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FROM INTELLIGENT BUILDING TO SMART CITY – A CASE STUDY

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Abstract. This paper is to provide some insights to professionals on the evolution of smart city, to present its concept and appropriate elements based on the author's 40+ years of experience in international building development projects.

With the oil crisis in the 1970s, the use of alternative energy sources such as solar energy and energy saving measures were explored to combat the threat of fossil fuel supply. The concept of intelligent building to improve the productivity of the occupants and energy saving was then emerged in 1980s, followed by the focusing of the built environment like green building and sustainable construction in the 1990s. Various metrics were developed by different countries for assessing green building provisions e.g. LEED in a more structure manner. Building resilience has recently become popular for abating the increasing natural disasters. The features of intelligent building, green resilient building and smart city will be illustrated by making references to developments which were designed and project managed by the author.

On a more macro scale, with the rapid advancement of ICT in recent years, the concept of smart city has been advocated. The various definitions of smart city would first be depicted. Based on these definitions, the attributes of smart building and the respective features were suggested. The appraisal of the designed provisions of a mixed development project in Southeast Asia was then illustrated with suggestions on further elements to enhance its smart city characteristics.

Keywords: Intelligent building, green building, building resilience, smart city.

1. Introduction

With the oil crisis in the 1970s, the use of alternative energy sources including renewable energy such as solar energy and energy saving measures were explored to combat the threat of fossil fuel supply. The concept of intelligent building was then emerged in 1980s, followed by the focusing of the built environment such as green and sustainable building in the 1990s and subsequently building resilience. With the rapid advancement of information, communication and technology (ICT) in recent years, the concept of smart city has been advocated. Project in South-east Asia will be cited to illustrate the salient features of each type of developments.

2. Intelligent Building

2.1. Definition and objectives

CityPlace in Hertford, Connecticut completed in 1983 was heralded as the world's 1st intelligent building. The Intelligent Buildings Institute in Washington had proposed that an intelligent building was one which integrates various systems (such as lighting, HVAC, voice and data communications, and other building functions) to effectively manage resources in a coordinated mode to maximise occupant performance, investment and operation cost savings and flexibility [1].

The main objectives were to increase the effectiveness of office workers and to create an image for the users' customers and competitors. It also aimed to avoid major refurbishment as office automation progress and to have the flexibility to meet the future changes and expansion of the office. The building services systems would be equipped with state-of-the-art technologies to conserve energy with energy management facilities and to enable the owners/operators to effectively manage the resources and hence the investment return [2].

2.2. Hang Sang Bank New Headquarters Building, Hong Kong SAR

The development which comprised of 27-storey end-user bank office building with 3 basement levels and gross floor area of about 44 000 m^2 was planned and completed from 1987 to 1991 in the prime site of Central District, Hong Kong Island.

Salient intelligent features [3] covered energy saving tinted glass with external vertical fins façade, flexible air-conditioning and electrical services with spare capacity for future expansion, reliability of services supplies, controlled environment for minimizing sick building syndrome, flexible / user friendly building management system with software for maintenance schedule, early warning, energy management for lighting and air-conditioning control and integration with other systems. Communication systems included backbone and structural cabling system, CABD and satellite telecommunication, video teleconferencing facilities, voice system and telephone interface control for office lighting. Security system covered CCTV, magnetic door contact, watchman tour, car parking access control, access control and individual occupier's specific security alarm monitoring. Other features were multiplexed automatic fire alarm and smoke control system, high performance (i.e. waiting time and handling capacity) vertical transportation and allowance in structural design to cater for additional live load and internal staircase if required in future. Most of the features were still widely adopted in the subsequent sustainable/resilient design.

3. From Sustainability to Resilience

3.1. Sustainability

Sustainable development concepts, applied to the design, construction, and operation of buildings, can enhance both economic well-being and environmental health of communities and around the world and could interact more positively with the environment. Benefits acquired include resource and energy efficiency, healthy buildings and materials, ecologically and socially sensitive land use, transportation efficiency, and strengthened local economies and communities.

The United States Green Building Council has established the LEED assessment rating system, which was used as framework for many green building rating systems around the world including in Asia Pacific. The assessment aspects cover location & transportation, sustainable sites, water efficiency, energy and atmosphere, materials and resources, indoor environmental quality, innovation and regional priority.

3.2. Resilience

Sustainability is all about protecting nature and the environment from human endeavours. However, there is need to protect humans from both the Mother Nature (climate change) and human threats by which the built environment has been confronted today. As a result, resilience has become the next evolution of sustainability [4]. Hence, the society has a strong desire in advancing the sustainability to resiliency to cope with these vulnerabilities reactively and proactively.

RDI [5] described resilience is the capacity to adapt to changing conditions and to maintain or regain functionality and vitality in the face of stress or disturbance. It is the capacity to bounce back after a disturbance or interruption. Through resilience, livable conditions in the event of natural disasters, loss of power, or other interruptions in normally available services can be maintained. In the context of built environment, resilience means incorporating into the design of a building, aspects and features that allow the building to carry out its intended functions, now and in the foreseeable future [6].

The principles of resilient building design are:

(a) meeting basic human needs including potable water, sanitation, energy, livable conditions, lighting, safe air and occupant health;

(b) anticipation of interruptions and a dynamic future – adaptation to changing climate such as higher temperatures, flooding, earthquakes, solar flares and anthropogenic actions like terrorism and cyberterrorism;

(c) diverse and redundant systems;

(d) use low carbon-input materials systems;

(e) maximising the use of day-lighting;

(f) design for future flexibility of use e.g. modularity and standardization;

(g) durability and robustness including strong building envelope;

(h) systems that can be serviced/maintained with local material/parts and labours;

(i) low energy inputs for constructability and ongoing building operations;

(j) renewable energy for less reliability on grid power; and

(k) water capture and storage, and usage reduction [6–8].

The existing sustainability or green rating tools, such as LEED can be used to assess whether new developments address both the adaptation and mitigation demands of climate change. There are overlaps between resilient design principles and the LEED certification system and that some of the principles identified had already been incorporated by the existing LEED rating system [9]. Therefore, it is necessary to integrate resilience into the sustainable building certification system and consider the gaps in light of the local environment to incorporate the necessary resilient features in the development project life cycle.

3.3. Pacific Century Place (PCP) Jakarta, Indonesia

PCP situating in the new CBD area of Jakarta with 40-storey and 6 basement and gross floor area of about $150\,000\,\mathrm{m}^2$, is a green, sustainable and prestigious Grade A office for international tenants and was completed in 2017 to solicit a higher yield in the city by a Hong Kong developer. In light of the local context in which there were gaps in culture, technology savvy, body of management knowledge, mind-set and approach, the strategy to cope with the local situation as shown in Figure 1 was crafted so as to transcend sustainability to resilience.

The development was certified with platinum grade by LEED and by Greenship which have illustrated that applicable features of sustainability and resilience

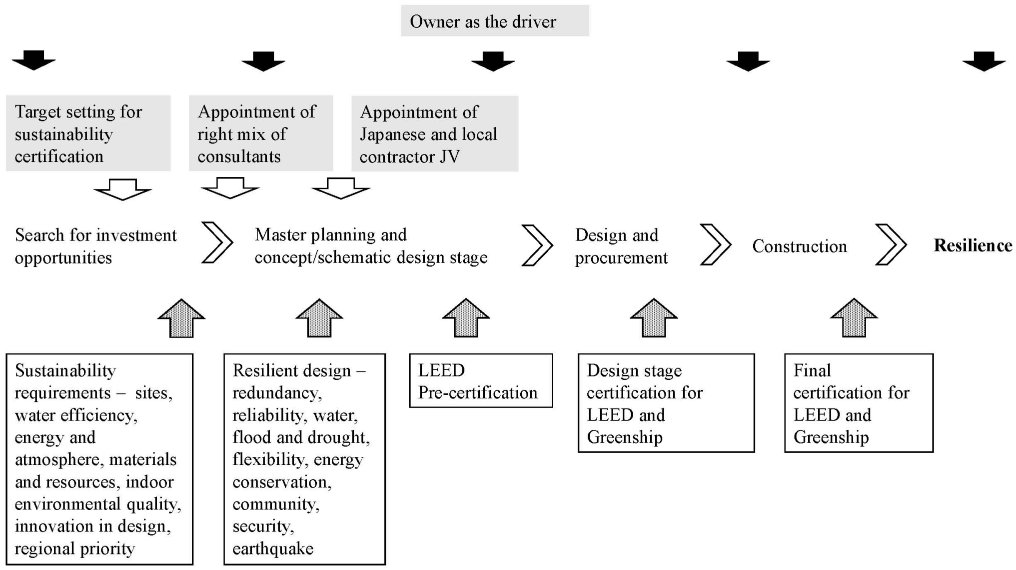

Figure 1. Approach to Sustainability and Resilience for PCP Jakarta [10].

such as site connectivity, heat island mitigation, landscaping and biodiversity, recycled materials, regionally manufactured materials, daylighting application, energy conservation, low emitting materials, heat recovery, increased ventilation etc. were incorporated. The more salient resilient features are succinctly described as below [9].

(a) **Redundancy and reliability** – 100 % backup power by diesel generator; dual electrical risers and telecommunication lead in and risers; spare chiller cooling capacity for future increase in cooling load; and 100 % Wi-Fi coverage in common area and mobile network for connectivity;

(b) **Water** – reduction in water use by using efficient water devices and sanitary fitments; and deep wells as backup water supply;

(c) **Flood and drought** – zero run-off design; ground floor level at 1 m above the flood plain; installation of water gates to prevent backflow; critical equipment on Level 6; long soak pond to control the site run-off; greywater, black water and rainwater recycling; and reducing landscape water use using drip irrigation system and indigenous plants;

(d) **Flexibility** – modular and standardized design; high floor to floor (4.5 m) and high false ceiling (3.05 m) with raised flooring system; variable air volume air-conditioning system integrated with lighting system; coordinated ceiling and floor grids, column spacing and façade modular size; and spare electricity and chilled water supply in each tenancy floor for future expansion;

(e) **Energy conservation** – low-e glass with external horizontal shading fins façade; waste heat recovery from the toilet exhaust; chillers optimization control; LED lighting with daylight sensors in perimeter zone and motion sensors in staircase and toilets; VVVF lift system with destination control and regenerative braking; hence with 25 % and 33 % saving as compared to baselines of LEED and Greenship respectively; and

(f) **Community** – clear goals for sustainable parameters in tenancy lease, fit out guidelines and manual; post occupancy evaluation; measurement and verification plan to mitigate deviation of building performance.

4. Smart City

4.1. Definition of smart city

Smart city is a new concept which covers a continually evolving definition. Generally speaking, a smart city is a city which capitalizes on new technologies and developments to enhance its systems, operations and service delivery. Smart cities share one thing in common, the application of ICT to connect and integrate the systems and services of the city [10].

A smart city is an urban area that uses different types of electronic Internet of Things (IoT) sensors to collect data and then use insights gained from that data to manage assets, resources and services efficiently [11]. This includes data collected from citizens, devices, and assets that are processed and analyzed to monitor and manage traffic and transportation systems, power plants, utilities, water supply networks, waste management, crime detection, information systems, schools, libraries, hospitals, and other community services. Smart city was defined by eight key aspects: smart governance, smart energy, smart building, smart mobility, smart infrastructure, smart technology, smart healthcare and smart citizen [12].

ISO [13] defines 17 key indicators for evaluation of performances of cities from the point of view of ensuring urban services and quality of life i.e. economy, education, energy, environment, finance, fire and emergency response, governance, health, recreation, safety, shelter, solid waste, telecommunication and innovation, transportation, urban planning, wastewater, water and sanitation. Nonetheless, a more encompassing definition is that the concept is not static, there is no absolute definition of smart city, no end point, but rather a process, or services of steps, by which cities become more "livable" and resilient and, hence, able to respond more quickly to new challenges [14].

4.2. Attributes of smart city

Against the above backdrop, the attributes and the respective elements of smart city are as follows:

(a) **Smart environment** – green and smart buildings, green energy, environmental monitoring (air pollution monitoring), managing environmental challenges, high efficiency air conditioning and ventilation systems, mitigation of the heat island effect, control of the site run-off;

(b) **Smart living** – safe, well managed and informed community, public information systems, complaint redressal, efficient management of day-to-day operations, smart retail and shopping experience, smart home;

(c) **Smart community** – active and healthy lifestyle, recreational facilities, community centers, public art, disabled accessibility, gaming community, medical and social care;

(d) **Smart infrastructure, utilities and public realm** – smart grid and energy management, integration of electrical vehicle, zero waste environment, smart water distribution and waste management (sewage and solid), water, waste and sewage monitoring, smart metering of natural gas, water, electricity consumption on real-time basis, smart logistic supply chain, information communication infrastructure, smart ambient lighting (LED-based lamps and use of sensors to switch on/off automatically when necessary), public kiosks with internet, Wi-Fi hotspots, electromagnetic emission, climate control environment (e.g. landscaping);

(e) **Smart mobility** – smart car parking, prioritized clean and non-motorized options (e.g. bicycle, electric vehicle cars), smart traffic management including real time information sharing, smart parking places using sensors, walking path, traffic monitoring and control, multi-modal options, access management, minimizing the impact on the environment; and

(f) **Smart governance** – ICT enables security, surveillance such as CCTV and Automatic Name Plate Recognition System (ANPRS), secured data management and cloud storage.

4.3. Purpose, objective and benefits of smart cities

The goal for smart cities is to improve city management and residents' quality of life through the efficient use of resources and service delivery whilst at the same time reducing environmental footprint [10]. The purpose of the smart cities mission is to drive economic growth, provide core infrastructure and improve the quality of life of people, enable a clean and sustainable environment. In the nutshell, smart city technologies improve the efficiency of city operations and services, thereby reducing energy and water consumption, cutting down traffic congestion and in turn carbon emission.

More specific benefits include:

(a) efficient public utilities reducing the inadvertent waste of water and electricity, and identifying times of peak usage and outages, ensuring proper efficiency and mitigating risks, reducing damages;

(b) providing good living conditions for anyone living inside the city; thus increasing the overall morale of a city, leading to an overall increase in happiness and hence, the citizens will care more about the city itself and work to improve it further;

(c) safer communities enabled by technologies such as ANPRS, security cameras in real time give law enforcement an edge while on the job;

(d) connectivity which is the fabric keeping everything together in a smart city to create a more equitable environment for citizens and enabling people and their devices connected with public Wi-Fi hotspots that are strategically placed throughout the city offering reliable internet services to all residents;

(e) more inflow of talent because smart cities give their citizens access to safer, happier living conditions, enabling the cities to have access to more talent and have a healthy mix of populous, thus a rising economy and GDP;

(f) smart ecosystem, better sustainability because of reduced environmental footprint, air quality monitoring, energy use optimization, and electricity, water, and waste tracking, resulting in fewer GHG emissions, fewer kilograms of solid waste and water saving;

(g) smart transportation with improved transportation saving the commuters tons of time and reduce fuel consumption; and also smart parking management, intelligent traffic signals optimizing traffic flow, relieving congestion during peak travel times;

(h) Smart and green buildings; and

(i) big data which can be used for analytical purpose in commerce.

In Europe, there was a research concluding that smart cities would see an overall economic development of 5 % annually, which translates to almost

$20 trillion in a decade [15]. From the developer standpoint, smart city provisions will enhance the value of the investment because of higher rate of return due to sustainability and resilience of the development. Smart cities in India offered substantial scope for price appreciation. Kochi Smart City could expect 30–40 % price appreciation over the next three years. GIFT development was expecting 10–15 % annual price increase. Wave City and Palava City have the respective rise of 9 % from June 2012 to June 2014 and 128 % appreciation from June 2010 to June 2014 [16].

4.4. Appraisal of a smart city development in South East Asia

The development is to be built on a land of 70 ha for a population of 140 000 and comprises of hospital, wellness center, religious church, residential, retail / shopping mall, car parking, office, data centre, duty free shop, hypermarket (DIY & festive market), pharmaceutical hub, super automobile show rooms, financial hub, hotels, convention centre, police and fire stations. Appraisal on features of the development for each attribute of smart city are depicted in Table 1 (Appendix A).

5. Conclusion

Intelligent building was emerged in the 1980s because of the aspiration of the society to use technology to maximise the occupant performance, as well as the investment return of the development in terms of the operating cost such as energy efficiency and the flexibility to cope with the future demand of the tenants. Green/sustainable building concept was subsequently developed to encompass the features of intelligent buildings but covering wider perspective of environmental protection and conservation as well as the well-being of occupants. To protect humans from the vulnerabilities of the Mother Nature and human threats reactively and proactively, resilience was evolving from sustainability. With the rapid advancement of ICT in recent years, concept of smart city has been strongly advocated and is proliferating worldwide.

Whatever the development is intelligent building, sustainable and resilient building or smart city, it is important that an integrated approach be adopted to incorporate the features at the early stage of the project life cycle to maximise the benefits while optimising the investment cost.

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A. Appendix – Table 1

Designed Elements	Recommended Enhancements
Attributes 1 – Smart Environment	
EIA to mitigate the impact on environment; Ground level of the site 1.6 m above the normal ground level of neighborhood for future flood proof; Box culvert across site for drainage discharge of neighboring sites to minimize flooding potential; Centralized potable water treatment plant to reduce the reliance on plastic bottle water and plastic bottle waste; Reliance on hydro plant to provide green energy.	LED instead of HPS for the street lightings; Water-cooled air conditioning; Green building certification for each plot; Metering of electricity and water consumption to provide real time data to the portal dashboard of development; Air pollution monitoring station to provide real time levels of CO, NO_2, O_3 and RSP PM 2.5; Softscape with area at least 20 % of the total site area to reduce heat island effect; Use of pervious/permeable pavers for on grade hardscape to control run-off and minimize flooding potential; Formulation/implementation of waste management plan to reduce waste; Promoting the use of electrical car by installing EV chargers.
Attribute 2 – Smart Living	
Fire services and police station inside the development to enhance peace of mind of the community; Site fenced off with controlled access points and equipped with security CCTV; Central control to monitor the security and fire safety.	Formulation of mobile app and portal to provide e-services, public information and real time data on weather and air pollution data, parking space availability, traffic information, smart retail and shopping experience; Smart home for residential development; 24 hours manned central control to monitor security and fire for enhancing safety and peace of mind of the community; Extensive coverage of CCTV with future proof quality for incorporating facial recognition and AVNPR systems.
Attribute 3 – Smart Community	
Mix land usages to achieve a self-sustainable development and community; 24 hours operation European medical center / hospital and wellness center to enhance the health of the community; Community centres and religious community halls and bicycle tracks to provide an active and healthy lifestyle; International standard of facilities management service level to the community, proper operation and maintenance of the infrastructure assets, training and educating the local human resources on the best practices.	Street furniture and jogging path to provide recreational facilities and create active and healthy lifestyle; Bicycle parking to promote healthy life style; Extensive softscape to provide amenities and healthy environment to community lifestyle; Infrastructure and each plot to incorporate barrier free access (disabled accessibility).

Designed Elements	Recommended Enhancements
Attribute 4 – Smart Infrastructure, Utilities and Public Realm	
Centralized potable water treatment plant to control the quality of water and monitoring the usage; Centralized sewage treatment plant enabling the monitoring of the waste water and ensuring the discharge standard; Centralized refuse collection point to allow collection, storage, sorting and disposal of solid waste; New hydro plant to enhance the reliability and capacity of the electricity supply; Own step down transformers with spare transformers to meet future demand and dual feed to increase the reliability of supply; Telecommunication sub-station to improve the service level and future flexibility to expand the services; Street lamp controlled by photo sensors.	Softscape and hardscape with street furniture, amenities and jogging path to improve public realm and climate control; Incorporating 4G (LTE) or 5G small cells on the smart lamp pole to enhance the connectivity; CCTV at strategic locations to monitor traffic and give real time information in the portal Smart metering for energy management and water consumption; Smart metering at the centralized sewage treatment plant to monitor the disposal data; Centralized refuse collection point in the infrastructure to reduce and recycle waste; EV charger provisions in the infrastructure to promote the use of electrical car.
Attribute 5 – Smart Mobility	
Traffic impact assessment on car parking provisions, loading/unloading requirements, capacity of the road network, type of control, configuration at intersections and access locations; Road divider, signage, traffic signalization and road hump to smoothen the traffic; Clean and non-motorized option i.e. bicycle track network infrastructure; Site fenced off with vehicle access control points; Delivery to hypermarket planned outside the site to avoid affecting the traffic inside the zone; Road designed to be all season ones; Close proximity to highways, conventional train stop and high speed train station.	Smart parking system in each plot to provide real time indication of the spaces availability locally (parking sensors) and remotely at car park entrances and individual floors space panels as well as the portal of the development; Bicycle parking to enhance clean mobility.
Attribute 6 – Smart Governance	
Data center to enable data security, ICT provision and secured storage of the operational data.	Reliable infrastructure backbone with sufficient capacity to facilitate the current and future smart city attributes.

Table 1. Appraisal of the Smart City Features in the South-east Asia Development.