3D and Spatial Analysis for Smart and Healthy Cities

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Abstract: In the coming decades, cities will increasingly use data, technology, and computational systems to improve many aspects of urban life. Distributed sensors and networked systems will be ubiquitous and fundamental for achieving important goals, such as connecting people to technology, enhancing efficiency of city infrastructure, streamlining city operations, improving public health and safety, and monitoring environmental and social conditions of urban life. "Smart Cities" has emerged as a name to describe these systems. "Healthy Cities" includes physical and economic health, plus overall quality of life. Effective, smart, and healthy communities will combine creativity, innovation, and collaboration of academic research, public and private partners, and citizen engagement to enhance communities by making data-driven decisions. This paper describes past, present, and future projects that rely upon such collaborations to bring smart and healthy community projects to fruition.

Keywords: Smart cities, healthy cities, 3D visualization, spatial analysis

1 Introduction

The term "Smart City" is a clear framework and understanding of the digital infrastructure necessary to help cities discover and unleash the vast amount of data and tools necessary to make a smart city is invaluable. It also sets the stage for partnerships between government, business, non-profits, community groups, universities, and hospitals, all focused on one goal: creating a smarter and healthier city [1]. One such successful framework can been seen in Metro21, a city-university collaboration aimed at Smart City collaborative projects between Carnegie Mellon University and the City of Pittsburgh, located in Pennsylvania, USA.

Carnegie Mellon University was established in 1900 by steel magnate and philanthropist, Andrew Carnegie as a school to provide technical skills for the citizens of Pittsburgh. Today, CMU is a global university with more than 13,000 students, 100,000 alumni, 5,000 faculty and staff, and its seven schools and colleges include the College of Engineering, College of Fine Arts, Dietrich College of Humanities and Social Sciences, H. John Heinz III College, Mellon College of Science, School of Computer Science, and Tepper School of Business. CMU's vision is "*to have a transformative impact on society through continual innovation in education, research, creativity, and entrepreneurship"* and its mission includes *"to impact society in a transformative way – regionally, nationally, and globally – by engaging with partners outside the traditional borders of the university campus"* [2].

Located at the confluence of the Allegheny, Monongahela, and Ohio rivers, Pittsburgh has long been known as both the "Steel City" for its more than 300 steel-related businesses and as the "City of Bridges" for its 446 bridges. America's "deindustrialization" in the 1980s led to massive closures of steel mills and other industry-related businesses with resulting loss of jobs for blue collar, industry workers in the area. Pittsburgh has responded to this loss by embracing existing infrastructure such as museums, libraries, parks, sports teams, building a new cultural district, and supporting renowned research centers (home to 68 colleges and universities). This led to the Pittsburgh of today, which counts Google, Apple, Bosch, Facebook, Ford, Uber, Nokia, Autodesk, and IBM among the 1,600 technology firms generating

Journal of Digital Landscape Architecture, 2-2017, pp. 76-84. © Wichmann Verlag, VDE VERLAG GMBH · Berlin · Offenbach. ISBN 978-3-87907-629-1, ISSN 2367-4253, e-ISSN 2511-624X, doi:10.14627/537629008.

$20.7 billion in annual Pittsburgh payrolls [3]. The region is a hub for leadership in creativity, energy, environmental design, innovation, and sustainability as seen through partnerships such as Metro21.

In July of 2014, CMU and the City of Pittsburgh launched Metro 21, an initiative devoted to enriching the University's research and development capabilities to address challenges faced by Pittsburgh and its surrounding metropolitan region. Metro21 owes its roots to Traffic21, a CMU institute, created in 2009 by Pittsburgh businessman, civic leader, and philanthropist, Henry Hillman. Traffic21 aims to solve transportation problems by using information and communications technologies developed at CMU, with the City of Pittsburgh as a "real-world" partner to deploy projects and test solutions.

Based on its success, Metro 21 recently expanded to MetroLab Network, a city-university collaboration for urban innovation. Members include 38 cities, 4 counties, and 51 universities. Like Metro21, partners focus on research, development, and deployment (RD&D) projects that offer technological and analytically-based solutions to challenges facing urban areas including inequality in income, health, mobility, security and opportunity; aging infrastructure; and environmental sustainability and resiliency [4].

The following are just a few of many examples of Metro21 and related projects that highlight areas of university-city collaboration focusing on planning and design, transportation, citizen engagement, green infrastructure, and health.

3D Visualization, Gaming, and Simulation Tools for Urban Design, Transportation, and Policy Decision Making

Creative uses of 3D simulation and gaming tools are used by CMU researchers in conjunction with the Pittsburgh Department of City Planning to provide designers and city officials real time "what-if" scenarios in developments of the built environment, public realm, and city infrastructure. A team of faculty and students in CMU's School of Architecture, Heinz College, and Entertainment Technology Center, in collaboration with City Planning , Esri, Inc., and Simcoach Games, created 3D models to visualize and analyze the city as a whole. They then focused on three urban design scenarios for a potential down-town development project along Smithfield Street.

The project debuted at the 2015 City of Pittsburgh and Heinz Endowments inaugural P4 (People, Planet, Place, Performance) Summit and ongoing collaborative research is targeted towards helping the City decide what visualization and analytic tools can be used to best represent various planning scenarios. These tools can also be used to guide the Mayor's Complete Streets Policy that aims to change how Pittsburgh thinks about mobility and transportation by encouraging more than one way of travel, taking into account pedestrians, bicycles, public transit, private, and autonomous vehicles [5]. The following describes the processes, data, and software used in the project.

Using 2D GIS and LiDAR (Light Detection and Ranging) data, 3D buildings for Pittsburgh were created and mapped using Esri's ArcGIS Pro GIS software. Such 3D data allows the City to improve architecture, urban planning, and design processes, better understand built environment relationships, and have the potential to perform line of sight analysis and visualization of zoning areas.

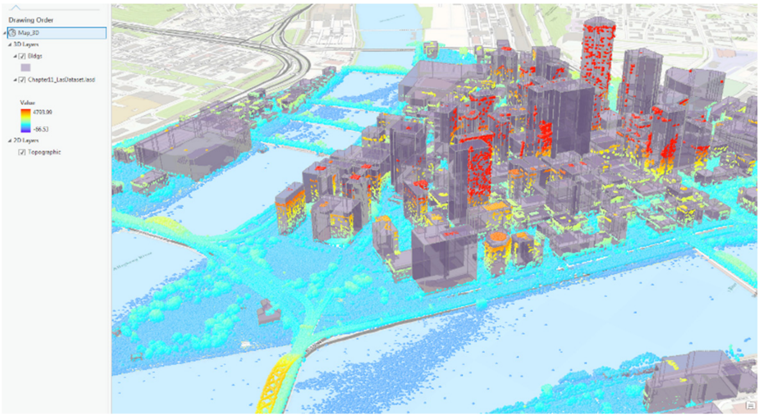

Fig: 1: 3D buildings and LiDAR data of Pittsburgh's Central Business District

Using Google SketchUp and Autodesk's AutoCAD and Revit, detailed building models were importing into Esri's City Engine where realistic building facades and data about buildings, streets, and other built environment features such as street furniture were added to make 3D visualizations as real as possible. In a design phase, these data quantify various design scenarios, enhances visualizations, and helps planners avoid costly mistakes. Solar analysis and shading studies using Esri's City Engine help designers make decisions about proposed buildings and their effect on the surrounding area.

Fig. 2: Sun study of Pittsburgh's Smithfield Street using City Engine

Fig. 3: Interactive tool showing Smithfield Street as a "connector" street with only bus and bike lanes

Software tools such as Computer Aided Design (CAD), Building Information Modeling (BIM), and Geographic Information Systems (GIS) used in urban design and planning require technical expertise that is limited to a few individuals. GIS data and layers can be uploaded and viewed using technology such as Esri's Web scenes where non-technical users can view and manipulate maps and layers. Many cities are also using interactive gaming tools to allow citizens to respond to their environment, enhancing bottom up engagement and buy in. Autodesk's 3D Studio Max software and Unity Technologies' Unity cross-platform game engine, provide video, movement, and easy to view scenes to better visualize, understand, and evaluate planning scenarios.

Interactive gaming tools can also be used to collect data about projects. Pittsburgh's Bus Rapid Transit (BRT) project is intended to better connect communities and residents in Pittsburgh's Downtown-Oakland-East End corridor to jobs, educational opportunities, medical services, and cultural attractions. It also has the potential to unlock development and contribute to neighborhood growth, increase transit ridership, and enhance the environment [6]. In this project, the Port Authority of Allegheny County worked with SimCoach Games to develop an interactive tool seeking input from stakeholders and residents about the location and design of bus stations. The problem many major transportation authority's face is that even with hearings and community meetings, constituent participation and engagement is virtually non-existent. The goal of this project was to communicate the value of a major rapid transit project to public transportation stakeholders and engage the public to gather data on preferences regarding features of the BRT. The solution was to create a simulation game where the player is allowed to design and submit their own proposal for a Bus Rapid Transit System. The player can modify road layouts, station design and amenities while seeing how the changes they are making affect aesthetics, travel time, cost, and more. The submissions were sent to the Pittsburgh Port Authority who gathered information about the public's opinions and desires in order to help design the BRT system [7].

Fig. 4: Bus Rapid Transit interactive simulation game

Sensors and simulations play a large part in transportation studies. Projects at CMU's Traffic21 Institute and Center for Technologies for Safe and Efficient Transportation (T-SET) are many and include safety issues related to autonomous vehicles, safe cycling, multimodal distraction, human computer interaction in cars, driver fatigue, and accident investigation using 3D models.

Surtrac (Scalable URban TRAffic Control), a hallmark of Traffic21 research, is an innovative approach to real-time traffic signal control that combines artificial intelligence research and traffic theory. Surtrac optimizes the performance of traffic signals and improves traffic flow by reducing congestion that leads to reduced waiting time, shorter trips, less pollution, and happier drivers. A recent pilot project in Pittsburgh's East Liberty neighborhood showed that, by using sensors to optimize traffic flow, vehicles spent 40 percent less time idling and reduced emissions by 21 percent [8]. Surtrac projects also include real-time detection of pedestrian traffic that enhances adaptive signal control in areas where pedestrian traffic is substantial.

Traffic simulations are used in future development projects. CMU's Robotics Institute uses smart signal control to analyze how to mitigate traffic for Almono, a proposed development site. Using engineering drawings to render a simulation model, three metrics including travel time, delay, and number of stops are analyzed to determine the best way to alleviate possible traffic jams.

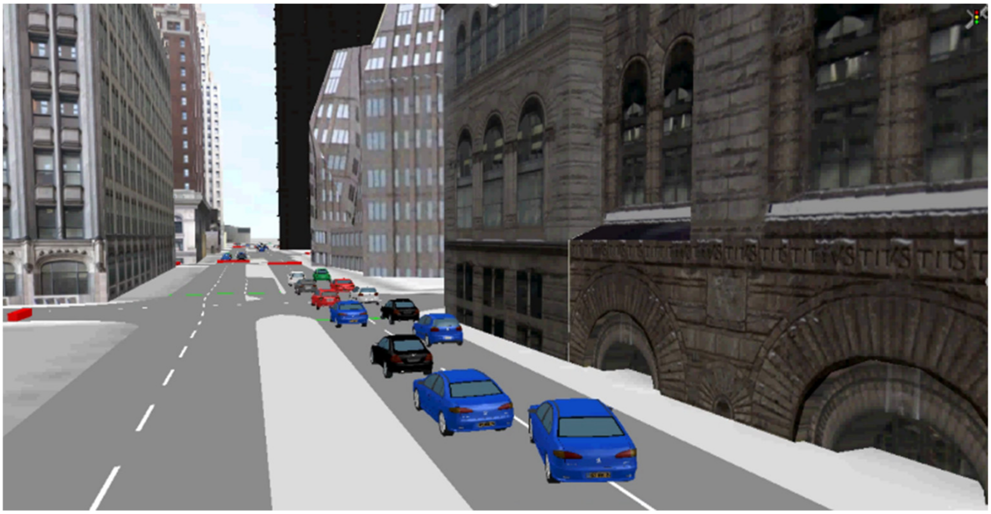

Fig. 5: Traffic simulation 3D model, downtown Pittsburgh

Potential future collaborations with other Smart City research being conducted at CMU around planning and transportation, include urban design and planning decisions related to autonomous vehicles, mobility analytics, sensors measuring air pollution and noise, video camera capture, Virtual Reality (VR), and Augmented Reality (AR).

Interaction of people and their environments for healthy and safe living

In order to make better policy decisions and improve the health of citizens, collaborations often extend beyond academia and the public sector. For example, improving the physical health of a community requires data and knowledge from hospitals with experts in public health, human services. Projects between CMU and medical doctors at Children's Hospital of Pittsburgh (CHP) add value to understanding how children's health and safety relate to green spaces. By studying medical conditions such as childhood obesity and pedestrian accidents, researchers can determine if parks and playgrounds are beneficial to improving physical activity and safety in neighborhoods.

In a recent study, researchers mapped home locations of children in an obesity study over a five year period and compared these locations to parks and fast food locations. Data about the children included positive or negative Body Mass Index (BMI) Z-scores. In other words, patients who gained or lost weight. GIS was then used to determine patient proximity to parks and fast food establishments. The study found that patients with moderate BMI decreases (43.75 %) live within 1,200 feet of a park and the mean distance to fast food was 1.1 miles. Patients with moderate BMI increase (83.3 %) live farther than 1,200 feet from a park and the mean distance to fast food is 0.8 miles.

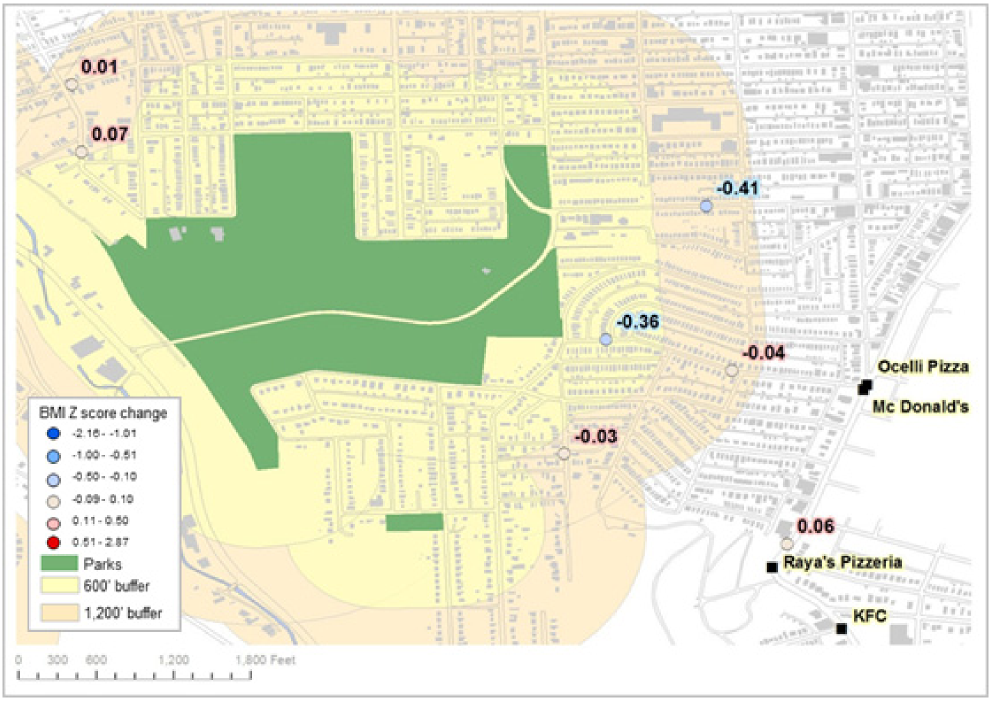

Fig. 6: Map of obesity patient home location and proximity to parks and fast food, Allegheny County, PA

Additional studies used satellite imagery to determine the type of park and its amenities. An interactive tool was created so physicians and health care workers could, along with the patient, view home locations, determine walkability and healthy amenities, encouraging patients to be more active in their neighborhoods.

Another collaborative project between CMU and CHP mapped patients with severe injuries incurred from pedestrian accidents. The study mapped the injury location residence and proximity to parks. The results showed that the injury rate per 10,000 youths was 37 % higher in a 601 to 1,200 foot buffer ring of parks, compared to a 0 to 600 foot buffer ring. Additional studies looked at demographic data (youths living in poverty) which showed that 65 % of the injuries were in the top 40 % of neighborhoods by youth population living in poverty. An additional study of all injuries throughout the city showed areas of concentrated accidents that led to design solutions such as extended sidewalks, camera installations at dangerous intersections, and other traffic slowing solutions.

When researching health and safety issues related to green spaces, other factors such as crime, dangerous traffic conditions, and poor lighting were reasons why children were not using parks. CMU studies related to LED lighting offer interesting findings related to public safety. A Metro 21 project between the School of Architecture's Remaking Cities Institute (RCI), School of Computer Science, and consultants C&C Lighting, LLC installed more than 4,500 LED lights in Pittsburgh. The team published a report of findings whose purpose was to provide an understanding of recent industry and technology changes, address common conerns raised when using LED lights, recommend model specifications, and make suggestions for improving industry norms and codes. Much of the study was related to energy and cost savings but there were additional findings related to health and safety.

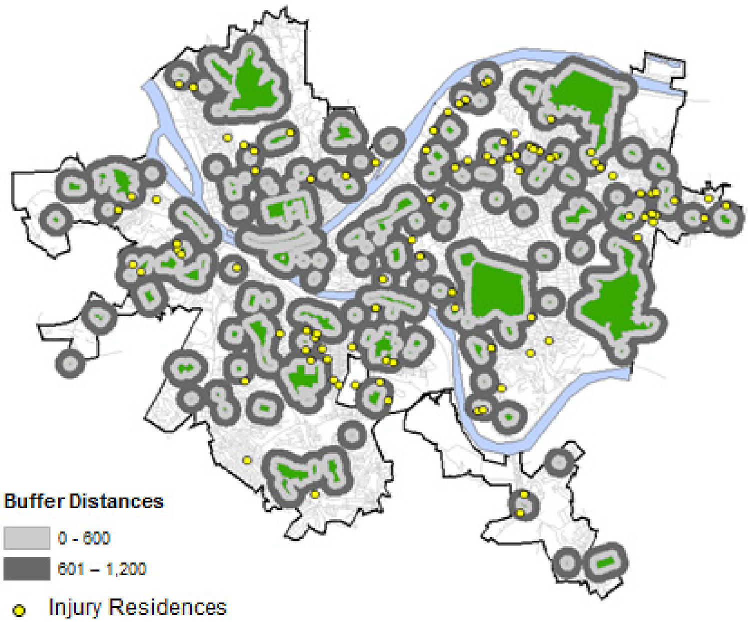

Fig. 7: Map of injury location residences and proximity to parks in the City of Pittsburgh, PA

Fig. 8: The entrance to Frick Park in Pittsburgh, PA with high-pressure sodium luminaires at left and LED luminaires at right

For example, the study showed how controls can be programmed for specific days and times to provide temporary high Illuminance for events, such as a block party, or increased on demand for emergency or public safety situations. To improve safety, more illumination can be provided at intersections, crosswalks, areas of high pedestrian volume, change in road widths, and roundabouts. The study further shows that streetlights set to high levels of illumination, which many feel increases safety, actually distorts the balance and contrast needed to distinguish objects and increases eyesight adaptation time. Public safety officials sometimes turnoff streetlights at crime scenes because they cannot distinguish forms when the lighting is so bright that it hides suspects in dark shadows. They can see better with night vision goggles. The health and safety benefits of LED might be difficult to quantify nonetheless they should not be overlooked when contemplating LED retrofit programs [9].

2 Conclusion

Collaborations between academia, government, and the private sector are critical to ensure success of smart and healthy community projects. Civic engagement, beyond just publically sharing information, is essential. Government leaders need creative and innovative processes and tools to share data, ideas, and collect information, allowing them to make better informed data-driven decisions. Formal initiatives such as Traffic21, Metro21, and MetroLab Network offer robust research, development, and deployment of innovative and creative technologies, methods, and models for use across the country and around the world.

Endnotes

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