Smart Cities for Sustainability - An Analytical Perspective

Monica Mundada[1], Raghava Rao Mukkamala[1,2]

[1]Centre for Business Data Analytics, Department of Digitalization, Copenhagen Business School, Denmark
[2]Department of Technology, Kristiania University College, Oslo, Norway
Email: {mmu.digi, rrm.digi}@cbs.dk

Abstract—**Smart cities is an trending concept with an focus of development in urban areas from all edges.**

The primary aim of this research work, is concentrated for literature review on Smart Economy, Smart Environment, Smart Government, Smart Living, Smart Mobility, Smart People integrated with technology research themes with a key focus on data analytics approach towards sustainable development. Our conclusion reveals that a lot of research in smart cities is focused on prescriptive analytics, which indicates that smart cities initiatives aligned on taking the data analytics perspective for sustainable development in urban areas.

Index Terms—**Smart cities, Sustainable Development, Predictive analytics, Descriptive analytics, Prescriptive analytics**

I. INTRODUCTION

As we are moving towards 21st century, there is major shift in the paradigm of urbanization, where people are increasing adopting the urban life styles. According to UN survey [1], there will be raise in 68 % of world population living in urban places by 2050. As per the increase in demand of people living in urban areas, to have more efficient life style, there is need for well organised, efficient establishment of smart cities. Smart cities can be defined as a place where there is integration and transformation in different sectors with a focus for economical and sustainable development. In other words, Smart cities is an initiative for resilient, sustainable and liveable cities, using smart technologies such as Artificial Intelligence (AI) and other, for the betterment of the urban life using sustainable development [2], where the focus is more or less related to transportation, government, people, economy, environment and living habitats [3].

The primary focus of this paper to analyse the current state of the art in the area of smart cities from the analytical perspective with help of systematic literature review. Section 2 introduces of the conceptual framework and research method, where as section 3 presents the analysis of various research papers on smart cities. Section 4 presents discussion and the future work.

II. SUSTAINABLE DEVELOPMENT IN SMART CITIES

The concept of sustainable development relies on three important pillars i.e economy, society and environment [4]. As shown in Figure 1, smart cities involve key sectors like environment, infrastructure, people, transport, health, education, government and technology. Smart environment focuses on major components like quality of air, climate change and energy. Along with maintaining and protecting natural resources, the waste and fuel consumption must be aligned with the sustainable goals [5]. The term smart infrastructure includes the well design of homes with IOT devices and urbanization of buildings [6]. This will help in appropriate use of land with satisfying environmental objectives. Smart living and lifestyle of people are the limelight areas of smart people [7]. This will help government bodies to track different age groups and meet their respective demands. Smart transport avail the mobility structure of traffic on the roads and their network. The efficient decision support system in this area, will emerge the new friendly routes with less emission of pollution and ease mobility of people in time [8]. Smart health leads to development of smart hospitals, medicines and treatment which makes diagnosis process easy and best curative measures for the disease [9]. With an unexpected emergence of pandemic COVID-19, the important transformation is seen in the education and other domains as well driving towards digitalisation in many aspects. The innovative way of smart learning and teaching are much more focused in the smart education [10]. The policy makers of smart government must be citizen-centric governance with well informed decisions and adequate policies. The smart governance is focused on adopting new technologies with improved methods for sharing data and decision making [11]. Smart technology compromises of multiple projects working effectively for building support system with the use of IOT, Blockchain and ICT [12].
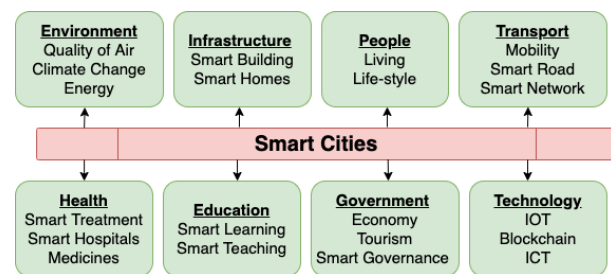

Fig. 1. Block diagram of Smart cities and key factors

A. Research Method

This paper covers the literature review of peer-reviewed papers for past ten years (2010-2020) focusing on the keyword 'smart cities' and 'sustainable development'. The research objective focused for this study is: *1) to identify the research covering the aspects of smart cities and sustainable development 2) to identify the type of analytics that are being followed in smart cities research*. The following inclusion and exclusion criteria is adopted in this paper: 1) A paper must contain smart cities concept 2) Must integrate and focus on technological and sustainable development. 3) Peer-reviewed articles only. The keywords *smart cities* and *sustainable development* are used as search words. Out a total of 425 research papers, 116 belongs to ACM digital library and 309 belongs to IEEE explorer databases. We segregated the data on the basis of title and keywords in the first level, and second Level filtration is done on basis of title, abstract and summary related to Smart cities and behavioural status of sustainable development. This step narrows down the search by removing duplicates and topics relevant to the present objectives. In the third level filter, we further filtered with respect to their analytical research further categorised into descriptive, prescriptive and predictive research in the different domains. In the last step, the papers are filtered with target of sustainability development and finally we ended up with 54 papers.

III. Data analytical research

Data analytical research focuses on meaningful insights for the smart cities growth aligned with the sustainable development goals [13]. This lays background to identify the requirements and research gaps in this field. While studying, sustainability of smart studies we noticed that there is a minute differences between descriptive and diagnostic analytics in the context of smart cities, therefore we have combined the both into a single category i.e descriptive analytics. Articles are classified into following types summarised into different sections as shown in table I.

Descriptive analysis: Descriptive or reporting analysis is engrossed to understand what is happening in the organization/research with consolidation of identifying some fundamental trends and reason's of its occurrences. This method is the most popular in organizations and for analysis of social media [14].

Predictive analysis: Predictive analytics, using statistical and data mining methods, focusses on predicting the future aspects of a phenemenon [15]. The main methods in predictive analytical applications are primarily classification algorithms and this review will provide an overview of their usage in smart cities.

Prescriptive analysis: Based on the current trends and likely forecasts, prescriptive analytics focus on building of decision support system [16]. This study is oriented to provide a decision or a recommendation for a specific action or overall development in smart cities.

IV. Discussion and Conclusion

We have reviewed the papers according to the data analytics dimensions specified above. Out of all the papers, the prescriptive analytics dimension constitutes of 39%, then predictive contributes for 33% and the papers under descriptive analytics constitutes 27%. The figure 2 shows a clear indication that the number of articles in prescriptive analytics category increased over the years.
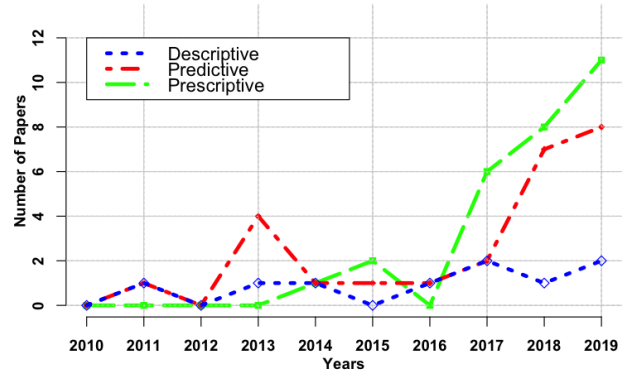
Fig. 2. Distribution of research articles related to different type of analytics

Our study shows that sustainable development goals of smart cities identified in different sectors as follows.

- **Smart Environment**: The ICT sustainability [5], [71] aspect for climate change mitigation is the major research area under this theme. The decision support system for Waste management is considered as another key aspect [53]. Tools for simulation studies of renewable energy resource is also prominent [52].
- **Smart Infrastructure**: The sustainability aspect is prevalent in proper planning of land utilization [50], building smart furniture [69], smart homes [51], and smart lightening solutions [70] under this research theme.
- **Smart People**: Assessment of sustainability based on public values and citizen centric goals [21] [7] [35] [36] [37] [38] [39] [60] is one of major research areas under this theme. This is focused with digital citizenship which maintains the cyberphysical approach for privacy and public data.
- **Smart Transport**: The main focus is on several problems related to transport, road optimization routes and friendly transport networks [32] with less carbon emissions. Model shuttle routes [55], car and bike sharing [56], dynamic road markings [74], development of smart bikes with IOT [33] [54], and use of data mining [10] for parking lots are also prevalent.
- **Smart Health**: IoT based system with real-time data for Knee angle assessment [68] and use of AI for correct diagnosis and efficient treatment [72] [73] are some of the main research areas.

Part I - Descriptive Analytics			
Author	**Data**	**Method**	**Findings**
Christine Meschede [17]	Open urban data	Case study	The open measurement tool is used and measures the goals of sustainable development using open urban data
Trevor Clohessy [18]	Interviews / Questionnaire	Cloud computing	Cloud facilitated smart city development
Nielsen [19]	Research papers	Case study-Denmark	The strong eGovernance is beneficial for digital transformation
Lopes [20]	Questionnaire	Empirical Analysis	Smart cities development initiatives are relaying on technologies and Smart Governance
Porto [21]	Public value	DSR (Design Science Research) method	Framework supports maturation and generation of public value in public organizations
Daesung Jun [22]	Data set regarding citizen demand reports	Statistical method	Findings show that different age groups have different demands which affect the life quality of inhabitants
Kirwan [23]	Urban media	Ubiquitous computing	Describes how urban media is used for data collection and generation
da Silva [24]	Research papers	Review	Identifies the gaps between the technology and smart city
Anthopoulos [25]	Modelling approaches	Review	Reviewed modelling approaches with common findings related to smart cities and bench marking tools
Aljowder [26]	Maturity frameworks	Survey	Paper provides the technological aspects review but absence of assessments environmental aspects
Law [27]	Research papers	Survey	Review of smart cities from technology side , address challenges concerning cybersecurity, cyber privacy and infrastructure investments
Vasudavan [28]	Research papers	Contextual mapping	Studied and reviewed smart city characteristics and its dimension using method of contextual mapping
Dias [29]	Onotologies database	Report	Report provides Data Management plan, guidelines and tools for data organization, sharing and reuse in context of smart cities for Porto city
Zhu [30]	Iot and cloud data	IOT techniques	Providing comprehensive and intelligent solutions with different aspects of engineering
Gascó [31]	Semi-structured interviews	Case study	Findings shows that policy, management and organization, of people and communities are most important of smart city strategy
Part II - Prescriptive Analytics			
Anagnostopoulou [32]	Not specified	Route planning mobile application	Findings provides decision support system that takes care of transportation with environmental friendly routes resulting in less emissions reduction
Makarova [33]	Sensor data	Prototype	Proposed prototype tracks the condition of the both cyclist and environment routes and also ignites electric motor in problematic situation
Zheng [2]	Big data and open data	Vertical and horizontal integration	Provides the 3 dimension level i.e horizontal, vertical and whole-of-society approach that can be integrated in different sectors
Razaghi [34]	Not Specified	Interdisciplinary approach	Findings shows that smart governance is an important aspect to design the smart city using technological perspective
Bolívar [35]	statistical information from EUROSTAT	Descriptive statistics and correlation analysis	Paper insights the co-relation between public values and Smart cities
Dominguez [36]	Open urban data	Case study	This paper provides scope of improvement in social life communities with an agenda for involved participation of government agencies
Atif [37]	cloud-platform	Application or Web portal	With the help of integration of smart homes and IOT it is easier to track energy usage and modify the behavioural changes
Agnihotri [38]	Not specified	Case study	Smart city design centres the aspect of citizen and their demands as key aspect
Beneicke [39]	Publicly accessible online platform	Simulation tools and machine learning	With the help of Machine Learning and Simulation, the method of taking decision in ecosystem can be improved
Ouoba [40]	Not specified	Mobile-phones with SMS-based services	This case study provides different ways of integrating technology in the field of transportation and healthcare
Xia [41]	Index system of different sectors	BP neural network	The global optimization is achieved using neural fuzzy controller thus it avoids local minimum
Agnihotri [42]	Urban data by Microsoft Azure	axxessity	User-centric solution which is designed and applied for traffic management, smart parking and noise pollution
Yokoyama [43]	Sensor data	Festival framework	Using sensor data to improve the experimentation related to interconnection and federation
Bibri [44]	Big data	Data Mining	Data mining and big data provides sustainability goals using the cross–industry standards
Vidiasova [45]	Open data	Not specified	The development of smart city at early and middle stage can be tracked using this framework

Karim [46]	MongoDB data warehouse	Hadoop cloud-based eco-system	Innovative model is designed to understand traffic congestion using method of trajectories meta-model and algebraic structures
mostafa Bourhim [47]	Image data	Augmented reality and VR techniques	Smart cities implementation VR immersion and interaction
Patel [48]	IoT data	ifog simulator	A framework using fog computing method with IoT data and plots the analytics which can be used for analysis of smart cities
Wey [49]	Big data	Fuzzy Delphi Technique	Fuzzy Delphi techniques are used to predict future variance of smart sustainable city parameters
Jat [50]	Remote sensing & GIS	SLEUTH model	Appropriate land use policy for environmental objectives
S Ghosh [51]	Not specified	Building Codes Mandates	The areas of architectural and engineering codes can be utilised in constructing the codes of Smart cities
MI Aceleanu [52]	Municipalities data	Case study	Findings shows that implementation of circular economy to improve decision support system in recycling of waste at Romanian
S Mallapuram [53]	Real time data from web servers	Simulation	With simulation tool, the real time data can be extracted and further used for research of smart city sustainability
Part III - Predictive Analytics			
Harris [54]	Real time data	Case study	Urban development initiatives and a integration platform
Nelson [55]	UNO shuttle data	Graph theory	Optimized route to use shuttle, save fuel costs
Kalašová [56]	Not specified	Sharing Economy	Adoption of technology to influence road user's behaviour
Anastasi [57]	Sensor data	SMARTY project	Use of data mining for traffic flow and parking lots and optimal routes
Angelopoulos [58]	Big Data	Circular Economy	City's finite resources and citizens aspects can be utilised through crowd sourcing and real-time decision making and planning
A Wolff [59]	Real satellite data	Novel approach	Concludes that large urban data sets are related to solve real life sustainability issues
Petrova-Antonova [60]	Big Data and IoT	Digital twin concept	This tool identifies the relative potential between stakeholders, and citizens to find the best possible solutions to improve the business in smart city
Gurgen [61]	Hetrogenous devices	Cyber-physical systems	This combination of physical to the cyber-world deploys the goals of sustainability in developing smart city
KL Raju [62]	Sensor data	Integration with Arduino	New ways to Smart waste management system, Fire Detection, Air pollution monitoring, Smart parking system,Automatic Street Lights
F Cirillo [63]	IoT data	Atomic Services	This outcome presents a new approach depicting the adoption of the atomic services
S Lima [64]	Social networks, crowdsourcing	Deep learning algorithms	Findings shows that the perspective of efficiency, sustainability and resilience increases with the adoption of these methods
J Wu [65]	cloud data	ICT based orchestration framework	The data sets are collected by sensors and IOT devices and are analysed for further improvement in goals of smart city
Verstaevel [66]	Open Data	neO Campus operation	The citizen perspective centred approach with an objective to focus the inter-disciplinary work to resolve the challenges of development
K Tei [67]	Cloud data	ClouT concept	With the help of cloud data and IoT devices there are significant methods that can be deployed to built the smart cities
ME Fezazi [68]	physical measurement of knee angle	Cloud storage and simulation	Real-time measurement of knee are generated using simulation tool and forwarded to experts for real-time feedback & supervision
O Krejcar [69]	Patent database	Not specified	Integrating the Smart Furniture with policy making designed for innovation, inclusive economic growth sustainability
M Castro [70]	Not specified	Prototype	The traditional structure of street lighting can be improved with integration of the communications and logic
S Rasca [71]	Municipalities data	Case study	This case study overviews the small and medium sized cities to understand their aspects related to climate change
G Acampora [72]	Medical data	Ambient Intelligence	Using this innovative technique to provide smart medical system and medical wearable devices
HC Koh [73]	Healthcare data	Data Mining	Highlights the limitations of data mining and provide future directions

TABLE I
REVIEW OF SMART CITIES ARTICLES ALONG WITH DATA ANALYTICS DIMENSIONS

- **Smart Education**: The new approach for building online public libraries [10] and with the help of satellite data a novel approach is provided for smart learning [59].
- **Smart Government**: Sustainability in this sector is focused for efficient and digital public administrations [2]. Urban data and adopting smart governance leads to full-fledged ideal cities [4] [18] [19] [58] [20] [34].
- **Smart Technology** : It focuses on using many different technologies and methods [42] [43] [61] [45] [75] [48] [63] [64] [65] [66] for sustainable development goals with adoption of techniques like fuzzy neural network [41], ubiquitous computing [23], integration of cloud data with IoT devices [67], data mining [44], mobile application [40], Augmented reality [47], for innovation of smart decision support system.

The motivation of this study to understand the development of smart cities and sustainable development from the data analytics analytical research perspective. Along with identifying what are the new innovative methods in the

above mentioned research themes, our study also tries to identify to what extent data analytics have been adopted into the research of smart cities with a key focus on sustainable development. Our findings indicate that high number of research articles are in prescriptive analytics, which is good sign as it will contribute to more accurate future analytics and adaptive measures for smart cities with a focus on sustainable development goals. Furthermore, this study also indicates that the focus of sustainable development has also been primary focus of many urban developmental research projects.

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