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Green recovery planning from COVID for a low energy urban district using urban digital platform – A case study of Tokyo Shinagawa

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ABSTRACT

While global health concerns and risks have risen in the Post COVID era, methods of sustainable and resilient energy strategies are needed for making green recovery in cities to reduce CO_2 emissions and environmental risks. Cities are to be designed and redeveloped for being more sustainable and resilient to meet climate, urban and societal challenges. To pursue consensus for making effective community actions to mitigate urban carbon emissions, an urban digital platform is proposed to facilitate above systems design processes from scenario making, data analytics and performance evaluation to urban design plan making. The paper designs an urban digital platform to be open in data sharing, and transparent in decisions to empower users, communities and stakeholders to co-generate common goals for zero emission urban future.

Keywords: green recovery, urban carbon emissions, urban energy modeling, mobility, urban systems design

1. INTRODUCTION

During the Covid-19 pandemic, global health concerns and risks have risen while environmental risks and concerns decreased by reducing CO2 emissions. According to Le Quéré et al. (2020), daily global carbon emissions decreased by approximately 17% by early April 2020 when compared to the mean global carbon emissions in 2019 [1]. Liu et al. (2020) reported an abrupt 8.8% decrease in global carbon emissions in the first half of 2020 when compared to those in the same period in 2019 [2]. However, this is not a viable way to reduce global carbon emissions. As Covid-19 spreads around the world, there is an urgent need to transform our cities and communities to be greener, safer, and healthier, and to develop approaches to managing a nexus of complex problems that are resulted from carbon emissions, climate-induced disasters, and covid-19.

Many cities have announced their carbon neutral agenda to meet zero emission before 2050 [3]. Urban carbon emissions are mainly caused by emissions combined in both building and transportation sectors in urban environment. To mitigate carbon emissions in urban environment, it is critical to enhance building energy performance in the building sector and to reduce transportation energy and emission by changing modes while enhancing mobility in the transportation sectors.

Cities in Japan are facing challenges such as national population decline and hyper-aging society, disaster prevention and mitigation, climate change mitigation and adaptation, new infectious diseases, social safety and security, cohabitation with natural environment and the search for circular economy. Tokyo Metropolitan government adopted the Zero Emission Tokyo Strategy in 2019 that aimed at carbon neutrality by 2050 and "carbon-half style" by 2030 as the condition to determine the pathway toward 2050. The measures for 2030 "carbon-half style" are presented in the fields of regenerative energy, hydrogen, building, housing, civic life, mobility, resource and chlorofluorocarbon gas.

The design of post-fossil fuel and post-pandemic cities should be grounded on a profound understanding of urban complex systems when local communities are facing increasing risks of energy security, heatwave stroke, and community health. Innovative ideas for the "new normal" or "smart lifestyle" of post-pandemic cities are urgently needed. What will be the new normal lifestyle? What elements of the post-Covid-19 communities and cities should be redesigned? Methods of green recovery using digital technologies, near real-time big data, and artificial intelligence are to be tested.

This research has applied a spatio-temporal model to analyze the Covid-19 impact on carbon emissions in Tokyo from January 2020 to address these questions and explore green recovery scenarios of the post-Covid-19 Tokyo. Figure 1 shows urban carbon mapping of Tokyo with the averaged CO2 emissions during January, February, and March in 2020 based on three urban design scenarios of "green recovery" from impacts of Covid-19 (Figure 1).

The urban carbon mapping will constitute one of the key performance indicators of this project for benchmarking and evaluating post-Covid-19 urban design scenarios. Researchers can develop descriptive, analytic, and predictive models based on near real-time data, and come with short-term prescriptions to mitigate infection risks for situations and crises and long-term evidence-based decisions for future urban development that better fits the "Smart Lifestyle" [4].

2. GREEN RECOVERY SCENARIOS GENERATION

2.1 Research design: Urban systems design based on studio as an urban laboratory

Tokyo's Shinagawa was chosen as the site for the 2019-2021 Smart City Design Studio based on the collaboration of the Department of Urban Engineering of the University of Tokyo, the School of City & Regional Planning and School of Architecture of the Georgia Institute of Technology, and the Global Carbon Project (GCP) (Figure 2). Shinagawa area is envisioned as "the international communication hub that drives the future growth of Japan" that attracts people and businesses with global residential and hotel environment, vibrant and green landscape and environment, regional access function of the station, efficient road network, comfortable pedestrian environment and urban resilience [5]. The studio investigated the impact of new maglev high speed rail system to future redevelopment of Shinagawa and its surroundings. By 2037, the maglev train system will connect Tokyo, Nagoya and Osaka, the

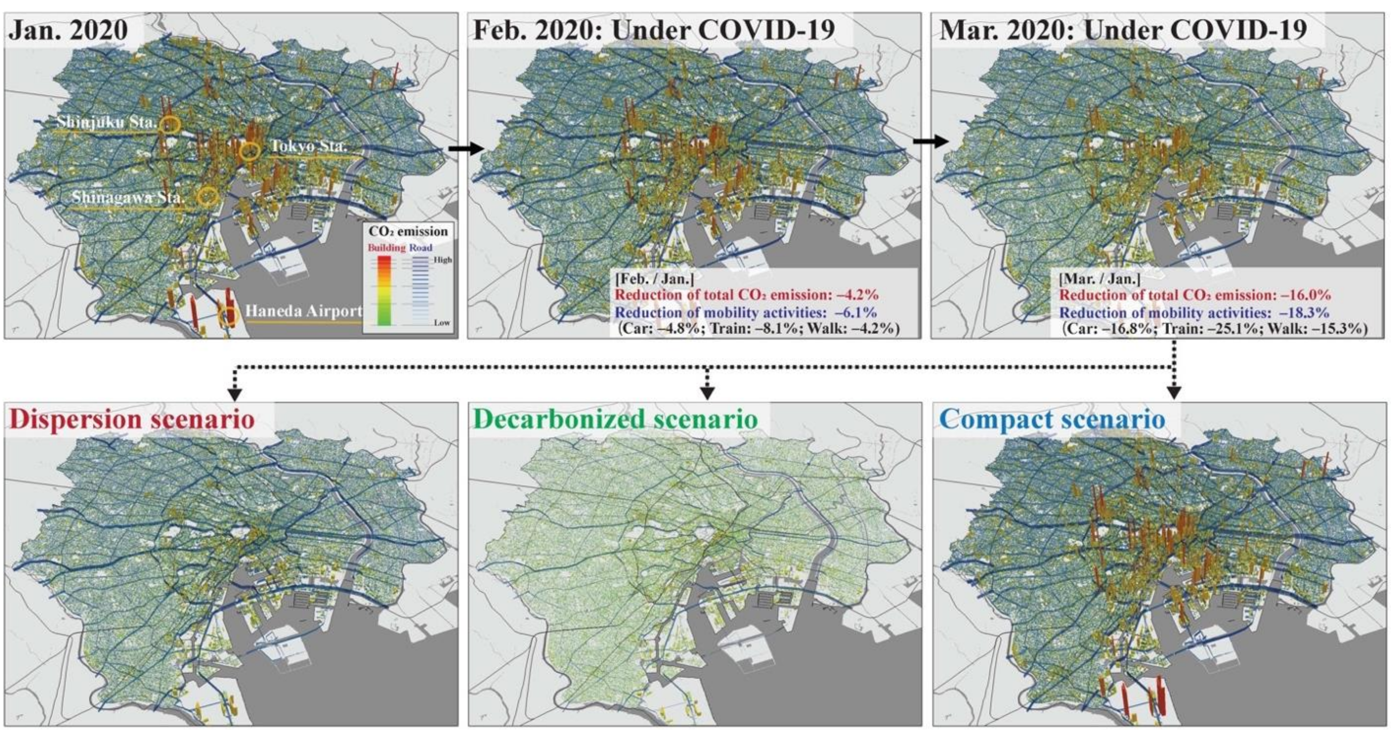

Fig. 1. Top: Urban carbon mapping in Tokyo during the last week of January, February, and March 2020. Bottom: Possible carbon emission implications of three "green recovery" scenarios of post-Covid-19 urban forms [7].

Fig. 2. Tokyo's Shinagawa waterfront site for the 2020-2021 Smart City Design Studio

three major megaregions of a total 70 million population in just 70 minutes.

An integrated urban design framework was proposed for the redevelopment of Shinagawa East to carbon neutral by 2040. The project took not only the conventional urban design methodologies, but also the urban systems design approach by applying emerging green and smart technologies to achieve the goal. The studio to speculated urban growth and its impacts to environment and energy performance and that is driven by the goal of zero emission.

The method of urban systems design is based on Geodesign, an approach to integrating geographic context, system thinking and digital technology [6–8]. It aims to demonstrate how a smart community is designed, evaluated, and implemented by interacting with governmental agencies, stakeholders and communities. Urban design is becoming data-driven. Empowered by new tools and technologies, particularly GIS data mapping, analytics and design support, cities are now far more designable than ever before. Ability to capture and analyze massive data in cities is now critical to addressing problems occurring in places, neighborhoods and cities. Urban systems design offers an approach to designing new forms of sustainable, resilient and socially responsible communities, in which creative urban design integrates data analytics, system thinking and digital technologies [9].

2.2 Policy-oriented planning scenarios

A policy-oriented approach was first taken to project urban growth scenarios, in which low-growth, mid-growth and high-growth scenarios are projected for the selected sites for redevelopment (Figure 3) [10]. The Japanese land use regulations include floor area ratio (FAR) without strict form-based control. It is difficult to predict the future urban form based on the designated land use regulations. The developments occur based on the market mechanism with minimum planning interventions especially in the growth areas of central Tokyo. The urban form alternatives were proposed using policy driven scenarios making of urban growth parameters including FAR, population and number of workers. Impacts of environmental performance and transportation of those urban growth scenarios are evaluated and compared.

By setting policy of growth, scenarios are made by forecasting urban growth in population, commercial and industrial activities. Since density in zoning is generally designated much higher than actual urban environment, urban growth and future development scenarios are market-driven in countries like Japan. While different

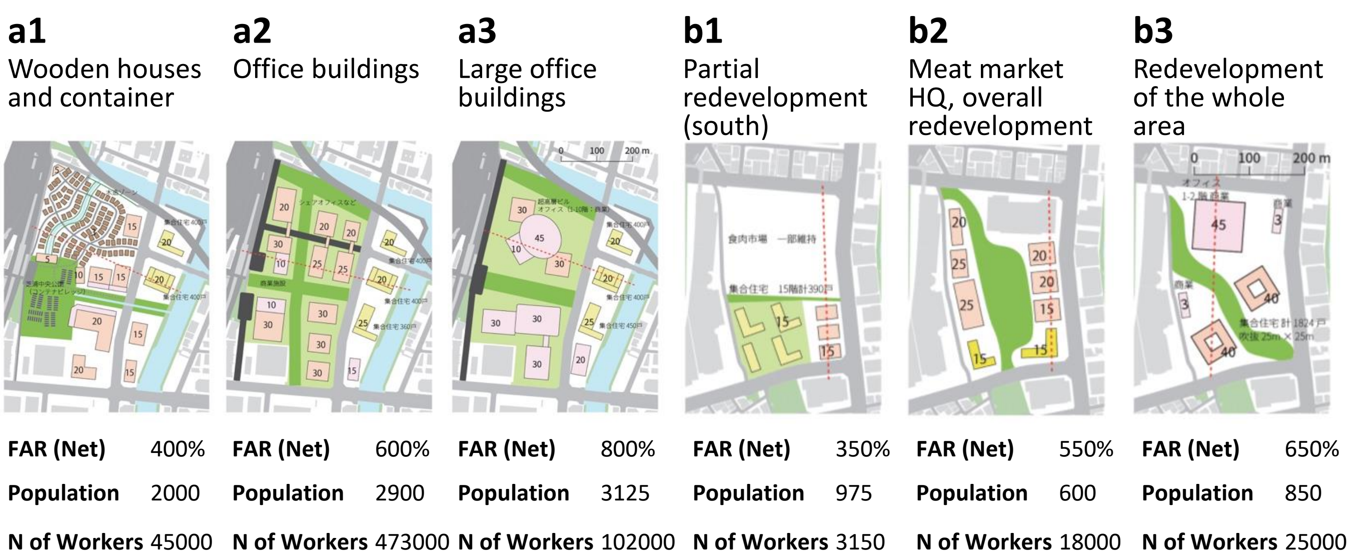

Fig. 3. Policy-oriented growth scenarios for the Site A & B of Shinagawa: A has Sewage Plant (Left) and B has Meat market (Right)

urban centers are competing with each other to attract urban growth, its unpredictability increases with population shrinking in Tokyo.

The policy-oriented scenarios were proposed given the above uncertainty and broader context of possible urban population trajectory. The results of those scenarios set basic planning parameters of land uses and density as future development guiding principles. The proposed urban forms are not specific in issues such as infrastructural systems, quality of public spaces or architectural propositions of future urban forms.

2.3 *Concept-driven design scenarios*

The second approach to generating future scenarios focuses on urban form making that normally rely on “concepts”, a term widely used in the field of architecture and urban design, or “ideation”, a term familiar to the field of systems engineering. Future urban forms are further elaborated in architecture and urban design based on certain conceptual propositions. The concept-driven designs were based on by propositions of how the specific places ought to be designed to be better in quality.

Using anticipatory design approach, new urban forms were proposed based on propositions about how the site should be reconfigured and changed. More details of design are provided such as urban form, building design, HVAC systems and functions related to occupants’ scheduling of energy uses that would provide further information to justify energy modeling for future building energy uses and potential carbon emissions.

The site A contains an internal green network was proposed for guiding pedestrian movements and flows from the station to the riverfront. A garden-like environment is surrounded by mixed-use development to accommodate commercial and cultural activities. In the Site B, a redevelopment proposal speculated a shopping environment that mimics Tokyo’s Ginza fashion design street. Basic parameters of the site planning such as land use and FAR were considered, while new urban forms were generated based on concepts and design propositions about quality places and future activities of the urban districts.

While the policy-oriented scenarios set planning parameters that are normally operated in the public sector such as urban planning agency, the concept-driven design is usually taken by designers to generate specific urban forms in the master planning processes as an urban design or real estate development proposal.

To design a low energy urban district, how would planners and urban designers design a high performance or energy efficient urban form from the beginning? What generates low energy urban form that would meet the performance criteria to mitigate carbon emissions and enhance energy performance at the district level? The requires further steps to connect design, modeling and performance evaluation.

3. BENCHMARKING PERFORMANCE OF ENERGY AND MOBILITY FOR CARBON NEUTRAL URBAN SYSTEMS

The urban form scenarios were taken for further performance modeling, including building energy and mobility. Both the building sector and transportation sector constitute significant portion of the overall urban carbon emissions. The experiment takes three steps:

1) Performance modeling of urban building energy is conducted for benchmarking existing urban form and how much energy performance would be changed based on the above scenarios;
2) The modeling of scenarios also includes renewable energy for measuring potential carbon mitigation.
3) The mobility enhancement of future urban design is then incorporated into the model for examining how a nexus of both urban building and mobility as complex systems would change overall performance for the urban energy at the district level system.

A performance metric dash board is designed for visualizing those data representation and performance outcomes (Figure 4).

3.1 *Benchmarking building energy performance*

In that building energy demand can be linearly proportionally measured with outdoor air temperature [11], thermal energy needs were calculated by using the degree-days method. Degree days are the hours at which the buildings need heating or cooling because outdoor temperature exceeds the setpoints. This is a simplified method [12] for estimating energy consumption of small buildings, and has a dominant influence by energy uses. The simplified degree days method presented in [13] was used to measure the overall building thermal loads. In this study, the effects of the mixed building use are separately considered. Considered buildings uses are office, school, residence, commerce, hotel, restaurants, entertainment facility including museum, and department store [14].

Building energy calculation showed as follows:

1) Existing/Planned introduces maximum PV generation in case PV panels are implemented to all rooftops.
2) Strategy-GS which installs low-wide buildings can be an eco-effective option.

3) Strategy-IW which develops high-rise office buildings needs to spend 10-20% more demands than others.
4) Strategy-JR which develops middle-rise office buildings is totally similar with existing/planned scenario.

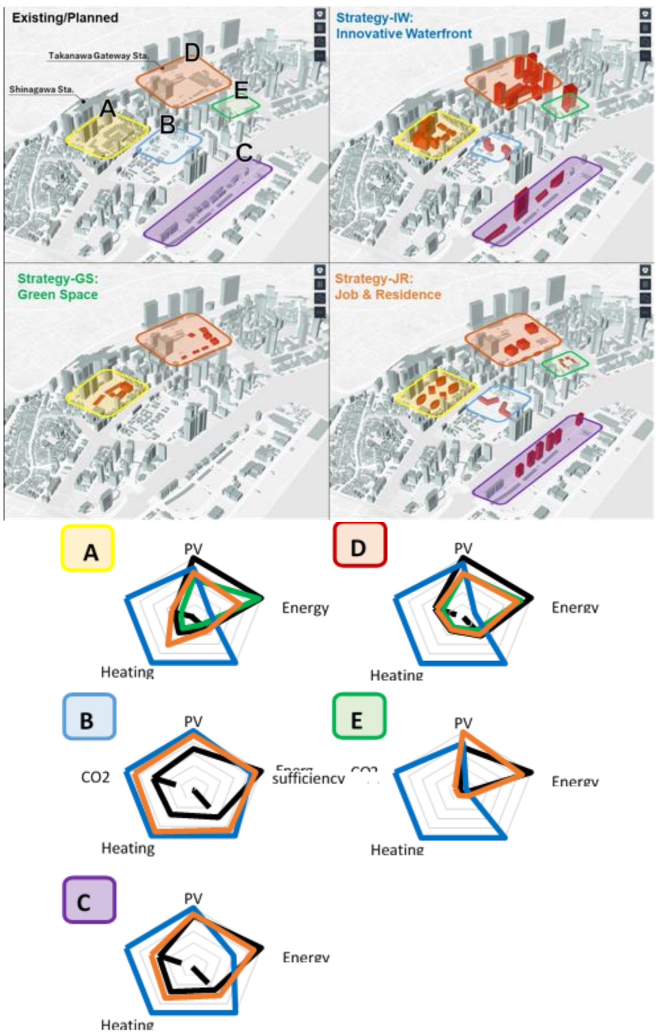

Fig. 4. Benchmarking building energy performance

3.2 Renewable energy and CO_2 emissions

To reduce the dependency on fossil fuel for electricity generation and its CO_2 emissions, renewable energy sources such as Photovoltaics (PV), wind turbines, biomass, etc. [15] were studied. Solar PV is one of promising technologies that can applied to existing building rooftops [16]. Solar PV can generate electricity energy based on the equation presented in [17].

In this research, we assume all rooftop areas are covered by the solar PV panels. According to Tokyo Electric Power Company (TEPCO) in 2018 [18], the carbon emission intensity of exiting grid in Tokyo is 0.455 (kgCO2/kWh). Carbon intensity of solar PV is 0.053–0.250 (kgCO2/kWh) [13]. The energy production from PV can cover 75% of demand in housing sectors. It indicates that about carbon emission per electricity generation can be reduced to 0.153 – 0.30 (kgCO2/kWh) after the rooftop PV installation.

3.3 Incorporating people flows mobility into the model

People spend more than 90% of their time indoor [19]. Energy demand for the mobility is required for trips generated from buildings to other buildings such as from homes to offices. Previous study has been conducted to estimate the mobility by considering travel distance, building occupants, and percentages of hourly travel demands of a day [20]. Mobility energy can be estimated, in which electric vehicles consume 0.169Wh/meter [21].

4. URBAN DIGITAL PLATFORM: FROM MODELING TO DESIGN

The GIS-based digital platform was tested by using ArcGIS Pro, ArcGIS Online and ArcGIS Urban (Figure 5) for organizing data and their visualization through representing layers of zoning, parcel and 3D urban form. Urban design scenario making processes were conducted in teamwork that resulted in new design data in different formats, such as sketches by hands, diagrams by Illustrators, and 3D massing design in Rhino. GIS tools were used to document those ideas that were turned to attributes of population, density and land uses. The proposed urban design scenarios were created in ArcGIS Urban, and then were published for sharing with the team. The ArcGIS Urban Connector was applied for importing scenario into ArcGIS Pro, in which some functions such as spatial statistics and viewshed analysis can be conducted there. Digital urban design tools including ArcGIS and Rhino were applied from data visualization, mapping, modeling, performance evaluation to new urban form making. By incorporating ArcGIS into urban design process, data of both existing site conditions and proposed design scenarios can be visualized and documented that include spatial forms and attributes, such as population, job creation, FAR, land use, building types and their environmental performance that are essential information in the public meeting when the studio group met community stakeholders and decision makers.

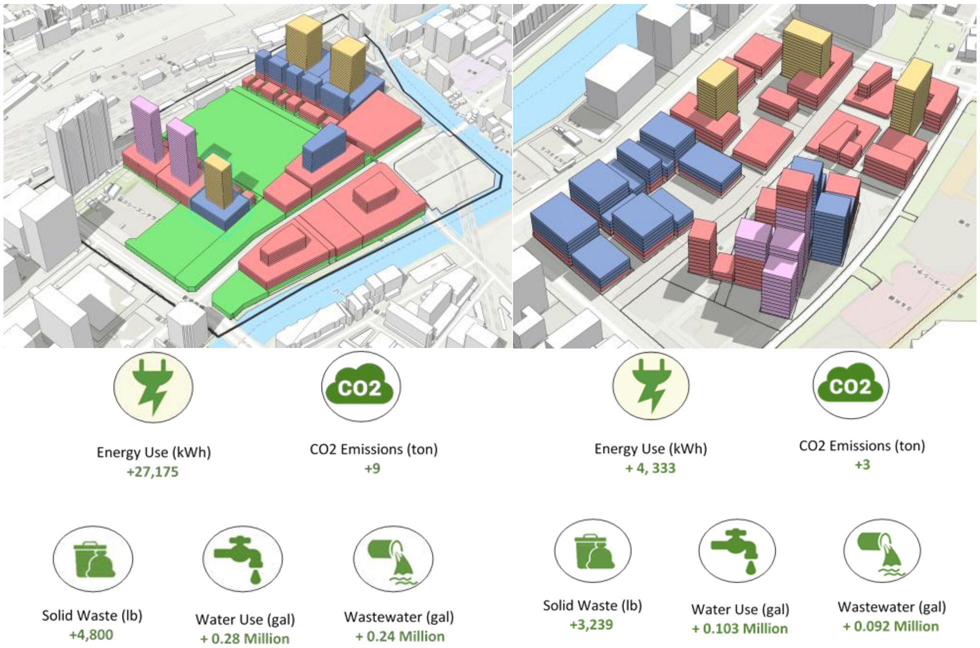

Fig. 5. An urban digital platform for Shinagawa Site A (Left) and Site B (Right), including urban growth, land use and environmental impact estimation (by Zainab Raza, Georgia Institute of Technology Studio, 2021)

Key planning parameters such as population growth, number of households, number of created jobs, required parking and daily trip require Tokyo's social demographic and planning database to produce such an estimation. The environmental database of Tokyo city is also be needed for estimating energy use, carbon emission, water consumption, solid waste, and waste water to be generated per capita in average in this district.

The studio experiment also shows that ArcGIS Urban offers opportunities for students to explore how data analysis integrates urban design. It is an easy-to-use tool for planning students without previous design background to engage in urban design project by managing future development scenarios. The ArcGIS Urban platform allows planners to manage spatial and attribute data including social demographics, zoning, environmental impacts to urban forms for development, and produce 3D scenarios for visual communication with studio partners and the community stakeholders in effective ways.

A GIS-based urban digital design platform (Figure 6) would allow stakeholders from both public and private sectors to engage, communicate and negotiate for making consensus. When architects and developers present their design and development proposals, the platform would allow planners and policy makers to review the proposals based on urban design guidelines and performance criteria, in which carbon emission and energy performance can be defined as one of key performance indicators. Mechanisms of this kind for making decisions are urgently needed when many cities are driving and managing their future urban development moving toward lower carbon and lower energy urban systems. There are potential connections between data analytics and urban design decision makings.

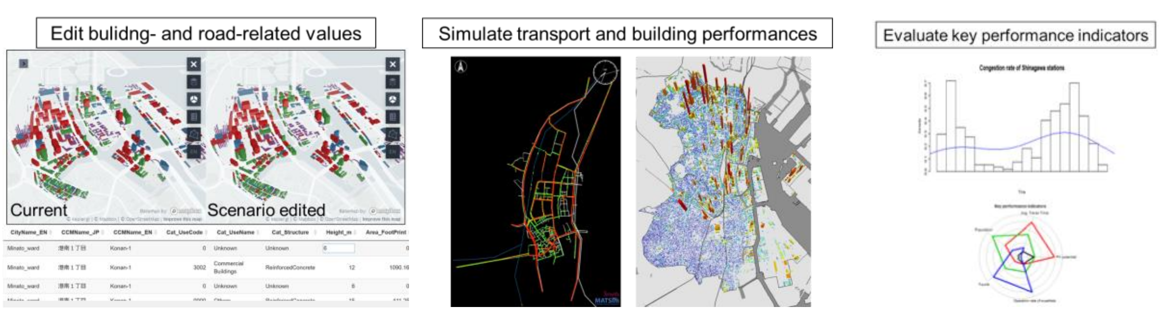

Fig. 6. GIS-based Urban Digital Platform

5. CONCLUSION

The above research design and test bed in Tokyo Shinagawa demonstrates how a low energy urban district can be designed from scenario making, performance modeling to urban design plan making by incorporating an urban digital platform to visualize data analytics and performance outcome, with a focus on energy and carbon emission measures. The Covid-19 pandemic from early 2020 shows a decreasing carbon emission in Tokyo, not a viable way to mitigate urban carbon emission. A post-pandemic urban digital platform is needed for incorporating data from building energy and mobility that jointly contribute to future carbon mitigation agenda, in which urban systems design is seen as an interventional approach to develop green recovery for planning a low carbon energy district.

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