UDC 711.4

DOI 10.36622/VSTU.2022.53.1.010

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SMART, SUSTAINABLE VERTICAL CITY

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Statement of the problem. Population explosion, urban sprawl, horizontal expansion, decentralization and social disintegration have affected the urban infrastructure and sustainable development. A vertical city is a sustainable design approach that provides facilities for people which are approachable in no time.

Results. The article aims to look into two design approaches for vertical city planning and similar design characteristics of these vertical planning with increased social interaction and functional design. The research elaborates on some smart features of vertical cities with an emphasis on sustainable development goals. The research is an attempt to map the sustainable development goals with smart and vertical city, a modern approach currently being adopted by many countries like Singapore, Hong Kong, China, USA, Russia and India. It will look into the three major aspects of sustainable development: environmental, economical and social in vertical cities with an emphasis to use smart approaches in the development of newly designed urban areas.

Conclusions. The smart vertical city is adding value to urban development and it will offer positive environmental, economic and social impacts, hence sustainable in the long run.

Keywords: Vertical city; Smart Design; sustainable development; planning; socio-economic analysis, Environment.

Introduction. High living standards, population explosion, overcrowded spaces, environmental issues are the current challenges of the built environment [15]. The sustainable stratification, global warming, climate change is affecting the eco-system. The horizontal expansion of cities, towns etc. has resulted in the evacuation of free land for people [16]. According to the United Nation statistic, more than 68 % of the world population will live in cities by 2030 and major growth is expected to occur in Asia, and Africa [12]. The designers are looking for an approach that serve the community at large and bring the architects, urban planner, environmentalist, agriculturist and socialist to one platform and work in humanity's interest [3]. The urbanization, industrialization and economic structure to manage an urban life, city growth, and development are the driving forces behind the demand for vertical growth.

A lot of developing and developed economies are facing the challenges of environment and equitable society. There are a lot of sustainable solutions that can help professionals to create a better environment and a better place to live. The cities require futuristic approaches to address the dynamic needs of the future significantly important for achieving the Sustainable Development Goals (SDGs). The UN SDGs has one devoted goal towards developing cities “SDG #11 — Sustainable Cities and Communities” that strives to make cities inclusive, safe, resilient and sustainable [11]. The adverse impact of Covid19 is more pronounced in urban areas and people have coupled issues of accessibility for public transport and open public spaces. The world is projected to have 43 megacities with more than 10 million inhabitants from developing countries till 2030 [12]. The low and middle-income economies are more prone to the effect of urbanization and unsustainable growth, social fragmentation, energy, and environmental crisis. The crisis has deprived a large percentage of the world economy with basic necessities of life including housing, transportation, infrastructure facilities, unemployment, health and education, etc. In order to ensure worldwide sustainable development there is need to have an equitable consideration of environmental, economic and social goals. The paper will look into the design approaches to address the socio-economic and environmental challenges to find their solution in futuristic growth of cities. The existence of various approaches towards the futuristic goals of cities comes from various terminologies like ecocities, smart cities, digital cities, sustainable cities, and green cities striving towards one common goal of sustainable development and vertical cities are an addition to the list. The cities of Singapore, Hong Kong, China, India, Russia, New York, Manhattan, Beijing, Shanghai are going through extensive growth and development to accommodate the future needs of urbanized cities. The above cities are on the track to achieve sustainable development goals for the futuristic development. There are very few studies that focus on the use and application of United Nation sustainable development goals in the vertical growth of smart cities. That is why the paper suggests the integration of two major concept smart and vertical cities. The vertical expansion is presented as a solution to urban sprawl with reliance on smart infrastructure. The paper is divided into a few sections. In Section I the paper identifies Sustainable Development goals 11 in the context of above mentioned problems of urbanization and technological advancement challenges and map three basic parameters of sustainability with the environmental, economic and social parameters, Section II conceptualizes the hybrid concept of combining smart and vertical growth. Section III outlines the methodological framework and Section IV explains the results based on two design concepts, Section V builds up

the theoretical framework for a vertically configured smart city in the context of sustainable three principle pillars. Finally, Section VI concludes with the mapping of a sustainable development model for a vertical smart city and its further links with additional future challenges.

Section I - SDG Goal 11 “Cities and Communities Sustainable”. The United Nation sustainable development goal echoes the idea to “make cities and human settlements inclusive, safe, resilient and sustainable.” With a population rise and in order to accommodate everyone’s needs, we need modern sustainable cities. That calls for new, intelligent urban planning that is green, resilient, affordable, safe and culturally stirred. The SDG goal 11 emphasis cities to be green, environment friendly, safe from disastrous affect, economically affordable and a reflection of strong social attributes of cultural and community influences. The goal 11 has been further mapped with the sub goals of SDG 11 for understanding sustainable connections. The paper is an attempt to find a solution for a new vertically planned smart approach featuring three common parameters of sustainable development (Fig. 1).

Fig. 1. SDG Goal mapping with sustainable target of Cities and Communities

Section II - What is a Vertical and Smart City? A vertical city is a series of interlinking, environmentally friendly, self-sustaining, mega towers that extend as high as a mile skyward [8], while smart cities carry sensory driven data to manage resources and services within cities. A smart city combines various smart technologies in diverse applications of various walks of life, from economic growth to social well-being and environment protection [7]. Smart city uses Internet of Things (IoT) to control, monitor and manage and give real-time insights to the users, machine learning devices to make decisions about city management. The system works by means of a smart sensor of RFID, IR, GPS, laser scanners connected through Internet protocols for intelligent recognition, monitoring, safety and decision making [5]. The integration

of smart technologies, vertical farming, building information modelling approaches, vertigo movement has facilitated the building user's interaction and brings the nature close to build a structure. The construction of Vertical Cities can help to save energy, preserve ecosystem, nourish our growing needs and is a solution to the world's greatest future challenges. Ken's vertical city solution is a massive structure with a multiplicity of towers depending on diverse needs for a sustainable living [17]. The vertical city model has been widely appreciated and successfully adopted in a lot of countries such as China, Singapore, Middle East, France, South Korea, India, United States, etc. The Sustainable living requires the consideration of environmental, economic and social aspects for building communities and societies. The key aspects of sustainability are social interaction, economic stability and livable natural environment. There are also studies [2, 4, 9] showing that ecologically and economically smart buildings are a part of a sustainable future. But [1] argue that high rise buildings do not respect the values and social connectivity. So the research will try to answer the question of how smart living can inspire the futuristic growth in newly emerging urban communities like vertical cities. The study is an attempt to develop a theoretical framework based on SDGs for a smart sustainable development in a vertical city.

Objectives (Purpose). The objective of the research is to explore the futurist approach of urban communities which are typically inspired by the effect of globalization, vertical building masses, technological improvements and environmentally friendly approaches. The paper will look into two urban design approaches for the distribution of activities and masses in a vertical city. The current study aims to justify sustainable living in vertical cities using smart methodology. The research will specify a vertical design model for a smart city on sustainable grounds.

Section III Methodology. In order to achieve the objectives, the opinions of 10 professionals (architects and town planners) were recorded in four focus group discussions. Through brainstorming sessions, their observation and suggestions for a sustainable development in vertical cities have been provided. For familiarity with the concepts of vertical cities, they were briefed about the concepts and theories of Kenneth King and Kellogg Wong, along the sides with smart design and technologies. The data was shared in the form of existing literature, video sharing to generate a productive discussion. The recommendations were given a philosophical design approach, considering the environmental, economic and social concerns. The three key themes were the point of exploration in developing bubble diagrams for vertical societies, inhabiting large population with shared

facilities and infrastructure. The survey from 10 retail outlets was also shared with professionals for the options of smart technologies, like appliances, and smart meters that helped in cost estimation for the two basic modules of vertical cities.

Section IV Results / Findings. The methodology helped in formulating two frameworks for the planning of vertical cities. The futuristic design of these vertical cities could be based on two concepts named as Vertical City 1 (VC1) and Vertical City 2 (VC2). Fig. 1 and 2 explains the design approaches using a bubble diagram, an initial step at the planning stages for space organization and optimization.

Fig. 2. Concept design 1 of a vertical city (bubble diagram 1)

A. Concept design 1. In VC1, buildings will be divided into zones through centric facilities. The service core or hub will be designed to control, monitor, and manage the whole city. The vertical city towers/buildings will be self-sufficient for the inhabitants with all basic necessities of life, residences, supermarkets, restaurants, shopping facilities, primary and secondary level education and training institutes, religious buildings and administrative places.

The concept of vertical society is more accurately planned for occupants creating a harmonious balance between a natural and built environment, a correct blend of hard and landscape in vertical proportion. The design of these societies will be the collection of mega towers giving a new form to urban structures and infrastructure. Each mega tower is essentially divided into multi-levels for the differentiation of activities and spaces keeping a close contact with the nature. The cities need to be housed with all facilities of opened, closed public and private spaces.

B. Concept, design 2. The second concept of VC2 vertical planning was to integrate and assimilate all building structures together with segregational zoning of residential, administra-

tive, office blocks and entertainment towers. In this case, the systems of interconnected pathways, sky bridges, and monorails require a more efficient planning. The interconnected network of towers containing residential, office buildings, hotels, educational facilities, religious places, entertainment, leisure spots and other public areas will be linked to form communities. In such vertical cities, inhabiting the societies will highly depend on the systems used for the vertical and horizontal transportation of peoples. A strong and interconnected network of monorails and elevators will facilitate people's movement across different towers (Fig. 3).

Fig. 3. Concept design 2 of a Vertical city (bubble diagram 2)

Section V. Theoretical Framework for vertical smart city, concept mapping with sustainable development Goals. The ultimate goal of SDG #11 is to consider the social, economic and environmental factors by balancing the outcomes in various domains. Using a participatory approach to improve the social system, technological consideration, an environmentally friendly system and economic stability will bring about a correct balance in the vertical growth of smart cities. Conventionally, cities are expanding in a horizontal configuration and slicing the same growth in a horizontal configuration of various sections and then shifting those sections in vertical stacking will help to transform the same natural or a planned skyward expansion.

Section V (i) Environmental consideration. Smart energy is a green system for a city's clean environment. All sectors of human consumption must be supported with smart energy in its applications. The increased dependence on the use of renewable sources of energy in commercial, residential, industrial and transport application must be a choice to be made [6]. The smart equipment and their smart control using clean technologies that are human and environmentally friendly, i.e., a system with an infrastructure of smart

transport management, monitoring road network, highways, subways, bridges, tunnels, airports, seaports and military areas. Sensory devices, computer application, artificial intelligence and machine learning will monitor real-time information of each infrastructure system to achieve operation, privacy, maintenance, and supervision. The city will be administered through a range of IoT devices and smart application to transmit information from users to the mainstream system designed to be flexible and respondent to newly emerging needs.

Smart infrastructure. One of the very important components of service design is a smart grid of a vertical city. Smart grids are advanced electrical power grids based on a vertical integration of a system [9]. Vertical cities integrate a smart grid infrastructure to co-ordinate the overall systems of energy management. Smart grid management must ensure the human need and their real-time applications that adapt to changing environmental and societal factors within buildings. Each building and tower will integrate smart features outlined in Fig. 4 for the optimization of energy efficiency.

A smart grid in a vertical city will work through the generation of clean energy using renewable resources. The transmission of electricity through an efficient infrastructure and its distribution through smart approaches of energy operation, e.g., a smart meter and smart appliances to end users will be guaranteed. Digital processes and information management are the key aspects of a smart grid.

Fig. 4. Smart features of Vertical city buildings

In addition to the use of renewable sources such as wind and solar energy, the system will equate the use of waste energy and materials. The use of wasted energy will be acting as decentralized and boundary-free within the designed system of energy management. The energy management system of a smart vertical city will be based on a smart grid and smart metering. The real-time measurement of smart responses from the user will ensure smart consumption and production of energy. This study uses smart units as generic classification for residential and commercial in a smart vertical city. The energy requirement, billing, energy losses will vary depending on the capacity, covered area and number of extreme users. Both commercial and residential smart units will rely on smartly monitored electrical devices. The smart meter will calibrate the smart response from the users who consume electricity, gas and water as well as specific consumption in energy units. The efficiency of a system is established through the two-way communication of a multiple sensor attached to various devices that control and monitor consumer energy use. Smart devices are interconnected through WiFi real-time measurements and continuous monitoring of multiple domestic appliances. The smart modules (either residential or commercial ones) are provided with a graphical user interface application on their Android phones. The application enables smart features associated and interlined with all devices to send and share environmental and thermal controlled information, illumination adjustments of lights, bulbs, fans, air conditioners, temperature and other access controls. The system controls are meticulously touched and voice integrated on tablets and smart phones. The other security features include fire safety, gas leakage and motion detection. So, smart applications are the result of a smart response that acts on smart components and equipments. According to an estimation done for a smart home simulation system, there are 9 devices that are connected to the Internet per person [13]. The configuration of a smart unit that responds to service core smart grid in the vertical city is challenging. Based on the smart meter, real-time measurement, peak-hour adjustment and smart scheduling will assist in smooth working of smart units in vertical cities. The smart modules of vertical cities will encapsulate the residential and commercial units. The design criteria for these units are based on the selection and installation of smart equipments and smart control systems. The smart applications work with the integrated network of software applications that will be responsive and smartly controlled. Similarly the safety configuration of a smart unit in a vertical city will be based on mass surveillance. Today mass surveillance is making the connection of a large variety of devices operated and controlled through the Internet. The automation, sensors, and actuators

have made it easier to respond to the smart need of the users, which has helped in reducing the overall cost of smart-grid operated buildings.

Section V (ii) Economic analysis. Home automation system incorporating Internet of things (IoT) are not costly and affordable [14]. A similar economic analysis has been performed for the residential and commercial units of the vertical city that shows the variation of a maximum and minimum cost range (in Euro) for a smart unit in a vertical city. These calculations can help as a convincing methodology for the trend shifting towards smart living within a vertical city. The initial cost of these smart units may be higher compared to the traditional way of living. However, smart metering and real-time monitoring of devices combined with reduced power losses in a central smart grid will add an additional advantage. Also, a payback period of initial investment will be considerably higher due to smart applications, which are further connected with smart meters and smart grid systems (Fig. 5).

Table 1 defines the criteria to calculate the low and high cost ranges for both commercial and residential modules of vertical cities.

Table 1

Criteria for Smart Residential and Commercial Units

No.	Equipments	Residential/apartment	Commercial
1	Light	10	30
2	Temperature control	5	15
3	Air conditioning control	3	15
4	Access control	3	10
5	Visualization	Yes	
6	Phone applications	Android	
7	System control	Voice integrated/tablet/smart phone	
8	WiFi wiring	Yes

Fig. 5. Cost of Smart systems in Residential and Commercial units

Section V (iii) Social sustainable development. In a smart city, the social factors will be achieved through smart people supporting diversity, tolerance, creativity, and participation. A

smart city is planned for a socially sound, equitable connection for long-term sustainable development. Although a social factor is qualitative and immaterial in nature, because it is affected by a lot of factors that are considered beneficial for society. As society is a group of people living together in an organized grouping, sharing benefits and working for certain common goals and objectives. Their social interaction defines the positive outcomes that actually formulate the structure of society. So, it is important to design cities with a high level of socially interactive places that are designed to bring people closer to each other and nature.

The planning of vertical cities will be based on social equality, a much needed factor in progress towards socially sustainable development. The availability of adequate facilities of basic necessities, their easy accessibilities and deep-rooted acceptability will be the priority for all individuals. The facilities of health, education, entertainment, social and spiritual practices will increase social cohesion (Fig. 6—8).

Fig.6. Group living concept in a vertical city

Fig. 7. Facilities of socially sustainable development in a vertical city

Fig. 8. Social inclusion concept in a vertical city

Section VI Discussion. Based on the above discussion, the paper suggests the following mapping of sustainable development goals and its subgoal with the key parameters of sustainable, environmental, economic and social development.

The discussion section will elaborate on some major findings towards the design and sustainable development in vertical cities. Human being the center of activity in vertical cities and their

design is governed by a natural environment. This natural environment includes renewable sources like sun and wind, forest and oceans, biodiversity, soil and atmospheric layers. The built environment in vertical cities is shaped by human values and culture of a particular socie-

ty. The design of the interaction between a human, natural and built environment should be such that it respects each other's identity and value. In such cities, the ecological balance between the three will help in addressing the issues of bringing people closing to nature with a lower impact on the environment. The thoughtful design is a major consideration of all environmental aspects to meet the world's greatest challenges of climate change, global warming and resource management.

Table 2

SDG Model for a Smart Vertical City (SDG11, 2021)

No	Goal 11-Cities and Communities Sustainable	Targets		Sustainable Parameters	Smart Vertical City Features
1	Safe and affordable housing	Adequate	Housing		
		Safe	Basic services		
		Affordable	Slum Upgradation		Natural Environment
					Built Environment
2	Affordable and sustainable transport systems	Adequate	Sustainable transport systems		Public Spaces
		Safe	Road safety		Efficient Vertical Transportation
		Affordable		Environmental	Renewable Sources
					Clean Technologies
3	Inclusive and sustainable urbanization	Inclusive and sustainable			Smart Transport Management
		Participatory	Urbanization		IoT devices
		Planning and management			Smart Equipments
					Smart Grid
4	Protect the world's cultural and natural heritage	Protection	Cultural heritage		
		Safeguard	Natural heritage		
5	Reduce the adverse effects of natural disasters	Reduction in Death rate in disaster			
		Decrease the direct economic losses relative to global gross domestic product			
				Economical	Low cost Home automation
6	Reduce the environmental impact of cities	Air quality			Smart Payback

End of Table 2

No	Goal 11-Cities and Communities Sustainable	Targets		Sustainable Parameters	Smart Vertical City Features
		Municipal management			Auto billing
		Waste management			
7	Provide access to safe and inclusive green and public spaces	Safe	Green spaces		
		Inclusive	Public spaces		
		Accessible			
8	Strong national and regional development planning	Urban areas	National development planning.		
		Peri-urban areas	Regional development planning		
		Rural areas		Social	Mass surveillance
					Diversity
9	Implement policies for inclusion, resource efficiency and disaster risk reduction	Inclusion			Tolerance
		Resource efficiency			Community Participation
		Climate change mitigation and adaptation			Group Living
		Disaster resilience			Shared Benefits
		Disaster risk management			Social Equality
					Social Cohesion
10	Support least developed countries in sustainable and resilient building	Financial assistance	Use local materials		Social Inclusion
		Technical assistance			

A. Nature and space optimization. The transnatural behavior of a landscape will be the priority of architects, urban planners and designers. The space optimization through verticality in design will give a new dimension bringing humans closer to nature. Stakeholders will gain a new experience of nature where the sky will be the limit. The densely populated masses of urban culture developed in various cities of the world are pushing architects, planners and builders for more environmentally friendly and sustainable solutions. These multi-functional buildings will improve the function of spaces and increase the social interaction among people. A variety of urban design approaches for infrastructure development, use of renewable technologies, vertical farming, and gardening will ensure sustainable design in vertical cities. People will grow their own food in their houses.

Cities are a highly complex functional and sensational blend of spaces occupied by the individuals. So, the space optimization and land use in agriculture, green lands, vertical farming, aquaculture, roof greenery, green areas, and parks will be blended in with a built structure. High-rise buildings provide a scenic view, a close contact with nature. The naturalistic design will increase the receptive ability of spaces towards individuals.

B. Sustainable Development. The vertical cities will be sustainable, resilient minimizing the disadvantage to the environment while, at the same time, achieving acceptable economic benefits and, wherever possible, having a positive impact on society. The design idea of a vertical city is sustainable as it meets all the three areas of environment, business and society. The societal actions are direct results of all the three parameters. An ideal city will maximize all the three areas, which is good for the environment. Also, it is profitable for individuals and society. A mutual exchange between spaces through natural and technical connections in vertical cities will help the environment and celebration of spaces in society.

The consideration of the three basic pillars of sustainable development that form the core of urban growth can also be guaranteed in vertical construction with a reliance on smart technologies. A smart-grid infrastructure in vertical cities will act as a core service area for the whole urban development. The efficient system of energy generation through clean resources, its transmission and distribution to the end user will be done by means of smart approaches. In vertical cities they will bring the efficiency to the system, will be environmentally friendly and economical, affordable and socially connected. Vertical cities are a manifested experience of increased social interaction between communities with a close contact with nature. Smart Cities will offer smart benefits of high-standard living, system efficiency, fast and securely connected network of services and infrastructure, clean environment, clean technologies, space utilization, interactive, inclusive, smart governance, real-time need, smart management, and never people's less smart behavior.

C. Challenges in smart vertical city. One of the primary challenges is to deal with the hybrid concept of smart development in vertical configuration. The horizontal expansion of infrastructure in smart cities is currently being addressed in many areas of the world. But shifting the infrastructure vertically will serve as the next-level defiance in favor of space optimization. The services like drinking water, rainwater harvesting, sewage treatment and drainage, waste segregation, collection and biogas generation, energy utilization are additional challenges. Also, an interlinked, environmentally friendly, self-sustainable, inclusive, safe, and resilient system is required in a vertical growth. In a vertical growth, the system of an information and

communication network is based on web of the Internet that manages the entire infrastructure and services in a city with a smart networking of power and electricity, waste, and water management. The next-level challenge is how cities can be expanded and design to shock resilient effects of infrastructure and facilities like water, sanitation, waste management, public transport, health facilities and air pollution as identified in SDG goal 11.

Conclusion. In order to address the problem of rapid urbanization, the sustainable development can play a significant role in meeting the new challenges of the urban environment. The smart infrastructure and its incorporation in developing new vertical cities with an equal importance given to all major outcomes of sustainability, e.g., environmental, economic and social benefits. The research is unique in the sense that it has proved that smart is sustainable, especially when it comes to a vertical growth. The research is based on a convincing methodology for multidisciplinary professionals to design corresponding to the environment, save energy, smart growth with real-time monitoring, keeping a contact with nature, effective payback time in economical consideration and promote social equalities in cities through same facilities. The paper is recommended to future professionals for equal approach and utilization of digital smart technologies to all members of society in vertical hubs. Certainly, the vertical cities will open up new design opportunities and challenges for the building stakeholders. In order to meet the future expansion, need in all urban societies, the vertical expansion will also open a different paradigm for sustainable development. The social equality, harmonious connection with nature, space optimization, smart infrastructure, group living, and many more are the common agenda of the world community as part of millennium development goals.

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