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Impact of Disruptive Technologies on Smart Cities: Challenges and Benefits

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Abstract. The growing importance of leveraging disruptive technologies is gaining prominence, while digitalizing smart cities. This paper is grounded in theory of disruptive technologies and seeks to develop and empirically test a comprehensive framework to leverage key disruptive technologies namely Internet of Things (IoT), Autonomous Vehicles (AV), Artificial General Intelligence (AGI) and 5G Networks (5G) for smart cities. Further, it not only identifies key disruptive technologies and the challenges while implementing them but also the benefits that the smart cities could attain by leveraging these disruptive technologies. With systematic literature review of 700 articles and using Structural Equation modelling (SEM) technique, to analyse the data collected from a sample of 575 industry practitioners and scholars, the results provide an appropriate model to leverage identified the disruptive technologies for smart cities. This article further provides implications for researchers, theories that govern smart cities and industry practitioners, while leveraging disruptive technologies of smart cities.

Keywords: Disruptive Technologies, Smart Cities, Internet of Things, Artificial General Intelligence, Autonomous Vehicles, 5G Networks.

Introduction to disruptive technologies and smart cities

There is radical change in smart cities due to impact of disruptive technologies [28]. Further, the authors described that International organization for standardization (ISO) and the International Electrotechnical Commission (IEC) had recognized smart and sustainable city as the one which is able to meet the social, economic and environmental requirements; also help improve the efficiency of urban operations and quality of life. The importance of disruptive technologies have been underscored by stating contributions to plan the policy of smart cities [4]. Disruptive technology is defined as the one that has capability to change lives of the human, industry trends and other factors like communication and transportation [1]. Smart cities are defined as those that use digital technologies cohesively drive economic growth, to provide information, enhance welfare of the public and improve services of government. [14]. This definition by Gil-Garcia after researching over 200 scholarly publications is a benchmark definition of smart cities arrived at exhaustive study of literature and is adopted as the definition of smart cities for this research study.

Theories for Smart Cities and Disruptive Technologies

Leveraging disruptive technologies in smart cities, as we digitalise them so that urban planners, strategists, digital consultants, regulatory bodies and stakeholders incorporate them and leverage the opportunities to achieve holistic objectives of smart cities is essential. Many theories that govern smart cities namely theory of connecting networks and theory of urban systems, indicate the importance of enabling micro-instrumentation for smart cities to advance the theories governing smart cities and studying disruptive technologies that can enable this micro-instrumentation of the smart cities. In this study, theory of disruptive technologies defined by Prof. Clayton Christensen has been chosen as the theory, as it aims to explain establishment of disruptive technologies.

Literature Review Approach

The databases that were used for the literature review include EBSCO host Business Source Complete, ProQuest Business complete collection, Directory of Open Access Journals and Google Scholar, as they are considered to be the most wide-ranging databases for scholarly study in this field. Articles were selected only from peer-reviewed journals and conferences and date between 2014 and 2020 to ensure that we have considered the latest work, trends and technologies in this field. It is not only clear from [8] who mentioned that IoT, AV, AGI and 5G networks would function in an integrated fashion in the context of smart cities, but it can also be inferred from [34] that AV, IOT and AGI need 5G technologies' support to provide highly efficient services to smart cities. The scope of the study also included the success factors that affect the digitalization and disruptive technologies of smart cities, namely, sustainability, digital citizens and ecosystems to make it comprehensive. The following table (table 1) provides details on systematic literature review conducted for the study.

Table 1. Nine Phases of the Systematic Literature Review

Stage wise representation of literature review
Step 1: Scanning for the literature through a search using keywords 'disruptive technologies' and 'smart cities' in the databases. Around 750 publications were identified (20.03.2020).
Step 2: Leveraging limiter texts in multiple fields like title, keyword and abstract, in order to ensure the relevance of articles. This reduced the number to 700 publications (25.03.2020).
Step 3: Elimination of duplicates and non-English language papers.
Step 4: Scanning of the abstracts of the remaining publications for selected independent constructs IoT, AV, AGI and 5G Networks disruptive technologies in development of smart cities.
Step 5: Complete review of publications for selected independent variables of smart cities
Step 6: Screening of references of shortlisted publications to identify further publications on digitalisation of smart cities leveraging the selected disruptive technologies.

Step 7: Inclusion of additional publications and books of researchers from the field of smart cities and disruptive technologies.

Step 8: Identification of key findings and research gaps in articles short-listed for smart cities and disruptive technologies.

Step 9: Identification of key findings and research gaps in disruptive technologies impacting smart cities.

Internet of Things

IoT is considered as most important disruptive technology since it can augment lifestyle of humans and drastically alter the way in which digital citizen interact and consume the digital information [27]. The importance of Internet of things is reiterated as one of the most promising disruptive technology [25]. Also in existing literature, factors affecting deployment of IoT technologies in smart cities is scarce.

1.1 Sub-variables of IoT

The literature review also focused on sub variables of disruptive technology IoT while studying challenges of its deployment and its impact on smart cities and are coded as IO1 to IO5. Interoperability (IO1): It is important to develop a software standard so that newly developed products across manufacturers will be connectable [22]. Collaborative IoT Architecture (IO2): Collaborative Internet of Things (IoT) architecture is required to test new data analysis methods [7]. Performance (IO3): Performance of the OAuth 2.0 protocol for authorization, in large IoT deployments should be evaluated [6]. Government IO4: Governments will need to collaborate closely with IoT providers to understand security risks [21]. Smart Engineering (IO5): It is important to model a smart engineering methodology that enables development of digital services [7]. Thus it needs to be investigated the impact of IoT on smart cities to enhance its policies, while it is leveraged as a disruptive technology leading to hypothesis (H1).

H1: Internet of Things (IoT), as a disruptive technology impact smart cities, leading to better policies.

Autonomous Vehicles

With autonomous vehicles, the smart cities are set to be revolutionized by autonomous vehicles and would replace current human driving activity for over a century [30]. The potential of autonomous vehicles as one of key disruptive technologies of smart cities and discusses about its tremendous opportunities and challenges [42].

1.2 Sub-variables of AV

The literature review also focused on sub variables of disruptive technology Autonomous vehicles, while studying challenges of its deployment and its impact on smart cities and are coded as AV1 to AV7. V2Control Networks (AV1): Communication between autonomous Vehicles to control Networks is important for content distribution of information [32]. Connected Cars (AV2): Adaptive solutions involving user preferences is required for content distribution in connected cars [9]. Protocols (AV3): Cross Layer approach involving infrastructure aspects is important to improve information-centric protocols in connected car applications [9]. Orchestration (AV4): It is important to further investigate orchestration of distributed autonomous systems [35]. Automotive OEMs (AV5): Automotive Original Equipment Manufacturers (OEMs) need to embrace identity as service providers [43]. Security (AV6): Autonomous vehicles and their mapping software need to be alert to the possibility of hacking [12]. High Reliable Network (AV7): High Reliable network provides opportunities for operating services and control functions for autonomous vehicles [29]. Therefore, it needs to be investigated, if Autonomous vehicles has significant impact on smart cities to reshape its mobility, while it is leveraged as a disruptive technology leading to hypothesis (H2).

H2: Autonomous Vehicles (AV) as a disruptive technology impact smart city, to reshape its mobility.

Artificial General Intelligence (AGI)

Artificial general intelligence as a disruptive technology that will help systems to operate independently on a specific problem domain and these guidelines would be used to integrate various systems that are able to perform it in an intellectual way similar to how human being is capable of executing a task and even beyond that [41].

1.3 Sub-variables of AGI

The literature review also focused on sub variables of disruptive technology AGI while studying challenges of its deployment and its impact on smart cities and are coded as AG1 to AG6. Robotic Systems (AG1): Robotic systems will be the main drivers of the digital transformation of the economy [40]. Human Effects – Methods (AG2) need to be developed to assess the human effects of Artificial intelligence (AI) [31]. Businesses (AG3) - Future development of AI will affect competition among businesses [26]. Learning engine (AG4) - Reliable data analytics process to explore properties of the available data is required to design the learning engine of Artificial General Intelligence systems [41]. Smart Environment (AG5): Technologies involved in the creation of smart environment (Space which can communicate digital data) requires attention [38]. Metasystem transition (AG6): Transition of metasystems (systems that monitor, model and process data from other systems) will lead to Artificial

General Intelligence [33]. Thus it needs to be investigated if Artificial General Intelligence has a significant impact on smart cities, to enhance their economic opportunities, while it is leveraged as a disruptive technology leading to hypothesis (H3).

H3: Artificial General Intelligence (AGI), as a disruptive technology impacts smart cities, to enhance economic opportunities in smart cities.

5G Networks

5G has capability to create significant impact in multiple industries and how it will deliver AI based services; how it will spawn technology, business and operations based innovations for all sections of society [34]. However, the vision of 5G will not become a reality without robust security measures in context of smart cities [23].

1.4 Sub-variables of 5G

The literature review also focused on sub variables of disruptive technology 5G Networks while studying challenges of its deployment and its impact on smart cities and are coded as FG1 to FG8. Scalability (FG1): Scalable business models that can be adapted to business is important for 5G. Traffic Dynamicity (FG2): Predicting traffic dynamicity will enable 5G Network to increase resource utilization. Co-ordinated Multipoint (FG3): Co-ordinated Multipoint Access amongst multiple heterogeneous base stations is yet to be explored in 5G [5]. Energy Harvesting (FG4): Energy harvesting techniques exploiting green energy resources is yet to be explored in 5G [5]. Interference cancellation (FG5): Optimization of Interference Cancellation amongst cells in 5G is yet to be achieved [5]. Trust (FG6): Architectures to improve trust of the user is required in 5G networks. Commercial Implementation (FG7) - It is important to commercialize implementation of 5G Networks [17]. Security (FG8): Security measures are required to protect the privacy concerns of users in 5G network. [23]. Thus, it needs to be investigated if 5G networks has significant impact on smart cities to cater to the real time needs of society, while it is leveraged as a disruptive technology leading to hypothesis (H4).

H4: 5G networks (FG) as a disruptive technology impacts smart cities, to cater to their real time needs.

Benefits to Smart Cities

The literature review on benefits that the smart cities that are expected to gain by leveraging the identified disruptive technologies are listed below as outcome measures BE1 to BE7. Improving Quality of Life of Citizens (BE1) - Optimizing digital ecosystems can improve the quality of citizens' life in Smart Cities [2]. Enhancing Sustainability of Cities BE2: Seamless amalgamation of their core enabling

technologies will help facilitate smart sustainable cities [39]. Participation of Digital Citizen (BE3): Digital citizens will have the opportunity to be involved in development of Smart cities [36]. Enhance policies (BE4): Open Innovation model will bridge the gap between IoT push and Smart Cities' policy pull leading to sustainable development [37]. Optimizing Urban Mobility (BE5): Autonomous vehicles shape urban mobility such that it contributes to sustainable smart cities [16]. Address Real time capability needs (BE6): Deployment of 5G communication networks will address real-time capability needs of smart cities [24]. Better Economic Opportunities (BE7): Digitalization of Smart Cities with disruptive technologies will lead to optimal positioning of businesses within the ecosystem to benefit from economic opportunities [20].

Research Methodology

We have chosen questionnaire survey as a research method using web-based data collection instruments using likert scale. Qualitative research is leveraged as a method of exploratory research to arrive at quantitative research hypotheses later [11].

1.5 Qualitative Research

We have used qualitative research for mining the existing literature and research gaps, as the research is about Impact of disruptive technologies on smart cities and it is a socio-technical subject. The literature review of 700 articles helped to understand the key independent variables that identify impact of disruptive technologies without attempting to look at inter-relationship. The research gaps identified were further verified and pilot tested with R-square value of 0.711 involving 12 industry experts, validating the questionnaire and research hypothesis. The pilot study provided insights to fine tune the questionnaire and received appreciations. The responses were obtained with informed consent to manage privacy and anonymity of the data collected in compliance with ethical considerations.

1.6 Quantitative Research

Quantitative research is leveraged to test the hypothesis arrived at from the theory and able to deduce the size of phenomenon of interest. It uses mathematics and statistics to report findings of research. In the study, the Structural equation modelling (SEM) is used to study structural relationships. It is used in our study to analyse the structural relationship between latent constructs and measured variables of smart cities. The strategy of using SEM permits various measures to be associated with one latent construct. SEM is also ideal when testing theories that include latent variables.

Survey strategy was used through questionnaires to address various research gaps in the study. The research questionnaire was administered to 575 participants

using convenience sampling. In this study, the stakeholders of smart cities were selected as respondents as respondents were either users, industry practitioners or research scholars involved in digitalization (or) smart cities (or) disruptive technologies. The role of the respondents in smart city was categorized as a) User b) Touch base with Smart City service flow c) Observer d) Implementer e) Developing software/hardware for smart city development. 60% of the respondents were from top and senior management, 28% of respondents were from middle management, while junior management and others contributed 10% of respondents. In terms of demography, around 59% respondents were from Asia Pacific region, 18% of responses were from Americas, around 15% UK & Europe geographies and around 8% of respondents were from Africa and Middle East. The data obtained through survey strategy was analysed using structural equation modelling. The conceptual framework of the research framework is given below in figure 1.

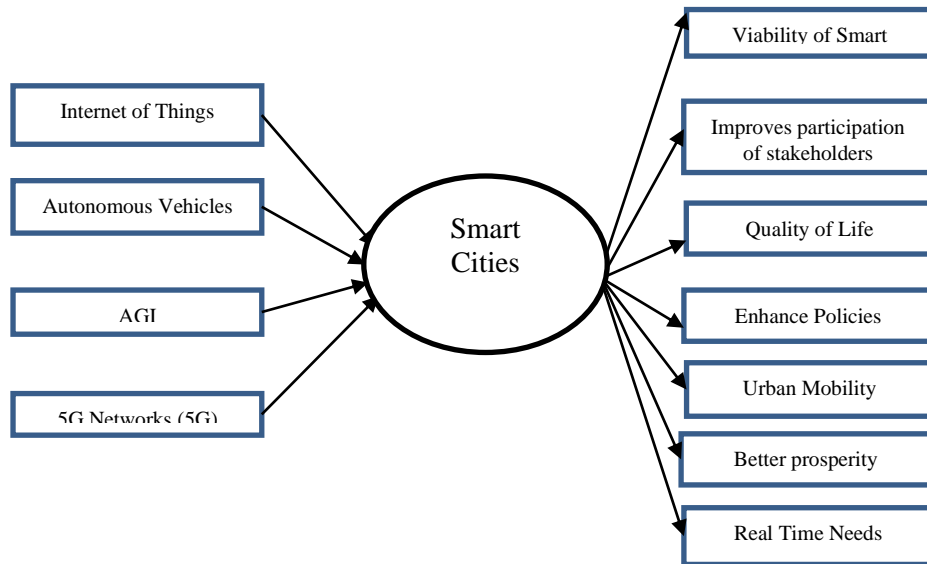


Fig. 1. Conceptual Model of Research Framework

Results and Analyses

The results were analyzed using ADANCO 2.0.1 software and the highlights of results are provided below. Examining the reliability of the constructs and discriminant validity of the construct is the first step to represent each construct [3]. These results are shown in Table 3.

1.7 Construct Reliability

The reliability of scale can be assessed by Cronbach's alpha and Jöreskog's rho. In Structural Equation Modelling (SEM) Jöreskog's rho is a better reliability measure than Cronbach's alpha, since Jöreskog's rho is calculated on the loadings rather than the correlations between the observed variables [10]. Jöreskog's rho required for validity of construct is greater than 0.7 [13]. In our model, value of Jöreskog's rho of all constructs are above 0.84 which demonstrates the validity of constructs. The minimum threshold value of Cronbach's alpha is also 0.7 and we observe that all our constructs are above 0.7. The reliability coefficient Dijkstra-Henseler's rho (ρ_A) need to be above 0.70 in case of exploratory research and above 0.80 for more advanced stages of research [15]. The constructs identified in the study satisfy Dijkstra-Henseler's rho's values as well [18].

1.8 Discriminant Validity

The factor of discriminant validity is evaluated in two steps using Fornell and Larcker criterion. It is leveraged to validate if the square root of construct's Average variance Extracted (AVE) is higher than correlations between any other construct within the model and itself. Secondly, the factor loading of an item on its associated construct should be greater than the loading of another non-construct item [19]. The measurement model in the study displayed good discriminant validity and the Fornell and Larcker criterion is met.

1.9 Goodness of Fit and Convergent Validity

The model established SRMR (Standardized Root Mean Square Residual) values of 0.0518 (saturated model) and 0.0796 (estimated model). A value of less than 0.08 for SRMR values is recommended and hence the model has good fitness of fit. The convergent validity is measured by Average Variance Extracted (AVE). The independent variables of the model have indicated a score of more than 0.5 indicating convergent validity and uni-dimensionality.

1.10 Multi-Collinearity

The model has also displayed lower degree of multi-collinearity amongst all sub variables and is measured through variance inflation factor (VIF) as per ADANCO user manual. All the sub-variables of model have VIF values of less than 2.2386 which is well below value of 10 and proves lower degree of multi-collinearity. The summary of hypothesis results arrived at through literature review are provided below:

H1: Internet of Things (IoT) as disruptive technology impact smart cities, leading to better policies.

H2: Autonomous Vehicles (AV) as a disruptive technology impact smart city, to reshape its mobility.

H3: Artificial General Intelligence (AGI), as a disruptive technology impacts smart cities, to enhance economic opportunities in smart cities.

H4: 5G networks (5G) as a disruptive technology impacts smart cities, to cater to their real time needs.

Table 2. Nine Results of hypotheses from SEM technique

Hypotheses	Representation of relationships	Font size and style	t-value	p-value (2-sided)	Results
H1	IO -> BE	0.4076	7.7381	0.0000	Accepted
H2	AV -> BE	0.3098	6.6928	0.0000	Accepted
H3	AG -> BE	0.4036	8.8371	0.0000	Accepted
H4	FG -> BE	0.1685	3.7633	0.0002	Accepted

From total effect perspective, all hypothesis have been proven such that all the dependant variables identified from literature review, have significant impact while digitalizing Smart Cities leveraging disruptive technologies as we have seen higher t-values to the associated hypothesis. Further we see that all p-values on the above table 2 have a value of lesser than 0.02 and all our hypotheses are accepted. The Coefficient of determination (R-Square Value) of the model is 0.6736 proving the structural validity of the model. Hence, we can conclude as follows for each of the hypothesis after analysis.

- Internet of Things (IoT), as a disruptive technology very significantly impacts smart cities leading to better policies.
- Autonomous Vehicles (AV), as a disruptive technology very significantly impacts smart cities, to reshape its mobility.
- Artificial General Intelligence (AGI), as a disruptive technology very significantly impacts smart cities to enhance economic opportunities in smart cities.
- 5G networks (5G), as a disruptive technology very significantly impacts smart cities to cater to their real time needs.

From the analysis of results, the values of loadings of outcome variables for Smart Cities (BE) are above 0.69. The values of loadings of all sub variables for AV are above 0.67. The values of loadings of all sub variables for AG, IoT and 5G are above 0.69.

Conclusion

The total effects from the study indicate that it is more important to focus on disruptive technologies IoT (0.4076) and Artificial General Intelligence (0.4036) amongst the set of chosen four disruptive technologies, as they seem to have higher impact on smart cities and help to achieve its objectives. It is to be highlighted that IoT is well positioned as a disruptive technology and that it is set to become ubiquitous and its key characteristic is that it helps merge the digital and physical world [44]. They are followed by Autonomous Vehicles (0.3098) and 5G networks (0.1685) in this study. It is also clear that while disruptive technologies like IoT, AGI, AV and 5G Networks can be utilized for smart cities to enable micro instrumentation, it is required to consider the factors of leveraging ecosystems, digital citizen and sustainability. These initiatives can have a broader transdisciplinary impact to truly impact on smart cities and thus it contributes to theory of disruptive technologies as the study identifies disruptive technologies in the context of smart cities. From theoretical perspective, it is clear that it also contributes to theory of connecting networks, theory of urban systems and evolving urban systems in terms of suggestion of deployment of combination of disruptive technologies that are to be targeted for smart cities as this enables micro instrumentation needed for smart cities. The limitation of this research is that it has focused on identified four disruptive technologies. The study also provided some insights to practitioners of technology of smart cities such as IoT practitioners to consider inter-operability with both IoT systems under open connectivity foundations and those that are not under open connectivity.

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