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Engaging the Business and Tourism Industry in Visualizing Sea Level Rise Impacts to Transportation Infrastructure in Waikiki, Hawaii

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DISCLAIMER

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PROJECT DESCRIPTION

Transportation planners in coastal communities plan for future hazards and risks of sea-level rise (SLR), and often, they communicate risk in public meetings via PowerPoint presentations with charts as well as two-dimensional (2D) maps that visualize information using Geographic Information Systems (GIS) technologies. The project investigates the use of immersive technology to communicate SLR risk, including the development of an immersive three-dimensional (3D) model of the Waikiki neighborhood of Honolulu, Hawaii. According to the project's original methodology, participants would have experienced the model using virtual reality (VR).

However, due to the COVID-19 pandemic, the team pivoted to creating and implementing an internet-based survey instrument with embedded 2D charts and video of the animated 3D model. The flooding projections were derived from National Oceanic and Atmospheric Administration (NOAA) data. NOAA supplies the SLR Viewer, a screening-level tool that uses the best-available national projections to map areas vulnerable to current and future flood risks.

RESEARCH OBJECTIVES

A. To test if an immersive visualization of sea-level rise (SLR) results in a deeper understanding than two-dimensional representations of impacts to streets in the Waikiki section of Honolulu, Hawaii
B. To test if immersive visualizations can be conducted and effective using a video-embedded survey distributed via the internet, since the COVID-19 pandemic prevented in-person meetings and workshops that would have utilized a virtual reality (VR) model

LITERATURE REVIEW

A critical part of modern urban planning and its development projects is active community outreach and engagement. Planners have the responsibility, not only to listen, but to take into consideration what the community wants or needs and whether the new design proposal is compatible with current surrounding establishments. However, as Ford (2020) stated in her article *Innovating Community Involvement in Urban Design*, "Traditional forms of outreach (i.e., the public meeting) often fall short of reaching the increasingly diverse and information-saturated citizens of today's American cities."

Fortunately, with advances in virtual reality (VR) and augmented reality (AR) technology, new tools have been introduced into the urban planning and design fields to aid the collection of data from community residents. In 2017, Kamel Boulos and colleagues focused on the benefits of implementing both virtual reality Geographic Information Systems (VRGIS) and augmented reality GIS (ARGIS) in new project opportunities, especially focused on public health, the environment, and higher-quality housing options for individuals and communities. One of the main benefits of using VR combined with the GIS database is its unique capacity to visualize 3D projects from all possible perspectives, and users including city managers and community residents can actually see and experience the design (Kamel Boulos et al., 2017).

DEFINING AUGMENTED, VIRTUAL, AND MIXED-USE REALITY

Immersive environments are the environments created by immersive technologies (Bach et al., 2016), including virtual reality (VR), augmented reality (AR) and mixed reality (MR). While VR completely occludes the natural environment and immerses users into digital environments, AR and MR superimpose virtual information into the user's natural surroundings in real time (Millgram and Kashino, 1994). MR distinguishes itself further by enabling interaction and manipulation between physical and virtual content (Foundry, 2017). AR and MR technologies supplement our perception of the real world rather than supplant.

Immersive technologies use stereoscopic techniques, thereby creating an engaging and immersive visual environment (Bach et al., 2016). VR/AR/MR head-mounted displays and mobile systems are becoming increasingly accessible, spanning a wide range of prices, levels of sophistication and functionalities such as Google Cardboard, Microsoft HoloLens, HTC VIVE, and Samsung Oculus Rift and others. The low-cost hardware technologies are expanding the opportunities for practical applications and scientific insights. Immersive environments have already started to transform how individuals learn, make decisions, and interact with the physical world across the fields of visualization, construction, architecture, urban and environmental planning.

VIRTUAL & AUGMENTED REALITY IN URBAN PLANNING

Real-time 3D visualization provides an in-depth analysis of the current urban fabric of a city, as well as future development. This software can also be used to present simulations of landscape structure flood disasters and other natural emergency scenarios, to better understand the impacts these may have on one community or several. To support the stated benefits that VR has on flood and natural disaster planning, Haynes, Hehl-Lange, and Lange (2018) introduced and studied a new prototype browsing and authoring tool used for in-situ flood visualization named Mobile Augmented Reality (MAR). The MAR application is available to run on most smart phones and gives users the opportunity to immerse themselves in real time visualization. The software accesses live sensor readings that provide real time annotations. The overall conclusion of the study was that VR apps could prove to be a valuable tool for planning, design, and emergency management.

With proper tools like the MAR app, significant access to different platforms of information and involving the community in the planning process is now easier and more important than ever. Schrom-Feiertag et al (2020) focus on the role of VR technology in participatory planning and integrating local residents in new project development. In one case, the users explored a virtual environment presenting a multi-modal traffic simulation using what the researchers called a “gamified approach with story-telling” (p. 119). Once the users were immersed into the virtual world, they encountered virtual questionnaires for in-situ feedback that helped city planners understand how the users both saw and felt the surrounding environment. Employing this technique and using the VR technology facilitated the site planning process and also simplified the community’s analysis via immersion and real time feedback from the participating users in the virtual scenario.

Van Leeuwen et al (2018) presented a case study and controlled experiment demonstrating the effectiveness of VR in participatory urban planning in The Hague, Netherlands. The researchers employed *human-centered computing*, meaning an equal combination or interaction of virtual reality with participatory design and its users. The study incorporates a novel approach, focusing on how VR can help direct essential municipal investments and justify them in the redesign of public spaces. The process incorporated 3D modeling tools and VR, empowering citizens to co-create and negotiate design decisions in collaboration with planning experts. The VR headsets provided a higher engagement with planners and successfully integrated the municipal process of citizen outreach and planning.

USE OF 2D VIDEO FOR PARTICIPANT ENGAGEMENT

Further research on the complementary effects of digital technologies on the public participation process were developed by the Meenar and Kitson (2020). Their New Jersey case study found that the level of participation and emotional response are much higher when multisensory or multi-dimensional VR simulations (immersive virtual reality) are used in contrast with simple 2D presentations or verbal explanations. Immersive virtual reality (IVR) technologies include 4D auditory and olfactory stimulation cues that fully immerse the user in the proposed model. In the current digital era where public engagement has become a higher priority in the planning agenda, multi-sensory 3D and 4D immersive virtual reality technologies offer urban planners and policy makers opportunities to expand and supplement public engagement simulations and participation. In a similar study conducted in Virginia, Polys et al (2018) found that the 3D models and videos are superior planning tools to support decision making and community outreach when compared with 2D presentations and survey questions, even though the latter remain relevant and useful tools.

Although the use of visual aids in the urban planning context has been used for over 20 years, VR and AR technologies offer new opportunities for community participation. For the project, *Visual Learning Spaces for Fieldwork in Urban Planning (VLF-BY),* students, teachers and research faculty collaborated to explore the role of visual and digital engagement tools in Bhopal and Trondheim (Vrebos, H., Nielson, B., & Styve, A, 2019). The VLF-BY project suggests the introduction of new tools such as mobile ethnography, app/web-based data collection, and the use of video and interactive 3D imagery in immersive technologies can innovate participation. Furthermore, the project explored how visualization and digitalization facilitates learning and participation for users and planners at a much higher level than previously observed, creating a "common language" between all parties involved.

Even though conventional methods of public participation can be improved with the introduction of new VR/AR technology, given the current circumstances of the COVID-19 pandemic, bringing community members and the administrative team together to test and experience the VR and AR technology was no longer a viable option. Nevertheless, the digitalization of the data facilitates both learning and public participation, even if in a 2D format. The 2D immersive video display helps participants better understand the proposal while still providing a reliable communication platform. This interaction will allow a distanced participatory process. Technology, and more specifically the video, will facilitate collaborative distant work and citizen participation (Hanzl, 2007). A 2009 digital workshop in Bowen Island, British Columbia proved the benefits of using digital visualizations for planning proposals and participant feedback. The workshop concluded that the abilities to "dynamically explore the visualizations of planning proposal" and to be able to see "real- time changes" were very informative to community member and administration (Salter et al, 2009). Additionally, the video interaction increased participants' overall understanding of the plan, allowing them to develop a better judgement of the plan's effects on the community.

SHORT- AND LONG-TERM EFFECTS OF VR/AR/MR ON CIVIC ENGAGEMENT

Community feedback is an integral component of the planning process. Participatory planning stands to significantly benefit from developments in VR/AR/MR technologies by enhancing stakeholder understanding of the existing and future built environment and increasing levels of informed deliberation about spatial and policy variables. However, the question remains: can VR/AR/MR visualizations motivate stakeholders, to not only participate in the immediate experience, but to stay involved in community planning activities in the short- and long-term? At present, further research is needed that focuses on whether VR/AR/MR technologies affect the sustainability of civic engagement.

METHODOLOGICAL APPROACH

This section describes the study area and the development of quasi-experiment, which includes the visualization and survey distribution.

SELECTION OF STUDY AREA

The study area was located in Waikiki, a neighborhood in Honolulu, Hawaii. The study focused on Liliuokalani Ave. from Ala Wai Blvd. to Kalakaua Ave with a focus on the intersection at Kuhio Ave. The flooding projections compared current conditions (see Figure 1) with those projected for the year 2100 based on data from NOAA presented by their NOAA Sea Leve Rise Viewer (see Figure 2).

Figure 1: Current Conditions in Waikiki, Honolulu, Hawaii from the NOAA SLR Viewer

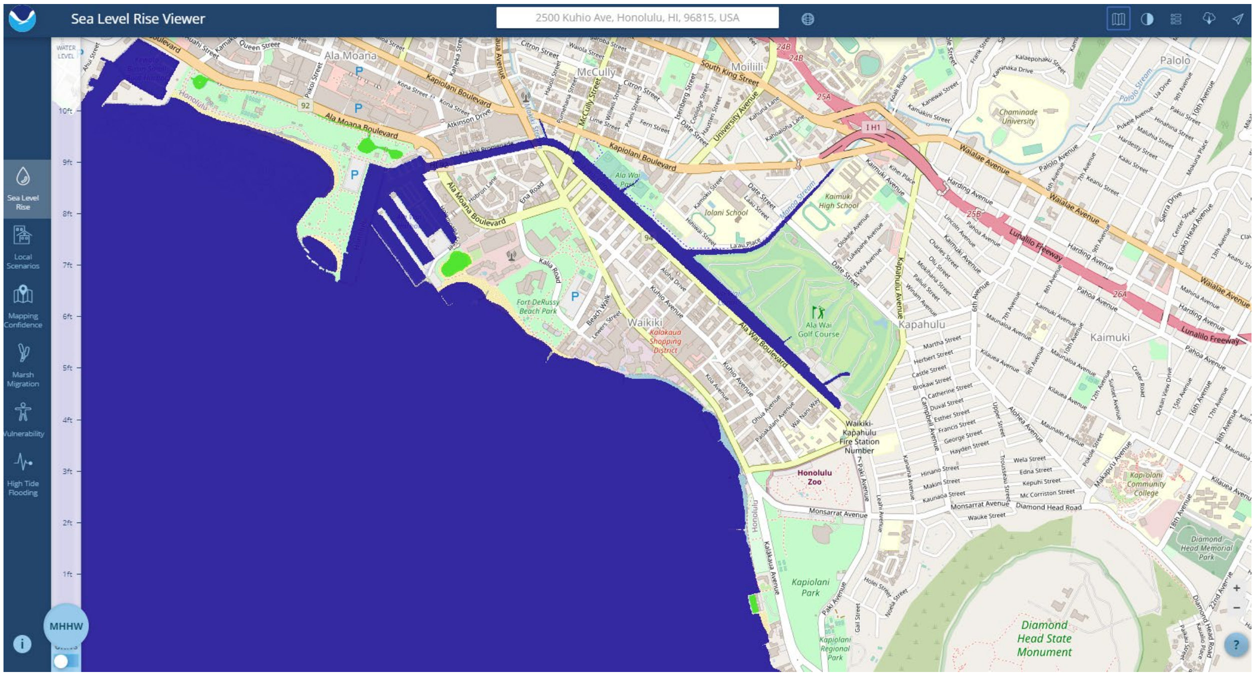


Figure 2: Five Foot SLR based on Worse-Case Scenario for Year 2100

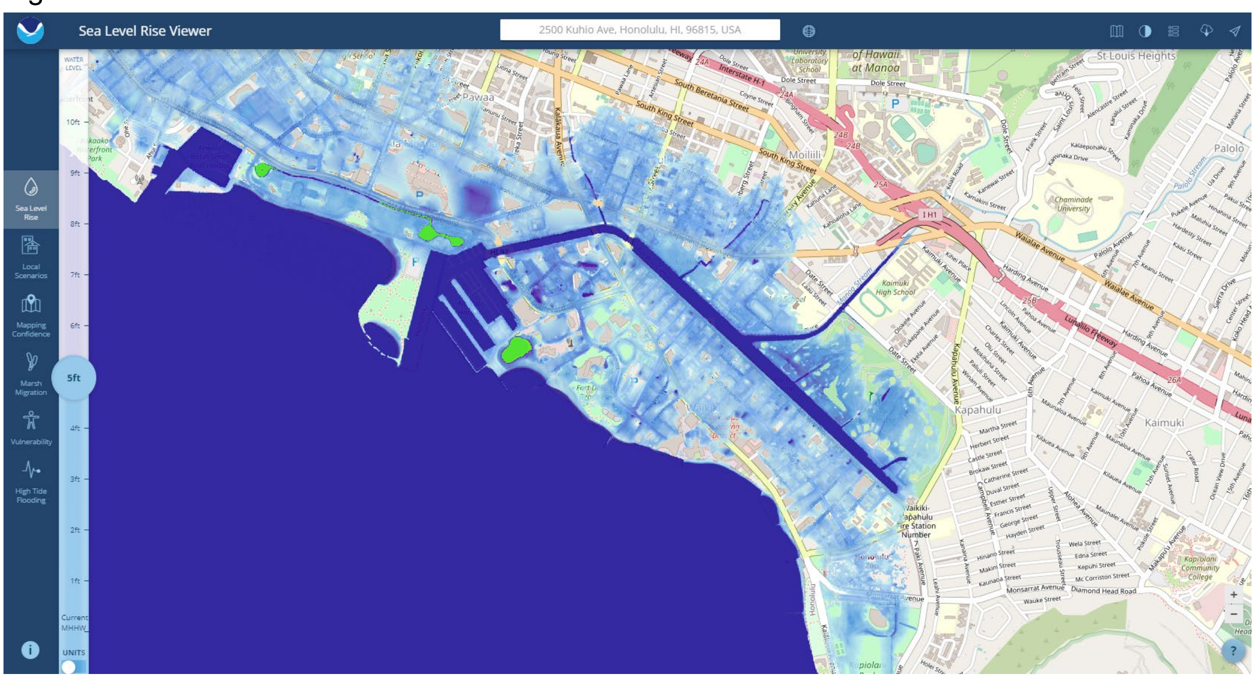


Figure 3: Snapshot from Immersive 3D Model of SLR in Waikiki


MORE VIDEOS
LUMION

VISUALIZATION AND SURVEY DISTRIBUTION

The research team developed two visualizations embedded into a quasi-experimental online survey. After participants consented to participate in the study, they viewed a four-minute, recorded PowerPoint lecture which included the maps shown in Figures 1 and 2, along with supplemental information to describe the timing of the worse case flooding by the year 2100. This video was embedded in a Qualtrics online survey and participants were asked to complete Survey 1 after watching the first video. After they completed Survey 1, they watched a 2 minute 30 second video that provided a narrated, immersive experience with the flood water shown in video 1 depicted in 3D model (see snapshot from video in Figure 3).

The survey was distributed to residents, the business community, civic organizers, coastal planners and managers including the following: the Waikiki Business Improvement District Association network of businesses, to neighborhood groups such as the Waikiki Neighborhood Board to distribute in their sub-districts, Waikiki Community Center and local interest groups such as After Oceanic and Protect Our Ala Wai Watersheds organization, coastal management professionals at the Department of Land and Natural Resources, University of Hawaii Sea Grant network, and the Office of Coastal and Conservation Lands (OCCL), who coordinate the state climate commission activities and manage much of the coastal planning work in Waikiki, and to the Hawaii Shore and Beach Preservation Association (HSBPA), consisting of many of the coastal management professionals in the state (including Sea Grant and OCCL representatives).

RESULTS

This section summarizes the results of the study, including an overview of the study participants, opinions about the immersive visualization quasi-experiment, and findings about opinions based on political views.

OVERVIEW OF STUDY PARTICIPANTS

The quasi-experiment conducted using the online survey format yielded 82 completed responses. Table 1 reports that the males accounted for two-thirds of the sample and females accounted for nearly 30% while 5% responded as other or did not respond. Table 2 shows the age distribution of the participants. The largest segment (37%) was in the 56-70 cohort followed by 22% in the 41-55 cohort and 20% in the 26-40 cohort. Ages 18-25 constituted 11% of participants followed by 8.5% 71 or older. Table 3 reports the race and ethnic profile of participants. The largest group (41%) identified as Asians followed by Whites (40%). Indigenous Hawaiian/Native American/American Indian constituted 11% followed by Hispanic/Latino at 4.4%. Collectively, Caribbean/Islander and Other were approximately 3% of participants.

As shown in Table 4, the vast majority of participants were highly educated, with 38% having bachelor's degrees and 49% having graduate degrees or higher. Table 5 shows the self-reported pollical profile of participants with 55% of the respondents identifying on the left, 23% as independent and 18% on the right. Approximately 4% did not respond to this question. Finally, Table 6 shows that the majority of participants are comfortable with technology. Only 9.7% indicated that they were not comfortable with technology.

Table 1: Sex of Participant

	Frequency	Percent
Male	54	65.8
Female	24	29.3
Other/prefer not to respond	3	3.7
Missing	1	1.2
Total	82	100

Table 2: Age Distribution of Participants

	Frequency	Percent
18-25	9	11.0
26-40	16	19.5
41-55	18	22.0
56-70	30	36.6
71+	7	8.5
Missing	2	2.4
Total	82	100

Table 3: Race and Ethnicity of Participants

	Frequency	Percent
Asian	37	41.2
Caribbean/Islander	1	1.1
Hispanic/Latino	4	4.4
Indigenous Hawaiian Islander/Native American/American Indian	10	11.1
White	36	40.0
Other	2	2.2
Total[1]	90	100

Note: Respondents were allowed to check more than one primary race/ethnicity.

Table 4: Educational Profile of Participants

	Frequency	Percent
High school graduate	2	2.4
Some college but no degree	5	6.1
Associate/Junior College Degree	4	4.9
Bachelor’s Degree	31	37.8
Graduate Degree or Higher	40	48.8
Total	82	100

Table 5: Self-Identified Political Profile of Participants (Question: Where do you consider yourself of the political spectrum?)

	Frequency	Percent
Very liberal	16	19.5
Somewhat liberal	29	35.4
Independent	19	23.2
Somewhat conservative	13	15.9
Very conservative	2	2.4
Missing	3	3.7
Total	82	100

Table 6: Self-Reported Comfort with Technology (Statement: I am comfortable with technology.)

	Frequency	Percent
Strongly Disagree	1	1.2
Disagree	7	8.5
Somewhat Agree	35	42.7
Strongly Agree	39	47.6
Total	82	100

OPINIONS ON EFFECTIVENESS OF IMMERSIVE VISUALIZATION

Participants answered a number of questions regarding the effectiveness of the immersive visualization. Tables 7 and 8 and Figures 4 and 5 report the findings on understandability. As shown in Table 7 and Figure 4, 87% of participants agreed with the statement that after visualizing the street in the video simulation, the respondent was better able to understand the data depicted in the charts/graphs, which was shown earlier in the study. Table 8 and Figure 5 found that 88% reported better understanding the data depicted presentation. In the first part of the survey, data were shown using 2D maps, therefore for the vast majority of respondents, the immersive visualization provided strong benefits for improving understandability.

Table 7: Understandability (Statement: After visualizing the street in the video simulation, I am better able to understand the data depicted in the charts/graphs.)

	Frequency	Percent
Strongly Disagree	1	1.2
Disagree	10	12.2
Somewhat Agree	32	39.0
Strongly Agree	39	47.6
Total	82	100

Figure 4: Understandability

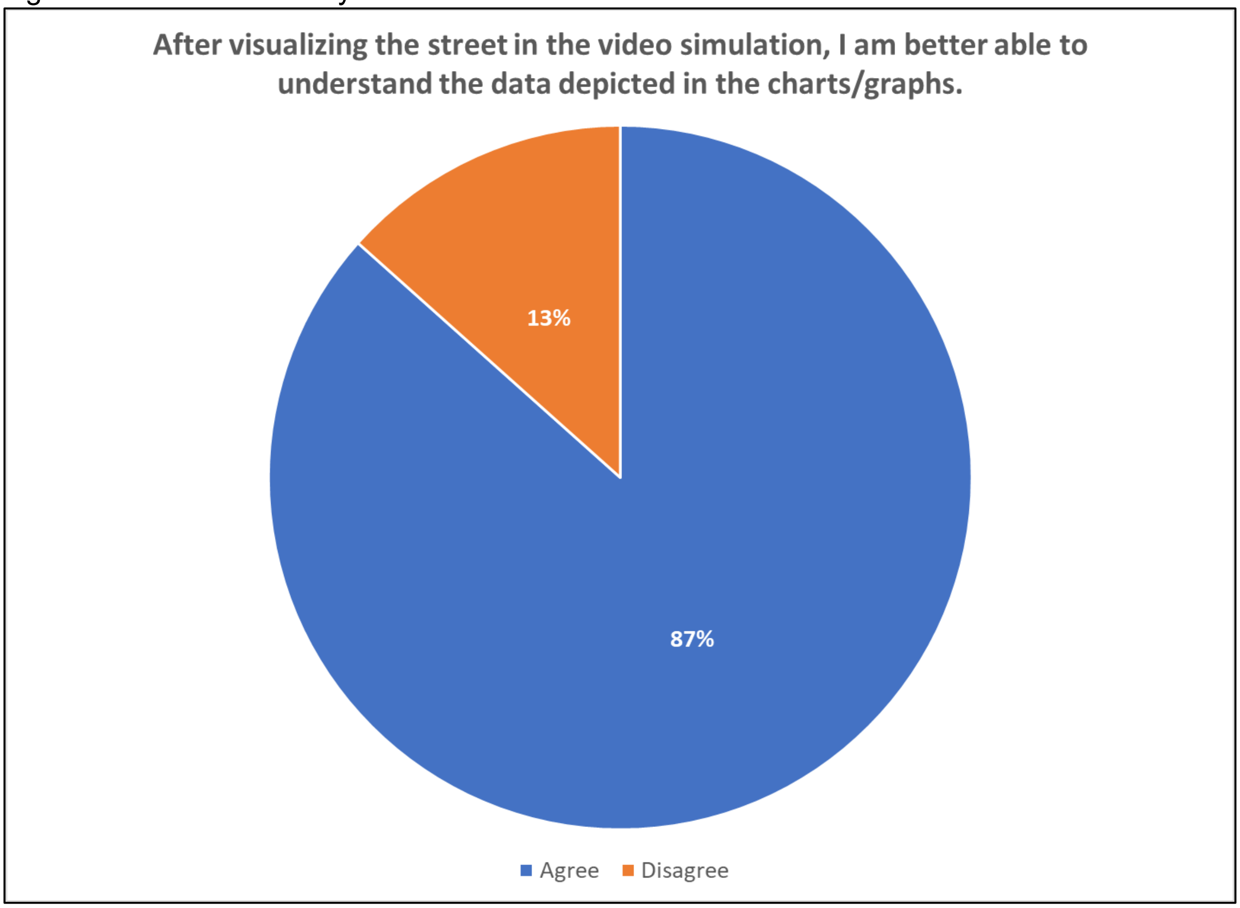
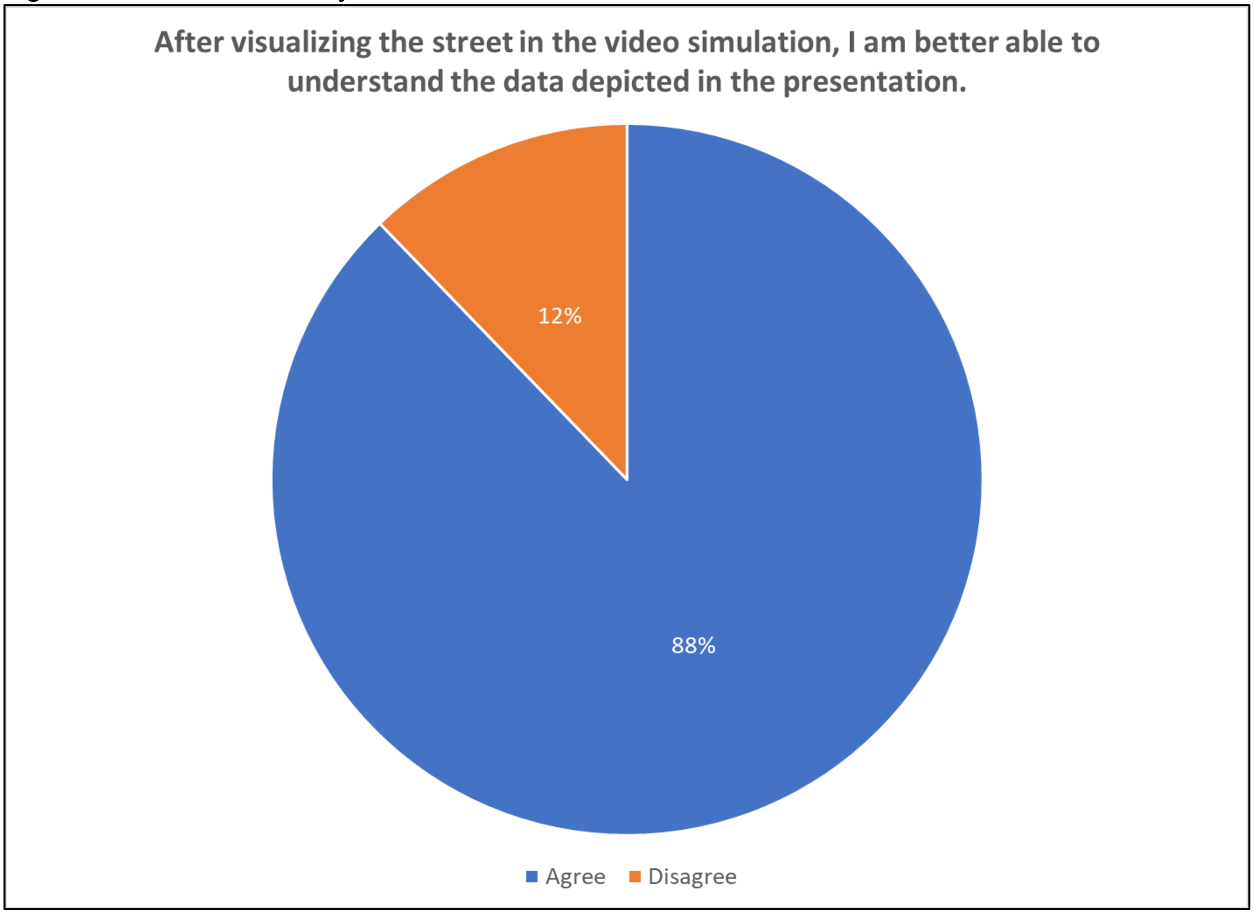


Table 8: Understandability (Statement: After visualizing the street in the video simulation, I am better able to understand the data depicted in the presentation.)

	Frequency	Percent
Strongly Disagree	1	1.2
Disagree	9	11.0
Somewhat Agree	33	40.2
Strongly Agree	39	47.6
Total	82	100

Figure 5: Understandability



The quasi-experiment showed participants a video at the beginning with a narration showing NOAA SLR maps (shown in Figure 1 and 2) that indicated flooding in the Waikiki study area. Afterward, participants viewed a second video showing the same Waikiki data modelling in a video with a 3D life-like model of the intersection at Liliuokalani Ave. and Kuhio Ave. (shown in Figure 3). Even though new data were not presented to the participants, 75% agreed that the video simulation provided them with new information on the topic (see Table 9 and Figure 6). This powerful finding speaks to the impact of the immersive 3D visualization.

Table 9: Visualizing “New” Data (Statement: The video simulation provided me with new information on the topic of sea-level rise.)

	Frequency	Percent
Strongly Disagree	1	1.2
Disagree	19	23.2
Somewhat Agree	39	47.6
Strongly Agree	22	26.8
Missing	1	1.2
Total	82	100

Figure 6: Visualizing “New” Data

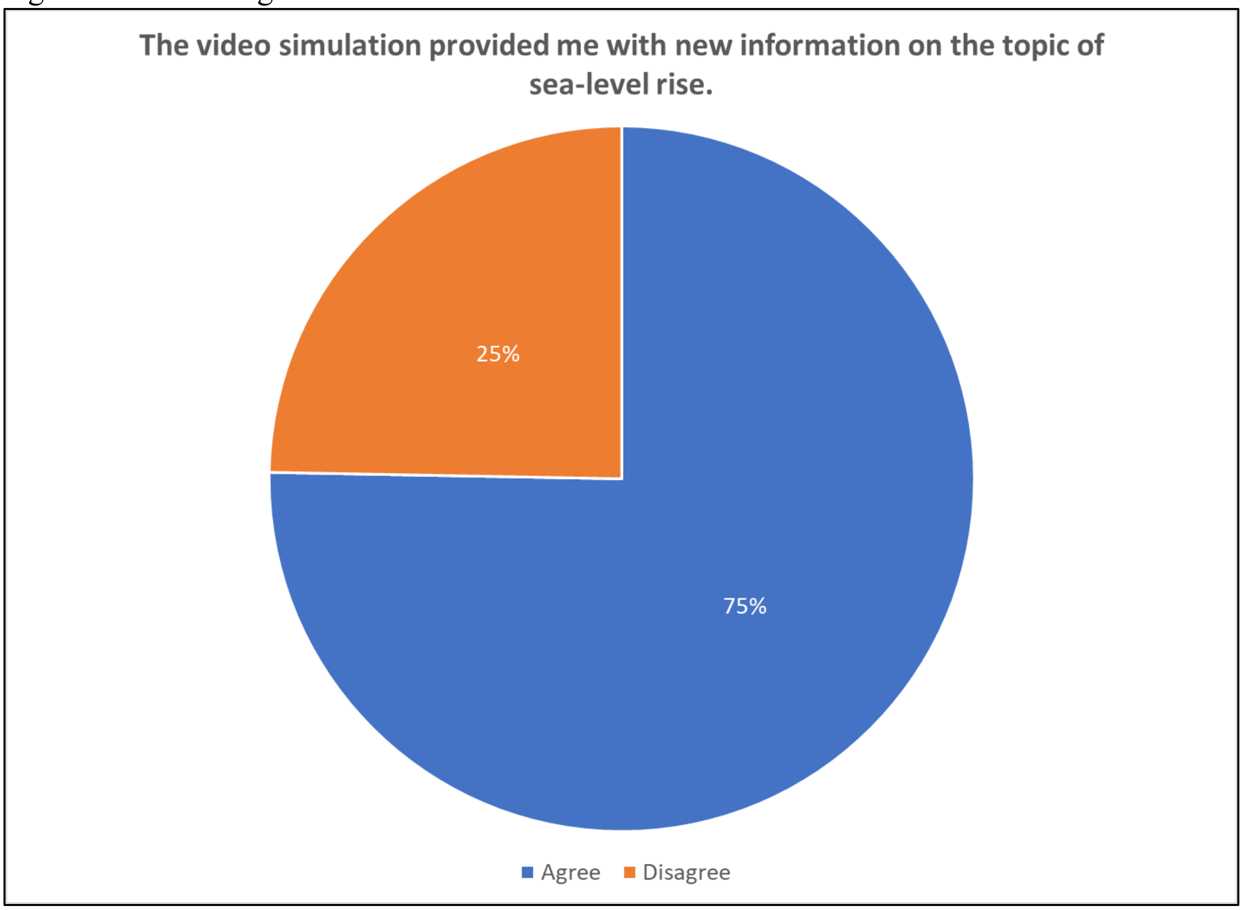


Table 10 and Figure 7 report that 95% of the participants agreed with the statement that people in their community would benefit from the video simulation. Table 11 and Figure 8 show that 76% of the participants did not agree that the experience was uncomfortable, and Table 12 and Figure 9 show that 93% of participants would participate in a video simulation experience again.

Table 10: Community Benefits (Statement: People in my community would benefit from the video simulation.)

	Frequency	Percent
Strongly Disagree	1	1.2
Disagree	3	3.7
Somewhat Agree	37	45.1
Strongly Agree	41	50.0
Total	82	100

Figure 7: Community Benefits

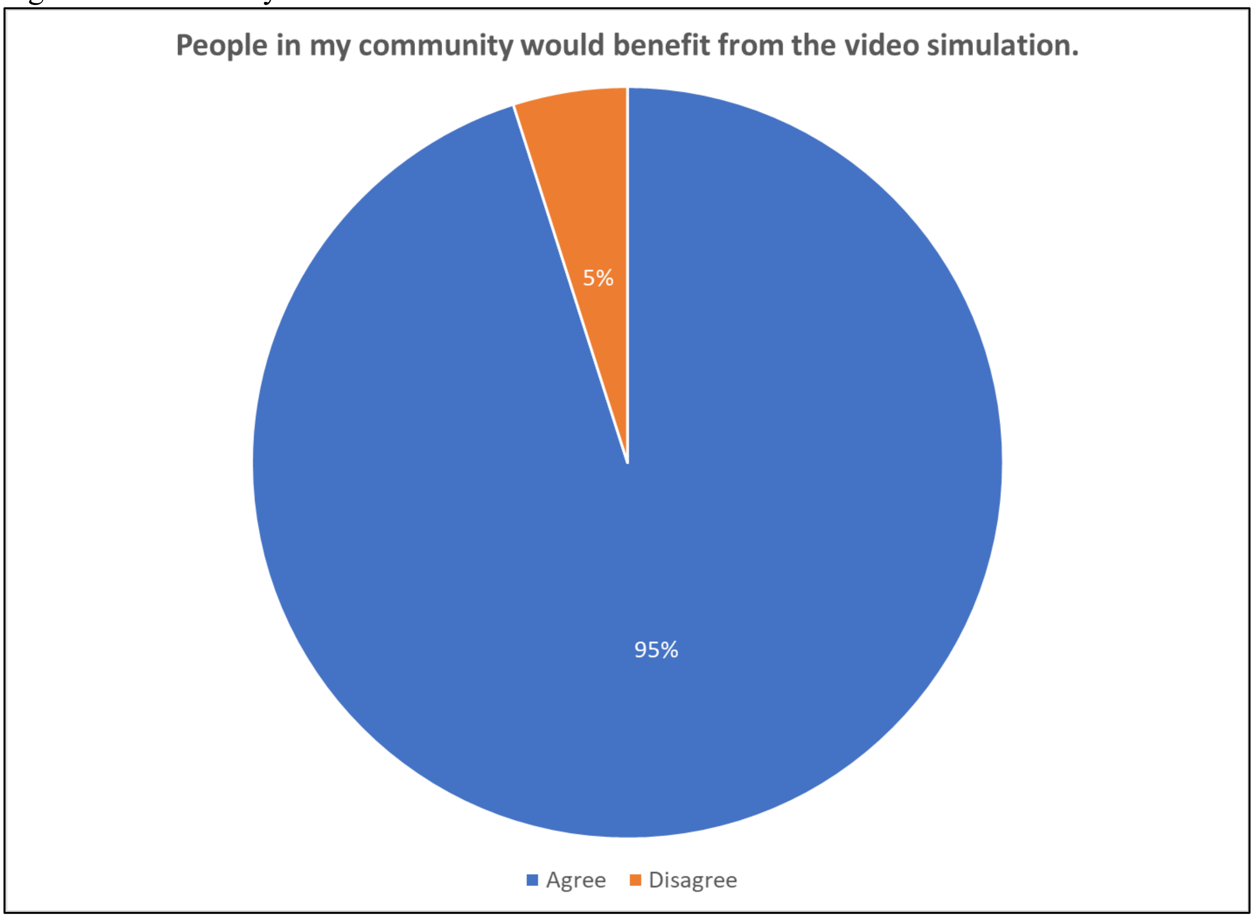


Table 11: Discomfort (Statement: The video simulation experience was uncomfortable for me.)

	Frequency	Percent
Strongly Disagree	20	24.4
Disagree	42	51.2
Somewhat Agree	16	19.5
Strongly Agree	4	4.9
Total	82	100

Figure 8: Discomfort

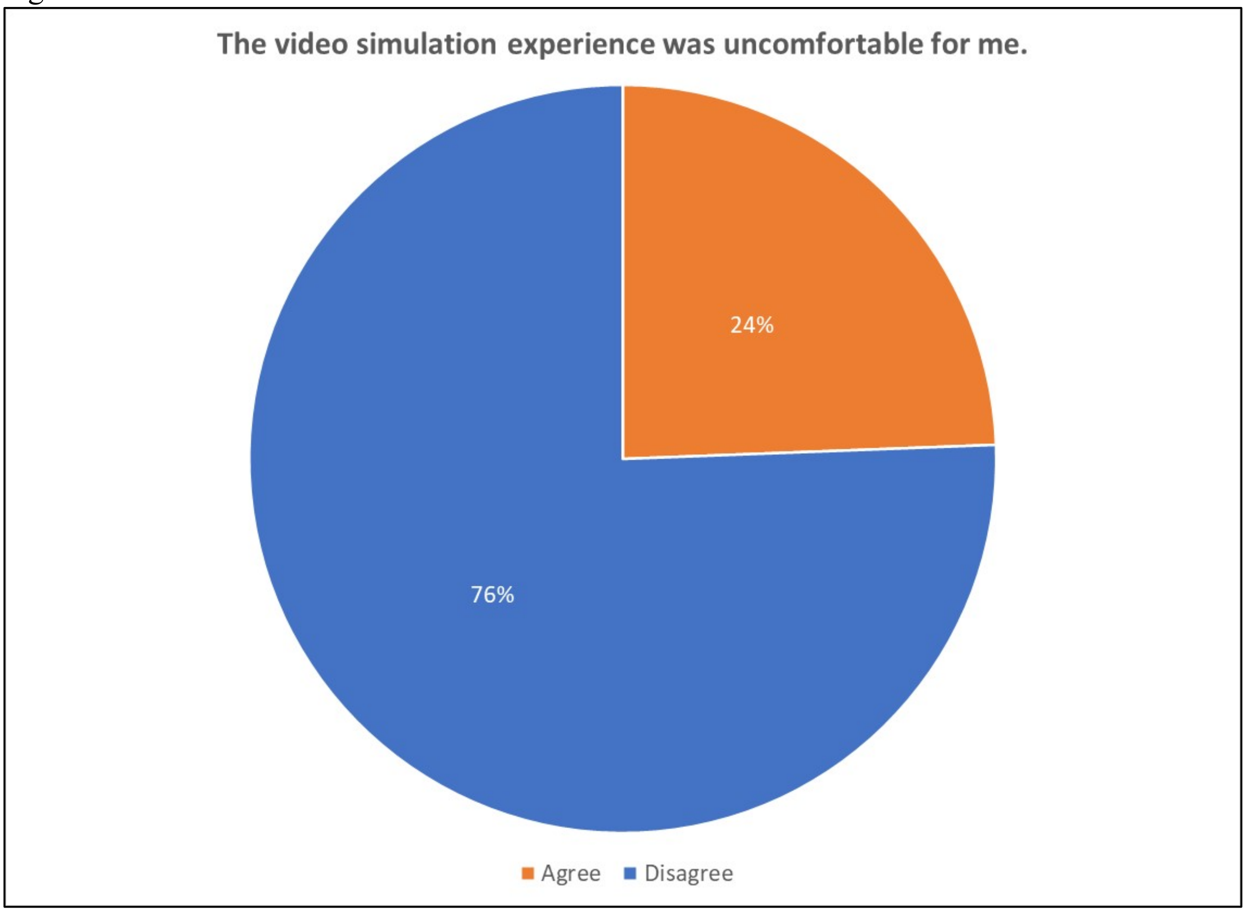
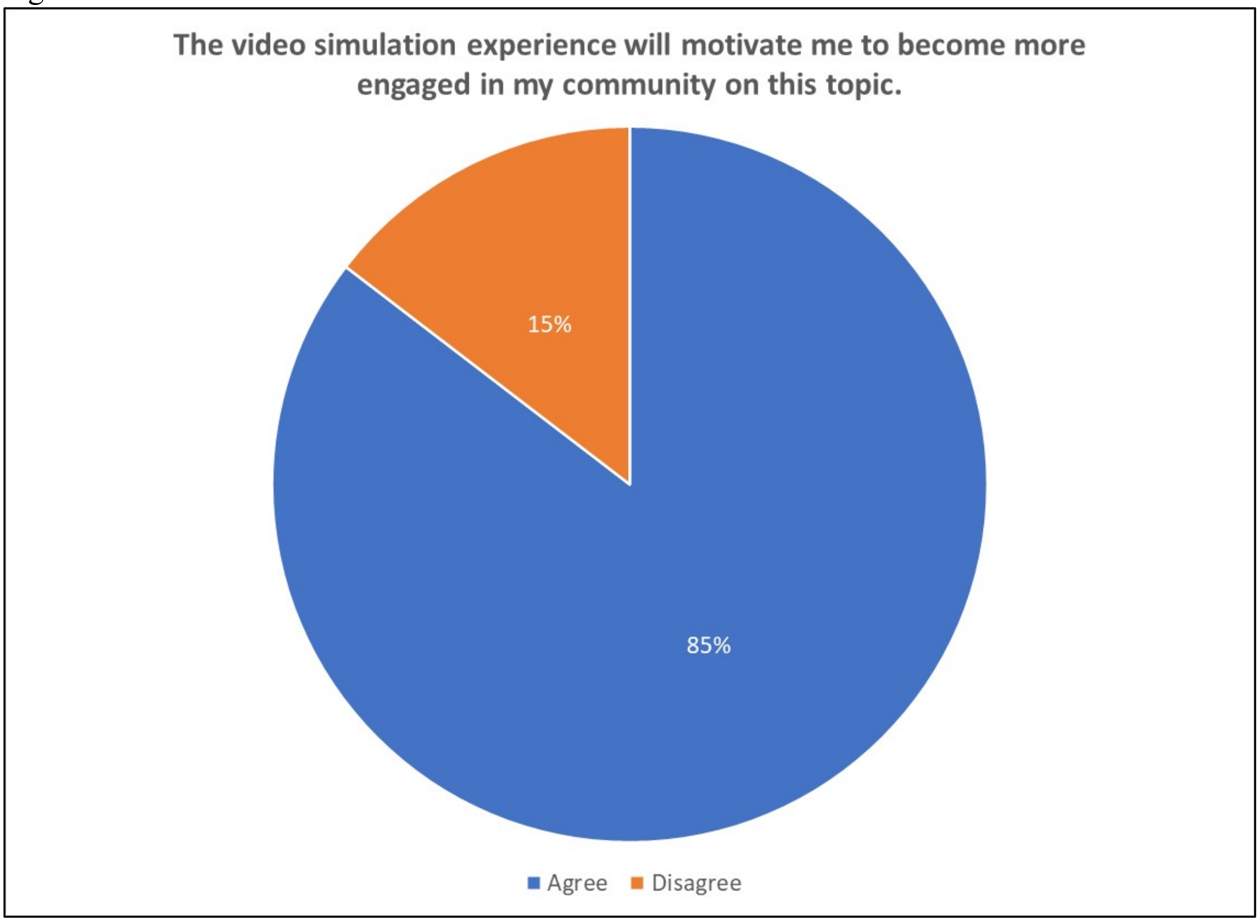


Table 12: Motivation (Statement: The video simulation experience will motivate me to become more engaged in my community on this topic.)

	Frequency	Percent
Strongly Disagree	2	2.4
Disagree	10	12.2
Somewhat Agree	50	61.0
Strongly Agree	20	24.4
Total	82	100

Figure 9: Motivation



OPINIONS BASED ON POLITICAL VIEWS

Table 12 shows the results of opinions in survey 1 (before the immersive video) and in survey 2 (after the immersive video). When looking at all respondents, the percentage who strongly agreed that SLR is a major threat to residents and businesses located in the study area increased from 73.4% to 77.2% (an absolute change of 3 people). When looking at this change based on political category, two on the left and one independent changed their views, and no changes were evident for those on the right side of the political spectrum. Other analyses were conducted which looked at before and after changes in opinions based on age and education level, but no patterns were detected.

Table 12: Before and After Opinions on SLR based on Political Views

Sea-level rise is a major threat to the residents and businesses located in the study area.	Survey 1 (Before Immersive Video)							
	Political Category							
	Left		Independent		Right		All	
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Disagree	0	0%	1	5%	1	6.7%	2	2.6%
Somewhat Agree	10	22.2%	6	31.6%	3	20.0%	19	24.1%
Strongly Agree	35	77.8%	12	63.2%	11	73.3%	58	73.4%
Total	**45**	**100%**	**19**	**100%**	**15**	**100%**	**79**	**100%**
	Survey 2 (After Immersive Video)							
	Number	Percent	Number	Percent	Number	Percent	Number	Percent
Disagree	0	0%	2	10.5%	1	6.7%	3	3.8%
Somewhat Agree	8	17.8%	4	21.1%	3	20.0%	15	19.0%
Strongly Agree	37	82.2%	13	68.4%	11	73.3%	61	77.2%
Total	**45**	**100%**	**19**	**100%**	**15**	**100%**	**79**	**100%**

CONCLUSIONS

This conclusion will revisit the research questions of this study, which include: A. To test if immersive visualizations of sea-level rise (SLR) results in a deeper understanding of impacts to streets in the Waikiki section of Honolulu, Hawaii and B. To test if immersive visualizations can be conducted and effective using a video-embedded survey, as a result of the COVID-19 pandemic, that prevented in-person meetings and workshops. This section will also discuss some of the limitations of this study.

This study found that participants were better able to understand the data about flood impacts in the future due to SLR after watching a 3D video depicting the extent of the flooding at an intersection within the study area. Seventy-five percent (75%) of participants reported that the video simulation provided them with “new” data on the topic, when in fact the visualization provided the same data shown earlier in 2D maps. The visualization was so impactful that 95% reported that other people in their community would benefit from watching the video and 85% reported that they would become more engaged on the topic of SLR as a result of watching the video. The study also found that those on the left and center of the political spectrum were more likely to change their opinions compared to respondents on the right side of the spectrum, but the sample size only included 15 participants that identified as conservative, so more research is needed before any conclusions can be drawn about political identity and how fixed opinions are on this topic. The other study in Fort Lauderdale found some shifting of opinions for those on the right.

In conclusion, this study provides evidence for the use of immersive video visualizations for improving the comprehensive of the impacts of SLR on communities. This quasi-experiment was initially supposed to be conducted at in-person workshops in the study area, but due to COVID-19 restrictions, the methodology was changed to include online immersive videos. In comparison to a recent study led by the same team in Fort Lauderdale that used in-person virtual reality (VR) googles, the online video format seemed to work well, and results were comparable to the VR model. This does not mean that VR is not an effective tool for planners to use in educating communities about SLR, but findings from this study indicate the immersive videos can also work well.

Limitations of this study included the need to change the study from an in-person VR experience to an online, video driven experience due to COVID-19. The participants who responded over-represented males, highly educated members of the community and individuals on the left side of the political spectrum. Furthermore, the survey captures self-reported, subjective increases in understanding. That is, the methodology did not include an objective measure (such as a quiz) of what participants had learned.

However, the self-reporting format captured the perception that the immersive model presented "new" data, whereas the data had been previously presented in two-dimensional form, a potential subject for further research.

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