smarter viz. (a) "Global outlook and political will; (b) Smart standards; (c) Smart regulations; (d) Public private partnerships; and (e) Local innovation" (WEF, 2015). The WEF report also indicates that 80 percent of GDP is generated in cities hence urbanization can greatly contribute for sustainable growth through innovation provided it is managed well. The European Union Parliament study (EUPS, 2023) towards Social approach to the transition to smart cities identified five components of smart cities are (a) "Smart and Safe livening; (b) Smart Economy; (c) Smart Governance and e-citizenship; (d) Smart Mobility; and € Smart Environment".

Finally, the smart cities are always closely networked world which promote innovation by way of collaborative efforts among its citizens, other stakeholders, civic bodies and government to provide quality civic services and building human capital (Albino *et al.,* 2015; Kourtit *et al.,* 2012; Yigitcanlar *et al.,* 2008).

II. OBJECTIVES OF THE STUDY

The objectives of the present study are to evaluate and find out answers to the following research questions based on the systematic literature review.

1. What are the primary and sub-enablers for the sustainability determinants of the Smart cities?
2. Which are these sustainability determinants are considered most important for the smart cities?
3. Which are the best and worst determinants and sub-determinants for the emergence smart cities?

III. RESEARCH METHODOLOGY

To identify the primary and sub-enablers for the sustainability determinants of the smart cities, Technology-Organization-Environment (TOE) framework (Tornatzky and Fleischer, 1990) as a theoretical basis through literature review has been used. The TOE framework basically indentifies three aspects of process it adopts to implement a technological innovation; organizational context and environmental context. Several researchers had adopted the TOE framework for their research. Based on the TOE framework, three contexts have been taken for the present study viz. Technological enablers for smart city emergence and sustainability (TG); Organizational enablers for smart city emergence and sustainability (OG); and Environmental enablers for smart city emergence and sustainability (EN). The research steps involved were using the 1-9 scales; determining the best to worst determinants and sub-determinants; performing research comparison and finally determination of optimal weightage for each determinant and sub-determinant using linear statistical methods and tools.

IV. RESULT ANALYSIS

A. Identification of Smart City Emergence Determinants and Sub-Determinants

As a first step, significant TOE framework based main determinants of smart city emergence and their corresponding sub-determinants (TG_1, TG_2, TG_3,OG_1,OG_2, OG_3, OG_4 , EN_1, EN_2, EN_3, EN_4 , EN_5) are identified through the literature review as given in Table I.

TABLE I SMART CITY EMERGENCE ENABLERS

Theoretical perspective	Sub Enablers	Description
1. Technological Enablers for Smart City Emergence and Sustainability (TG)		
Technological dimensions are significant for smart cities emergence and sustainability as the established settlements evolve and become more advanced with the integration of new technologies. As seen in the recent times, advent of 4G, IOT, Big Data Analytics, have changed the communication, and operational patterns of major work and living places and converted them into smart ways. Technological dimension -specify how the nature and characteristics of a innovative technology influence its adoption and absorption in a new system and -specify how its quality makes it more competent and capable to offer multiple functions and purposes in multidimensional settings. Additionally, the quality of technology allows it to capture and disseminate information and knowledge through a balanced use of infrastructural resources, strong connectivity, control systems and operational equipment. Sustainability in a smart city from technological dimension is incumbent upon the ability of technology to get diffused easily in a system; to allow transfer of knowledge and information across different portals for users to apply and benefit from it.	Absorption and diffusion of new technology (TG1)	Innovative technology could in all forms of development viz. Disruptive or radical or incremental (Grin *et al.,* 2010) and sectoral (Geels, 2004) in origin. Emergence change and absorption of new technology occurs across a range of geographical, and operational areas. Their presence can be felt in physical and non-physical practices and at varying governance scales and interventions to address growing and evolving needs (Hekkert *et al.,* 2007; Markard and Truffer 2008). Technology absorption is easy if city infrastructure, corporate infrastructure geographical distance between buildings and their state of connectivity is well founded or established. Additionally, other related indicators of economic development, levels of physical and digital connectivity between two regions and social and cultural similarity facilitate technology absorption and diffusion (Cao and Tan, 2012). Under the smart city projects, synergy between digital technology and data analytics are happening which improves the quality and sustainability of citizens (Pan *et al.,* 2021). All sustainable smart cities projects need absorption and diffusion of newer digital based technology for its successful performance.
	Competence and capability of technology (TG2)	Competence of technology with integration capability can be gauged through the number of ways the old infrastructures are mapped with the new age technology in the smart city models viz. Global positioning system (GPS) based vehicle monitoring, smart ticking to trace travel by passengers, RFID tagging, sensed data, capturing system etc. (Bibri, 2017). The technology competency is considered an interplay of various other smart elements integrated with the smart city sustainable development projects.
	Facilitate knowledge transfer (TG3)	Facilitating knowledge transfer in smart cities is one of the core enablers with its smart technologies and digital devices. The knowledge transfer is instrumental for better information services not only to the citizens but also for the policy making process and reduced burden on the authorities. The GPS and RFID data could be utilized for better vigilance as well as decision making process. Besides the knowledge transfer may accelerate the growth of the technology based services in education sector for embracing the technology by the institutions and business houses (Neirotti and Paolucci 2013; Bakir, 2016). Facilitating knowledge transfer is core to the successful implementation of sustainable smart cities.
2. Organizational Enablers for Smart City Emergence and Sustainability (OG)		
Organizational dimensions are significant for smart city emergence and sustainability as technology itself cannot function in isolation. Investments in technologies are massive, specific and are undertaken preferably at unit, or organizational level based on their scales and functionalities. Furthermore,	Institutional frameworks to facilitate (OG1)	A strong network of digitally enabled industrial, financial, commercial, educational, residential, and other institutional spaces forms the base for adoption and use of technology for smart city creation. Structural imbalances and inequalities cause problem of congestion, traffic, poor standards of livings, poor provision of civil amenities and facilities causing social and economic imbalance. For a city to turn smart it must overcome these hurdles for its

integration of technology requires infrastructural, human, and institutional, political, legal, support for its effective use and absorption. Organizational size, structures, connectivity, resources, decision-making mechanism, and major stakeholders contribute toward the acceptance of new technology for establishing smart city structures. Good governance and strong leadership supported by civil, academic, political, legal, and social systems provides health, education, safety, security, and sustainable resources, like clean energy, water to citizens which are the biggest stakeholders of smart city.		successful transformation. Benchmarking practices, stringent rules and regulations, standard work -procedures are must for easy diffusion of technology for smart city emergence. In addition, the institutional frameworks to facilitate emergency of smart city projects has to create a robust legal framework to protect the knowledge acquisitions through innovation and design through Patents, copyright protection as an incentive to the knowledge creators. If the smart city networks are to be successful, it need a support of a suitable but flexible institutional framework.
	Economic potential of technology (OG2)	Economic potential of a new technology could be considered as driving force for smart cities as 80% of GDPs are generated from cities as per World Bank report. Tapping of smart technologies for economic exploitation would help enhanced benefits and satisfaction to the citizens as well as the local government. Economic potential of technologies includes green smart IoT applications, Smart logistics and Retail, Smart Energy and Grid, Smart Mobility and Transportation, use of Fifth generation (5G) wireless communication etc. (Nanda and De, 2022). As there is a strong connection between the economic viability of new technology, chances are fairer for the success of new projects under smart cities.
	Leadership for innovation and new technologies (OG3)	Managerial characteristics is one of the several antecedents of the technological innovation (Ahuja *et al.,* 2008). A strategic leadership and innovation are completed with each other and enhances the chances of successful implementation of technology innovation and business pursuits (Gamatese and Hallowell, 2011; Cooper, 2001). Leadership being a critical for creation of values to the organizations and projects and positioning it a learning organization which accelerate the technology transfer smoothly (West *et al.,* 2004). The ability and agility to adapt to the newer technologies is one of the greatest challenges to the leadership in the modern world (Tidd and Bessant, 2018). If an effective leadership is provided for smart city projects, then the success rate of adopting newer technologies will be more.
	Stakeholders in the technology ecosystem (OG4)	Stakeholders expects in a smart eco system are reasonably expect optimum utilization of resources and reliable and fast services through technology with transparency and flexibility (Clohessy *et al.,* 2014; Jansen and Hoven 2015; Gooch *et al.,* 2015). Stakeholder's readiness, technology efficacy, training capabilities is important for smooth operations of technologies. The city layers of smart city are influenced by various stake holders viz. Citizens at bottom of the pyramid, followed by socio-economic constituencies and the city administrators and local bodies at the top (EPRS, 2020).
3. Environmental Enablers for Smart City Emergence and Sustainability (EN)		
Environmental dimension for smart city emergence covers broadly the impact and support of environment for easy diffusion and absorption of technology and vice-versa. Any given environment will support the integration of technology if it offers some unique or novelty concepts. Alternatively, technology having negative impacts on environmental will not be easily integrated in a system because of its unpopularity with stakeholders. Smart city concept acceptance and immersion is contingent upon the prevalent culture	Novelty impact of innovative concept Offering (EN1)	The fundamental character of novelty is innovation and newer technologies like IoT, Machine Learning, RFID are making storm in the digital space, product development and information retrieval. Digital identities, smart devices like 'SIRI', 'ALEXA', Touch screen devices, biometric, sensor sensitive and controlled appliances have been accepted because of their unique features. Similarly Chat GPT has achieved instant hit among the younger users because of its speed and accuracy. These are smarter technologies with novelty impact on the business environment ranging from product design to services sector to education. Past research indicates that

which is a resultant of customs, habits, rituals, and cultural practices followed by citizens of a city. These habits and trends are formed over time and are dependent upon the competitive benefits and economic returns and value offered by smart city concepts.		innovations are inherently risky and there is no guarantee of its success unless a careful planning is done (Agarwal and Prasad, 1998).
	Economic Impact of innovative concept Offering (EN2)	Schumpeter's economic growth model argued the importance of competition through innovation for ensuring economic growth and these model has been supported by several researchers (Aghion *et al.,* 2005; 2009). If smart city concepts add economic value to city infrastructure, share market, income potential of citizens, then its acceptance is fairly high.
	Competitive impact of innovative concept Offering (EN3)	Typically, innovation drives the competitive advantage of a company or organization and acquire the market share of a particular product or services. Technology plays a crucial role by converting the existing non-technical services into an intelligent urban system and stimulate the businesses (Hoskinsson *et al.,* 2013). Intelligent digital technologies opens up unexplored business opportunities or services and provide additional business opportunities and competitive advantage to the business (Zahra *et al.,* 2021). If smart city concepts provide added benefits, in terms of safety, better business, job, and professional growth opportunities and more benchmarking potential, then its acceptance is relatively easier, and its sustainability potential is strong.
	Value impact of innovative concept Offering (EN4)	The development and areas of application of innovative and emerging technologies quite often bring value potential but the same is not unrealized by the organizations and industry. Such emerging technologies drive innovation in the field (Küfeoğlu, 2022). Technological integration will have a binding effect on the urban infrastructure with intelligent networks, creating huge digital data bases or big data which could be useful for brining vast improvement in the services as a part of offerings under smart cities (Cohen *et al.,* 2022). Digitization in the field of social services like education, health care, basic services by civic bodies, transport, citizen welfare scheme (Kim *et al.,* 2013; Chamoso *et al.,* 2018). Citizens enjoy value, quality lifestyle, having facilities, some scope of entertainment and relaxation which smart city promises to offer.
	Cultural acceptability of innovative concept Offering (EN5)	Cultural transition has been seen in recent times where processes like e-waste, digital fingerprinting, eye scans etc. have become new norms. Knowledge management is key to the competition and exploitation of economic resources. Culture plays a vital role in Knowledge Management and any propagation about open innovation in smart city projects needs the acceptability by the community and the society at large (Allameh *et al.,* 2011).

B. Best and Worst Smart city Emergence Determinants

In order to find out the best to worst determinants of emerging smart cities, the researchers used the "best-worst method" (BWM) to address the "multi-criteria decision making" (MCDM) problems. According to BWM, "the best (e.g., most desirable, most important) and the worst (e.g., least desirable, least important) criteria are identified first by the decision-maker" (Rezaei, 2015).

The best and worst determinants and sub-determinants are arrived at and listed in Table II & Table III.

TABLE II BEST AND WORST SMART CITY EMERGENCE DETERMINANTS

TOE Framework	Best Determinant	Worst Determinant
TG	E1,E2,E5,E6,E7,E8,E9,E10,	E2,E10,
OG	E3,E4,E11,E12	E11,E12
EN		E1,E3,E4,E5,E6,E7,E8,E9

TABLE III BEST AND WORST SMART CITY EMERGENCE SUB-DETERMINANTS

Sub Determinants of TOE Framework	Best Sub-Determinant	Worst Sub-Determinant
TG1	E1,E2,E4,E5,E6,E10	E11, E12
TG2	E3,E7,E8,E11,	E4,E5,E6,E9,E10
TG3	E9,E12	E1,E2,E3,E7,E8
OG1	E1,E2,E7,E9,E10,E11,E12	E4
OG2	E3,E6,E8	E1,E10
OG3	E5	E6,E7,E8,E9,E11,E12
OG4	E4	E2,E3,E5
EN1	E1,E2,E4,E8,E9,E11	
EN2	E3,E5,E6,E7	
EN3	E10,E12	E4,E9,E11
EN4		E2,E3,E10
EN4		E1,E7
EN5		E5,E6,E8,E12

C. Detailed Weights of the Sustainable Practices Obtained from Each Expert

Weights of each of the main and sub-determinants were calculated by using eq (2) and pairwise rating obtained for all the main and sub-determinants (Refer to above Table). Table IV shows the detailed weights and ranking for sub-determinants. Local weight of the sub-determinant was multiplied by weight of its parent determinant to calculate its global weight. Average consistency (Ksi*) for each expert based on the main determinants and presented in above table and it was found to be <0.10 which was highly consistent (Rezaei 2015, 2016).

TABLE IV WEIGHTS OF THE SUSTAINABLE PRACTICES OBTAINED FROM EACH EXPERT

Sub Determinants	E1	E2	E3	E 4	E5	E6	E7	E8	E9	E10	E11	E12	Weight
TG1	0.563	0.583	0.313	0.563	0.583	0.579	0.225	0.188	0.629	0.628	0.647	0.688	0.516
TG2	0.313	0.306	0.563	0.125	0.111	0.105	0.650	0.688	0.143	0.140	0.235	0.188	0.297
TG3	0.125	0.111	0.125	0.313	0.306	0.316	0.125	0.125	0.229	0.233	0.118	0.125	0.187
OG1	0.603	0.495	0.291	0.091	0.083	0.140	0.466	0.267	0.473	0.562	0.574	0.280	0.360
OG2	0.086	0.280	0.485	0.273	0.250	0.495	0.259	0.473	0.267	0.097	0.099	0.495	0.296
OG3	0.172	0.140	0.146	0.182	0.417	0.086	0.103	0.082	0.082	0.128	0.109	0.086	0.144
OG4	0.138	0.086	0.078	0.455	0.250	0.280	0.172	0.178	0.178	0.213	0.218	0.140	0.199
EN1	0.373	0.244	0.229	0.424	0.261	0.244	0.244	0.256	0.424	0.236	0.499	0.246	0.307
EN2	0.211	0.407	0.398	0.254	0.443	0.407	0.407	0.449	0.254	0.157	0.181	0.164	0.311
EN3	0.211	0.163	0.229	0.068	0.104	0.163	0.122	0.128	0.068	0.417	0.076	0.404	0.179
EN4	0.141	0.122	0.076	0.127	0.130	0.122	0.065	0.103	0.127	0.073	0.108	0.063	0.105
EN5	0.065	0.065	0.068	0.127	0.061	0.065	0.163	0.064	0.127	0.118	0.136	0.123	0.098
CR	0.066	0.051	0.073	0.079	0.063	0.066	0.053	0.068	0.058	0.067	0.060	0.072	0.065

V. MANAGERIAL IMPLICATIONS

Smart cities have come with its own challenges wherein the citizens are trapped in with loss of human touch, isolation and remote services and online shopping etc. which may cause mental challenges to the population. Besides, there is a challenge with regard to over dependency on private vendors and service providers under a highly surveillance environment.

VI. LIMITATIONS OF THE STUDY

The limitations of the present study are that it is based on the secondary data in the form of literature review and not limited to any specific region.

TABLE V SMART CITY EMERGENCE DETERMINANTS AND SUB-DETERMINANTS WEIGHTS AND RANKS

Main Determinants	Main Determinant Weights	Sub-Determinants	Local Weights	Global Weights	Ranking
TG	0.492	TG1	0.476	0.234	1
		TG2	0.297	0.146	2
		TG3	0.187	0.092	4
OG	0.308	OG1	0.360	0.111	3
		OG2	0.296	0.091	5
		OG3	0.144	0.045	9
		OG4	0.202	0.062	7
EN	0.199	EN1	0.319	0.064	6
		EN2	0.296	0.059	8
		EN3	0.165	0.033	10
		EN4	0.101	0.020	11
		EN5	0.099	0.020	12
Ksi*	Main determinants 0.063	Technology determinants 0.053	Organization determinants 0.075	Environment determinants 0.069	

VII. CONCLUSION AND DISCUSSION

The results and analysis indicates that the absorption and diffusion of new technology (TG1) has been measured highest weightage for the emergence of sustainable smart cities, followed by institutional framework (OG1) to facilitate such technological enablers. Both competence and capability of technology (OG1) and novelty impact of innovative concept offering (EN1) are the major enablers under technology and environment categories. However, two of the sub-determinants namely value impact of innovative concept offering (EN4) and cultural acceptability of innovative concept offering (EN5) under environment enablers scored low in the study. The detriments and sub determinants in the present study is evaluated on basis of the secondary data and literature review.

The results of the study support the past studies under each of the sub-enablers for the emergence of sustainable smart cities. The outcome and the findings of the present study are expected to provide a useful basis for future studies to improve the understanding of the determinants influencing the emergency of sustainable smart cities. Some of the macro level challenges with the smart cities are surveillance, cyber security, safety aspects, data breach, digital divide or inequality, trust deficits and economic damages. Cities are the future of human civilization, and it is the responsibility of the city planners, administrators and the civil society at large to keep it smart enough to absorb digital technologies.

VIII. FUTURE RESEARCH

The smart technologies, Internet based IoT, data analytics which is one of the primary component of smart city projects is still evolving but posing a serious challenge. Local administration and technologists are finding difficult times to keep it safe and possible abuse from cyber-attacks, data breaches and denial of services. Cyber threats are increasing day by day and have the potential to create threats to even national security issues. The GPS data of vehicular movements may be misused by the Government Agencies for snooping of its citizens some time targeting vulnerable section of population. Future research may address these core issues of data abuses and cyber security in the context of smart cities.

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