Smart Moves

A Virtual Reality demonstration of a sustainable transportation system.

Hal L.N. Brynteson

University of Illinois at Chicago, hbrynt2@uic.edu

JD Peace

University of Illinois at Chicago, peace2@uic.edu

ABSTRACT

For many Americans, cars are the first, if not only, choice for transportation. This nation-wide car dependence creates a myriad of issues, such as congested roadways, increased pollution from vehicular emissions, and safety concerns. The United Nations (UN) Sustainable Development Goals considers resolving these issues as key for addressing the 11th goal of creating Sustainable Cities and Communities. Solving these issues is a complicated problem, as it is difficult to reduce the use of cars without exacerbating issues of a different kind. Thus, in search of a "no regrets" solution to create better traffic conditions that can ease Americans into the paradigm shift required to make transportation more sustainable, "Smart Moves" was created. In Smart Moves, we propose a "smart city" solution, focusing specifically on the way a smart, interconnected system of traffic lights could create more efficient traffic—traffic that spends less time idling, thus, less time polluting the air or creating congested traffic conditions. This solution is presented in a VR application for the CAVE2™ Virtual Environment that places the user in the streets of Chicago and tasks them with navigating to different intersections, building the smart traffic grid. As the user progresses, they see dramatized examples of the positive effects of the grid in the environment around them.

CCS CONCEPTS • Human-Centered Computing

Additional Keywords and Phrases Virtual Reality, Sustainable Development Goals

ACM Reference Format:

Hal L.N. Brynteson and JD Peace. 2023. Smart Moves: A virtual reality demonstration of a sustainable transportation system. In *CHI Conference on Human Factors in Computing Systems Extended Abstracts (CHI'23 Extended Abstracts)*, April 23–28, 2023, Hamburg, Germany. ACM, New York, NY, USA, 6 pages.

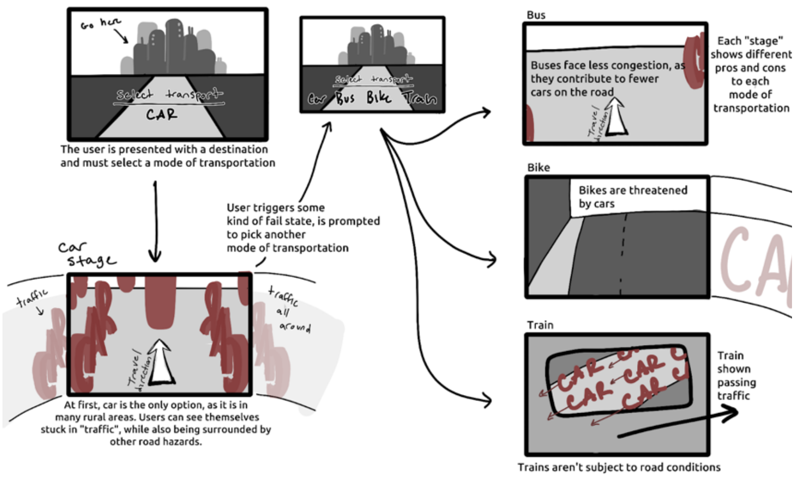

Figure 1: Initial storyboard design focused on a multipath guided tour to travel from the suburbs into the city through different modes of transportation.

Introduction

In the United States, there is a car dependency issue. Cities are congested with traffic [6], creating unsafe conditions for pedestrians, and generating large amounts of vehicular emissions [5][9]. According to the UN, 99% of people living in cities are breathing polluted air, contributing to a worsening of global health [3]. Urban populations alone are not the only ones threatened by car dependence; a report from Smart Growth America and Third Way shows that rural populations travel around 41% more by car than their urban counterparts. A car-centric infrastructure worsens rural and urban life [10], yet for many, to cease driving would be impossible. To solve the issues created by an overabundance of vehicular traffic, we will need to take the steps to create an overall more sustainable system.

The United Nations (UN) outlines 17 goals for sustainable development. Goal 11, Sustainable Cities and Communities, specifies ten targets, one of which seeks to "provide access to safe, affordable, accessible and sustainable transport systems for all" [3]. It can be complicated to define sustainability. The UN states that sustainable transportation can "enhance economic growth and improve accessibility" as well as "achieve better integration of the economy while respecting the environment." [9]. This definition is echoed by a 2006 report by Litman and Burwell, which adds that "sustainable development strives for an optimal balance between economic, social and ecological objectives" [6]. For our project, we took care to consider that, however we sought to solve a given issue with roots in transportation, we would need to consider sustainability in a larger context across multiple domains.

If we focus on the reduction of vehicular emissions to reduce pollution, the solution appears simple: remove cars as much as possible. Yet, this will have massive social and economic ramifications [6]. Industries employing millions would collapse, and millions more would be left with no access to society [12][10]. Thus, our proposed solution seeks to tackle some of the issues presented by car dependence without requiring a massive and costly paradigm shift.

The unique immersive aspect of the CAVE2™ Virtual Environment delivers this ideated solution in a more effective manner than a 2D format [15]. Audiences can gather for a collective experience of this proposed reality. Virtual reality has been shown to improve teamwork in other instances [14], which is critical for moving towards a sustainable community. This medium offers unrestricted degrees of creativity in portraying how a world with reduced car dependence could appear.

Figure 2: Final storyboard iteration features simplified implementation of smart nodes in various scenarios and introduces new elements, such as bicycles and specific interaction-focused objectives for the user.

Our Solution

The Smart Moves project proposes a "smart city" solution to some of the major issues presented by a car-based infrastructure, mainly pollution and traffic congestion. Aptly called "Smart Moves" because it recommends a smarter way to have populations move throughout their communities. In this solution, all traffic intersections are equipped with a "smart node" that will track the cars that pass through the traffic system. The nodes can then work together to control traffic flow. We have identified a reduction in idle time as an ideal metric of efficiency [5]. An idle car greatly increases pollution, while creating congested traffic conditions. The system of nodes will operate to keep idle time for cars stopped at intersections as minimal as possible, reducing the amount of time cars are spending doing no useful work.

This solution is inspired by other smart city and urban sensing projects. Cities across the world are implementing some form of large-scale sensing project to meet sustainability goals related to transportation, energy consumption, and waste management, to name a few [4]. In the United States, Argonne National Laboratory has deployed nodes of this kind in Chicago as part of a project called the Array of Things [1]. This network of nodes allows researchers to access real-time data streams, some of which pertaining to monitoring pollution. Further, Spectrum has a smart cities initiative to develop the smart city infrastructure, with traffic monitoring and management listed as one desirable goal [8]. Our project is modeled after these existing solutions, though we have chosen to target traffic management in specific and highlight the particular use of integrating these systems with the existing traffic light infrastructure.

Virtual Reality Development

To demonstrate the implementation of a smart city through smart nodes, a guided virtual reality environment was developed through Unity for the CAVE2 environment which would allow users to engage in the smart node installation process. An important aspect of sustainability is encouraging a population to be proactive about utilizing these types of technologies. By using an immersive virtual reality experience, a user can be encouraged to think about the challenges and long-term benefits of improving their immediate environment.

Storyboard Design

This project evolved over various iterations as detailed through storyboarding. Familiarizing with the limitations of user range of motion and field of view influenced changes from the initial design. The initial concept focused on altering popular opinion on why using cars should be avoided at all costs and instead replaced by sustainable

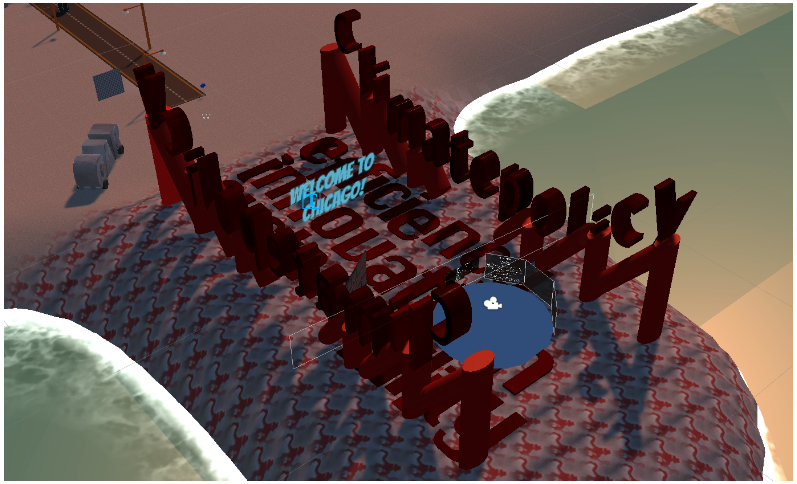

Figure 3: 3D Typographic model of the Chicago Washington St. bridge, featuring words pertaining to climate action and sustainability.

Figure 4: 3D typographic model of a car.

options like cycling or public transit (Fig. 1). This would have involved trying to force the user to dodge oncoming traffic to dramatize how many threats cars pose beyond air pollution. However, due to the limitation of being unable to dodge objects in such a manner in the CAVE2, this approach was reevaluated.

To maximize the advantages of the CAVE2 environment, the direction of the project focused on engaging the user through interaction, hence the simplification overall to what is seen in Figure 2. An abstract representation of the city being "smart-ified" through color changes provided a more comprehendible result for a user during a short immersive experience. As the user is guided into making smart moves for smart-technology guided traffic, this project was aptly titled "Smart Moves."

Aesthetic & Typography

A key artistic element of this experience was the use of typographic models. All primary interactable items were modeled with 3D typography. These elements included the cars, bicycles, traffic lights, city bridge, and most importantly the primary tool to be used for interaction by the user (Figures 3-5). Use of typography as a design choice simplified model acquisition for this project as all typographic models were designed through Maya and imported to Unity at no cost.

Typography also offered an opportunity to take advantage of semantics, most notably in this experience, using an unintelligible scramble of letters for the traffic lights indicated that something about the model did not "make sense." When the user updated the model through interaction, the traffic light model syntactically updated to spell out legible words (Fig. 5).

A replica scale of the city of Chicago provided a backdrop for this simulation. It was originally sourced from a Mapbox implementation which proved to be incompatible with the CAVE2™ Virtual Environment due to limitations with Mapbox API calls, so the building models were adapted from Mapbox to be network independent.

The design choice for creating a predominately red environment that would transition to green stems from multiple origins. Reds and warm hues can evoke a frustration within a user, which with the intentions of this exhibition were to suggest that the existing environment was less than ideal. The exhibition transforming from red to green can serve as an extended metaphor for common colors seen within traffic lights as they transition from red to green to allow vehicles to progress. Finally, it is typically recognized that sustainability is considered a "green" initiative, and therefore as solutions are applied within the environment, the greener it becomes both figuratively and literally. The aesthetic visualization of colors embodies all these ideas.

Car animations and interaction with streetlights to demonstrate car idling were incorporated to the custom typographic vehicles using Traffic Simulator package for Unity.

Figure 5: Before (left) and after (right) interaction models of traffic lights.

Figure 6: The user is faced with questions to that guide the user to think critically and navigate to the next point of interest in the environment.

Interactive Experience

To begin, the user is initialized on the Washington Street bridge in a virtual replica of a city block of Chicago (Fig. 3). The environment is overwhelming red, with pollution elements littering the gray overcast sky. They are welcomed by large floating text. The bridge is composed of typographic elements that encompass ideas around sustainability to prime the user on the issue at hand. To further enhance the immersive experience, the user must physically maneuver over a transparent block to proceed.

An idle car emitting pollution particles obscures the user's view from the initial introduction panel that provides information related to the issue of car emissions. Once being ushered further along the primary path with floating questions (Fig. 6), the user is introduced to a typographic wrench that represents "Sustainable Solutions" (Fig. 7). The user is provided context to their experience to utilize the tool to install smart nodes throughout city intersections as a city engineer who has been commissioned by the City of Chicago. The user is then equipped with a floating map to track their progress and relative location, shown in Figure 7.

Each intersection featured typographic representations of traffic lights that would update the model into an intelligible collection of letters when the user completes a "smart node" installation on the light. At this point, the user is granted independence to explore the virtual environment and interact with elements at their leisure (Fig. 8 and 9). The user is tasked with visiting a total of 10 intersections. Designed as a collective experience, other participants can observe and discuss how the primary user's interactions have impacted the environment (Fig 9).

Traffic lights were logically grouped together by intersection so that when a user completed installation of nodes for all lights at an intersection, an event would be triggered. The event caused a visible transformation of the surrounding environment. The building model colors would transform from red to green. Pollution particle emissions would be reduced. Lighting in the environment would update. Most pertinent, the car behavior and spawn frequency would change.

With each intersection updated and connected to the smart node system, car models in the virtual environment would reduce the amount of pollution they generated and spawn less frequently. Car spawning behavior was reduced to simulate the effect of having a more effective traffic system controlled by smart nodes. Bicycles would also spawn with greater frequency as the user progressed, representing the positive effects of reduced car congestion.

After completing all intersections, the user would navigate to City Hall to submit their floating interactable progress report to City Hall. At City Hall, once the user placed their progress report map into a submission box, a full environment change was triggered. The overhead skybox was changed to be clear All pollution particle systems were eliminated. Smaller elements (i.e., streetlights, benches, and trees) color schemes

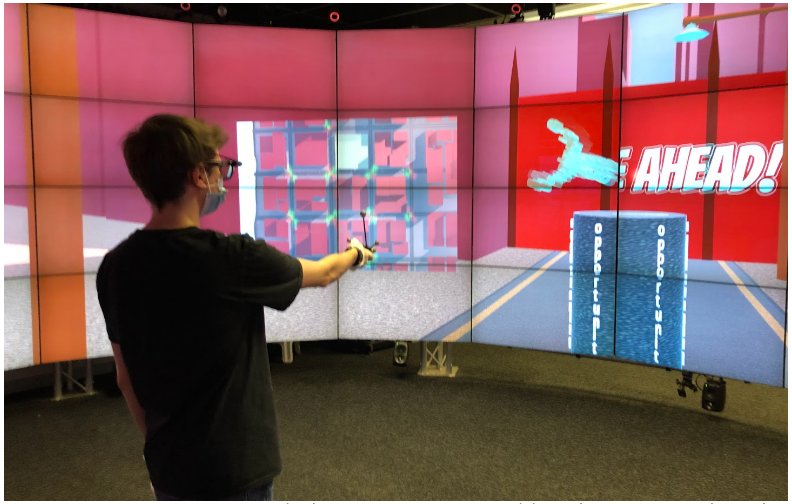

Figure 7: User interacts with the primary "Sustainable Solution" wrench tool from the pedestal. A map is displayed to show an orthographic view and to track progress. This map triggered the final event at City Hall.

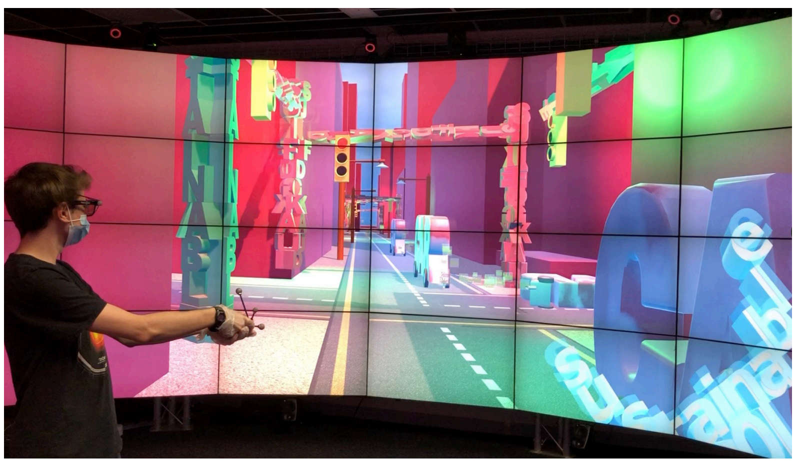

Figure 8: The user reaches an intersection and updates traffic lights from scrambled letters to intelligible "smart-ified" lights (as displayed by the far left model).

were updated to match the greenified aesthetic of the buildings. Celebratory sparks coupled with a completion message thanking the user for their work appear on a final panel indicating to the user their task is complete (Fig. 10).

Auditory Experience

To further immerse the user in the virtual environment, the user's auditory system was also utilized. Taking into consideration how the user's emotions can be manipulated through sound, audio played a key role in designing the environment and interactions.

Ambient traffic sounds were included to simulate a congested city environment. Each car model was equipped with an aggressive horn sound. Bicycle models were equipped with pleasant bell sounds. This contrast in audio elements was intended to subtly influence the user's preference against cars and towards bicycles.

The user received positive auditory feedback for completing smart node installations. For each traffic light upgraded, a rewarding 'blinging' noise would play during each model transformation. Once a full intersection (a logical set of traffic lights) was upgraded, a more robust 'bling' noise indicated that the user had triggered a larger event.

Exhibition

The efforts of this visual experience were exhibited within the CAVE2™ Virtual Environment hosted at the Electronic Visualization Laboratory at the University of Illinois, Chicago (EVL at UIC) with 50 audience visitors who provided feedback with their impressions.

Conclusion

Working towards sustainable cities and addressing air pollution with a single technology is ambitious. This project demonstrates that tackling a large issue will require multi-faceted solutions that will take time to implement. Despite this, through the virtual experience, a user explores the perspective that the solution of using demand driven traffic lights can still reduce idle car emissions to ultimately have a large impact on a greater goal. The latest technology in virtual reality immersion served as a tool to transplant a user and convey a better potential reality.

REFERENCES

[1] "Array of Things | Argonne National Laboratory." Accessed April 18, 2023. https://www.anl.gov/mcs/array-of-things.

Figure 9: Collective and collaborative exploration in the CAVE2™ Virtual Environment encourages teamwork and discussion for sustainable solutions.

Figure 10: User completion of the virtual experience after submitting their progress report triggers a final congratulatory message event.

[2] Donovan, Alyssa, and Eli Ong. "Study: Chicago Is Most Congested City in the Country, 2nd in the World." WGN-TV (blog), January 10, 2023. https://wgntv.com/news/study-chicago-is-most-congested-city-in-the-country-2nd-in-the-world/.

[3] "Goal 11 | Department of Economic and Social Affairs." Accessed April 18, 2023. https://sdgs.un.org/goals/goal11.

[4] Hope, Blaise. "Top 10: Smart Cities Driving Sustainability around the World," April 22, 2022. https://sustainabilitymag.com/top10/top-10-smart-cities-around-the-world.

[5] "Idling Reduction for Personal Vehicles." Argonne National Laboratory, n.d.

[6] Litman, Todd, and David Burwell. "Issues in Sustainable Transportation." International Journal of Global Environmental Issues 6, no. 4 (2006): 331–47.

[7] Salazar-Cabrera, Ricardo, Álvaro Pachón de la Cruz, and Juan Manuel Madrid Molina. "Sustainable Transit Vehicle Tracking Service, Using Intelligent Transportation System Services and Emerging Communication Technologies: A Review." Journal of Traffic and Transportation Engineering (English Edition) 7, no. 6 (December 1, 2020): 729–47. https://doi.org/10.1016/j.jtte.2020.07.003.

[8] "Smart City Initiatives | Spectrum Smart Cities." Accessed April 18, 2023. https://spectrumsmartcities.com/articles/smart-city-initiatives.html.

[9] United Nations. "Sustainable Transport | Department of Economic and Social Affairs." Sustainable transport | Department of Economic and Social Affairs. Accessed April 18, 2023. https://sdgs.un.org/topics/sustainable-transport.

[10] Wilson, Kea. "Study: Rural Areas Need Safe, Sustainable Transportation Now." Streetsblog USA (blog), October 6, 2021. https://usa.streetsblog.org/2021/10/06/study-rural-areas-need-safe-sustainable-transportation-now/.

[11] Xing, Yan, and Susan Pike. "Exploring the Consumer Market and Environmental Impacts of Microtransit Services in Sacramento and Citrus Heights, California | National Center for Sustainable Transportation." Accessed April 18, 2023. https://ncst.ucdavis.edu/project/exploring-consumer-market-and-environmental-impacts-microtransit-services.

[12] Xing, Yan, Caroline Rodier, Brian Harold, and Mike Sintetos. "New Mobility for Sustainable Suburban and Rural Travel." ITS. Accessed April 18, 2023. https://its.ucdavis.edu/blog-post/new-mobility-for-sustainable-suburban-and-rural-travel/.

[13] Febretti, A., Nishimoto, A., Thigpen, T., Talandis, J., Long, L., Pirtle, J. D., ... & Leigh, J. (2013, March). CAVE2: a hybrid reality environment for immersive simulation and information analysis. In The Engineering Reality of Virtual Reality 2013 (Vol. 8649, pp. 9-20). SPIE.

[14] Chiang, Chih-Huei, Chiu-Mieh Huang, Jiunn-Jye Sheu, Jung-Yu Liao, Hsiao-Pei Hsu, Shih-Wen Wang, and Jong-Long Guo. "Examining the Effectiveness of 3D Virtual Reality Training on Problem-Solving, Self-Efficacy, and Teamwork Among Inexperienced Volunteers Helping With Drug Use Prevention: Randomized Controlled Trial." Journal of Medical Internet Research 23, no. 11 (November 2, 2021): e29862. https://doi.org/10.2196/29862.

[15] Araiza-Alba, Paola, Therese Keane, Won Sun Chen, and Jordy Kaufman. "Immersive Virtual Reality as a Tool to Learn Problem-Solving Skills." *Computers & Education* 164 (April 1, 2021): 104121. https://doi.org/10.1016/j.compedu.2020.104121.