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The two-dimensional and three-dimensional sounds visualization ideation in understanding the feasibilities of urban skyway system and architectural designs

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Abstract: This research paper focuses on the two-dimensional and three-dimensional sound-visualization ideations that can be implemented in digital models and assists architects to understand the feasibility of the skyway system. This idea is derived from Christenson's "The skyway as an inhabitable mode of urban representation", suggesting a perspective lens to see the skyway as an architectural interface, considers it as an analogous city to examine local particularities framing the existing question of the society with a historicist critique. The sound visualization tools can be used to explore skyway construction as an architecture interface to frame some questions in the existing society and consider the possibility of skyway as a sustainable inhabitable model of living. In this research, the Great Northern Hall in Lowertown, St Paul, was closely analyzed to understand part of the St. Paul Skyway. The building's second floor level has incorporated the Skyway system in its mezzanine structures. This floor plan structure was used in our research to analyze the spatial relationship distributed in the system and how sounds distribute through spaces. The benefit of incorporating two-dimensional and three-dimensional sound visualizations allows architects to consider sound distribution through space in various building structures visually and redefine space function within the skyway to improve user experiences for all.

1. 0 Introduction

In this paper, the Great Northern Hall in the St. Paul Skyway system was closely studied on its space distributions and probable sound distributions from points. This identified study area of the skyway system was examined using the Rhino Grasshopper composed definitions generated through Isolvist views. An Isolvist view represents a defined, realistic surface in space that allows a person to see a set of points in space. The Isolvist view allows us to read the two-dimensional visible plan or three-dimensional pre-set vantage point and interpret the vision span at a specific point referring to the size of the space (Christenson & Foobalan, 2012). This view serves as a model for our sound visualization development template. The view guides us in exploring the potential of adding audio and texture elements to perspectives of construction within the skyway system. The sound visualizations have potential for development of two-dimensional visible sound wave spans (Figure 1.1) and three-dimensional volume pre-set audio spans from a preferred user vantage point (Figure 1.2), demonstrating the relationships between hearing perception

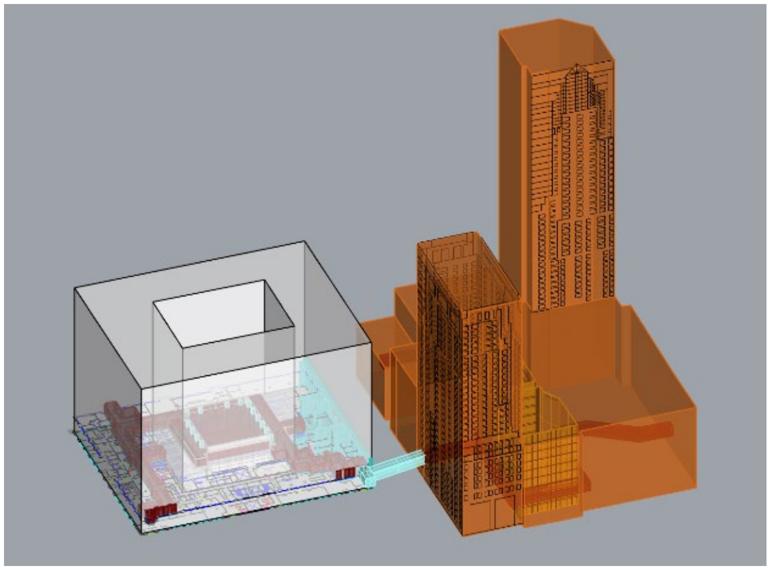

FIGURE 1.0
Digital model of Great Northern Building and Galtier Plaza / Cray Tower by Erin Kindell and detail polished by Mike Christenson

FIGURE 1.1
Digital model of two-dimensional sound representation in two-dimensional floor plan are randomly distributed in the air. The dots represent the air particles that are randomly distributed in the air. The model on the left represents no sound source. With the input sound's source on the left upper corner in the skyway space of the floor plan, the sound waves then vibrate and travel through these air particles as radial waves (pink dots) or longitudinal waves (black dots) for 2D visual representations. FIGURE 1.1 a. on the upper right represents longitudinal waves in black dots. FIGURE 1.1 b. on the lower right represents radial waves in pink dots.

and sociology problems within the urban environments or spatial bounded landscapes. In order to propose an urban skyway system application in more places, it is essential to consider the user experiences and the social structure changes in terms of accessibility and equity. The questions on feasibility of the skyway system proposed another way of living in the future, where people re-define their way of travel on foot indoors and spatial definitions to boost efficiency and health outcomes.

To answer the feasibility question of the urban skyway system, the user feedback on the St. Paul Skyway was collected to analyze the existing problem of the skyway for better user experience consideration in the future. This feedback was then integrated into the developmental function of visual sound representations in providing a deeper understanding of the skyway system. This idea stems from a sociological approach on the concept of understanding the underlying social structure behind human behaviors and interactions. The scientific and humanistic perspective of sound influences are considered within these studies. External and internal sound sources are essential to analysis on building sustainable structures of skyways. In addition to scientific sustainability, the user experiences of the skyway should be considered. Hearing is closely related to our perceptions of experiences, and pleasant experiences prompt sustainability and stem further utilizations. For the skyway system to be more sustainable and feasible to implement, representing and analyzing sound visually is vital. The ideas generated from this research will provide a gateway for the public to understand the importance of sound representation in digital models and construct a plan on sound representation development to understand the feasibility of a skyway. The feasibility of the skyway is an important question

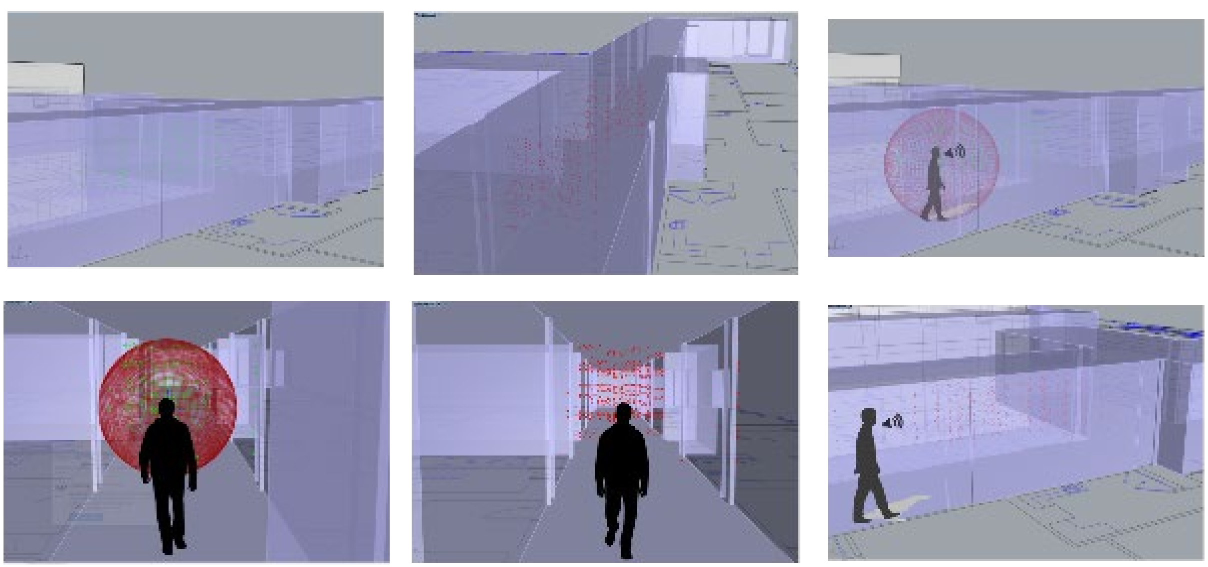

FIGURE 1.2
Digital model of three-dimensional sound representation in three-dimensional digital model. The green dots and red dots represent the random distribution of sound particles in the air. The red circle net is representing where there is an active sound source. In this graphic, the black silhouette person is talking and transmitting sound waves.

to examine. The skyway system changes our traditional definition of space. Before the skyway system was incorporated in our society, people traveled on foot or vehicles outdoors to get to other buildings. The elevated pedway system eliminates the problem of traveling outdoors and emerged as a replacement for street passage. Users can access the skyway from the street level of a building to travel in the elevated pedway to another building for convenience. Skyway user feedback was evaluated to consider the user comfort and feasibility of the skyway system. Christenson's "The Skyway as an inhabitable mode of urban representation" inspired the development of this research, considering the humanistic perspective on alternative ways of street passing to destinations and separation of passenger transit. These questions are integrated into the ideation model of sound representation to allow architects to understand the humanistic and scientific perspective of their building models, knowing that hearing cues aid in designing and building more sustainable, user-friendly structures. This sound representation model allows us to have a more comprehensive understanding of the skyway system and any applicable digital models for better feasibility design and user experiences.

2.0 Materials and Methods

The general research plan comprises five parts. First, we identify the geographic area within the Saint Paul Skyway system for detailed study. Second, we utilize and modify tools (ex. Rhino's Grasshopper plug-in) for a graphic analysis of feasibility questions. Third, we test on these tools within the identified study area and within other segments of the skyway system. Fourth, we create two-dimensional and three-dimensional digital ideation on a sound representation that can be developed and implemented in future architectural models. Fifth, we look into the existing user feedback to analyze the feasibility and problems of our existing skyway. Finally, we decide on features in the sounds visualization ideation that can boost architects designers' understanding of user experiences of sounds and feasibility, making sure the skyway is sustainable.

2.1 Identify the geographic area

We first looked at the location of the pedestrian passage and the surrounding floors. We mainly analyzed the Great Northern Buildings in the center of St. Paul, a densely populated area. We used three maps and one floor plan to observe the building and surrounding context. The Great Northern building floor plan lays out the spatial distribution and floor structure inside, which assists us to see how this skyway fits into this building and its purpose. Subsequently, we looked at the skyway map provided by the St. Paul City Council to examine the elevated pedway connecting buildings (City Council Of Saint Paul, 2020). After identifying its spatial distribution, we then used the three-dimensional model of the building to observe the architecture. We analyzed the volunteer commentary on the St. Paul Lowertown skyway website, and the pros and cons that people encountered when accessing the building are listed in the discussion section. The metric is if the descriptions fall into one category of our pros and cons, then we mark one on it. The Google street view (Figure 1.3) allows us to see how pedestrians enter the building from the outside (Google, 2020).

2. 2 Development of tools

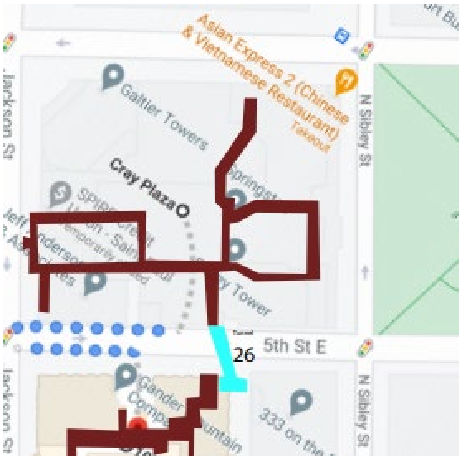

FIGURE 1.3
The Great Hall Google Map with embedded ortho view of Digital model of Great Northern Building and Galtier Plaza / Cray Tower by Erin Kindell (Google, 2020)

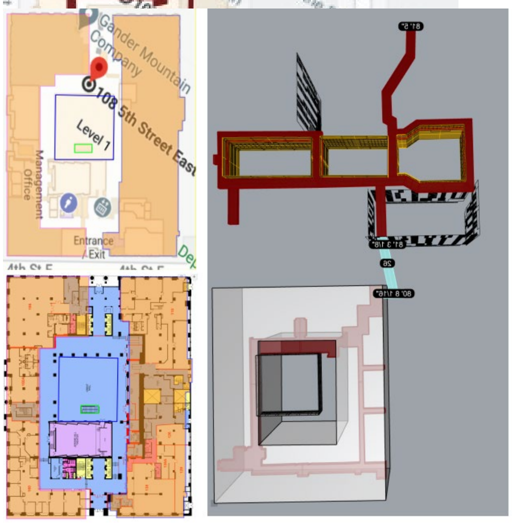

FIGURE 1.4
Comparison of The Great Hall Floor Plan and ortho view of Digital model of Great Northern Building and Galtier Plaza / Cray Tower by Erin Kindell and detail polished by Mike Christenson

Meanwhile, we looked at online components on three-dimensional Isovist Grasshopper definitions in Figure 1.5. We borrowed three-dimensional Isovist Grasshopper definitions from different worksites and assembled a functional three-dimensional Isovist Grasshopper. Each Grasshopper definition is composed of previously built python programs, so it is easy to integrate in Rhino without additional coding. This gives us insights on future development of sounds visualization Grasshopper definitions where users can listen and hear the surrounding sounds from the predefined perceptible range and visualize sounds as waves of dot representing air particles in motions. The 2D and 3D sounds representation in Isolvist can be 2D graphic area and 3D area of sounds. However, a constraint is that there is trouble accessing the three-dimensional Isovist Grasshopper online with its limited publication on its materials. We assembled an isovist Grasshopper definition from downloaded Grasshopper components online and modified it based on a screenshot of Andrew Heumann's Isolvist definition (Heumann, 2011) . These Grasshopper components allow us to generate a mesh sphere that simulates the viewer's perceptive vision wherever we set the points at.

2. 3 Testing of tools on identified area

Then, we tested the functional isolivst view on the skyway model to understand the spatial relationship between the skyway system and entrances.

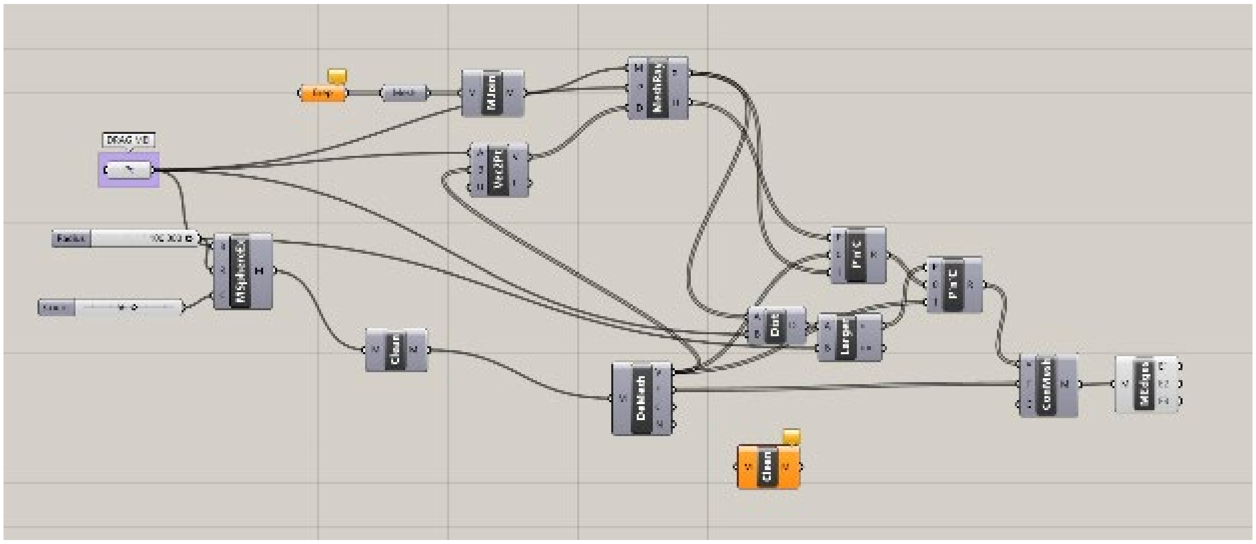

FIGURE 1.5

Andrew Heumann's Isolvist definition script modified and simplified version (Heumann, 2011)

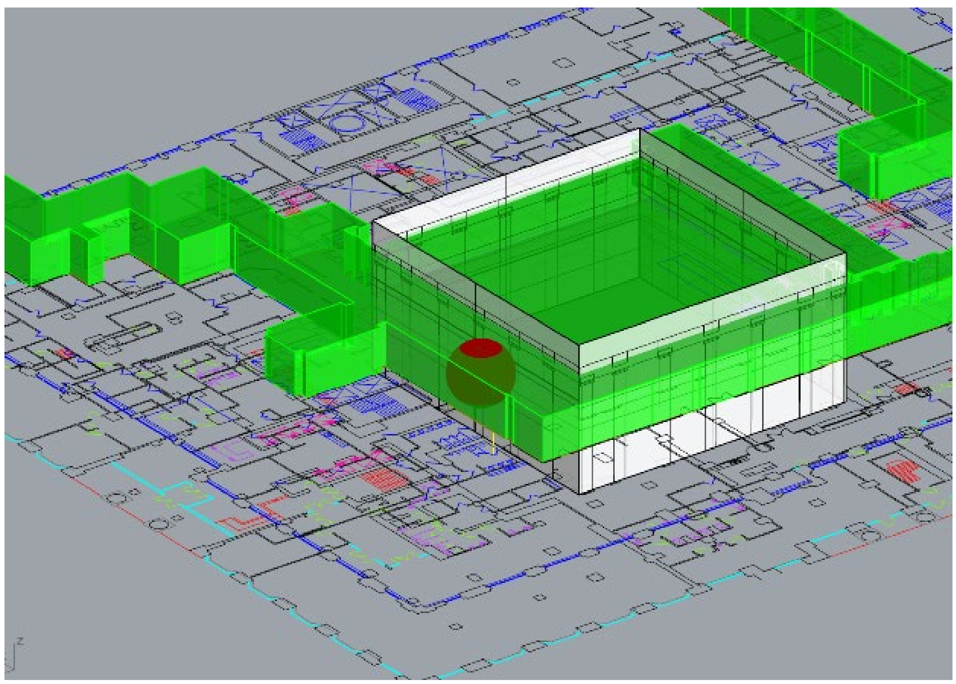

FIGURE 1.6

Digital model of Great Northern Building and Galtier Plaza / Cray Tower by Erin Kindell and detail polished by Mike Christenson with the Isolvist function displayed.

2. 4 Generate ideation of two-dimensional and three-dimensional sounds visualization digital ideation

Figure 1.1 represents the randomly distributed air particles in the air that create sequential vibrations in a linear and radial representation. The black dot represents the air particle in the air, and it transmits the sound from the left corner of the black dotted area. Figure 1.1 a. shows the black dots suspending forwards and backwards, representing the vibration of sounds reflected on the movement of the air particles. In Figure 1.1 b. represents the movement of the pink dots in a radial form instead of a linear form, similarly. Then, we converted the same idea into the three-dimensional Rhino model, making a prototype image of the model's capabilities. In Figure 1.7, the green dots within the transparent blue skyway represent air particles. In Figure 1.2, the person shaded with black with the volume icon in the image on Figure 1.2 represents the sound sources transmitting to the air and pushing the air particles away.

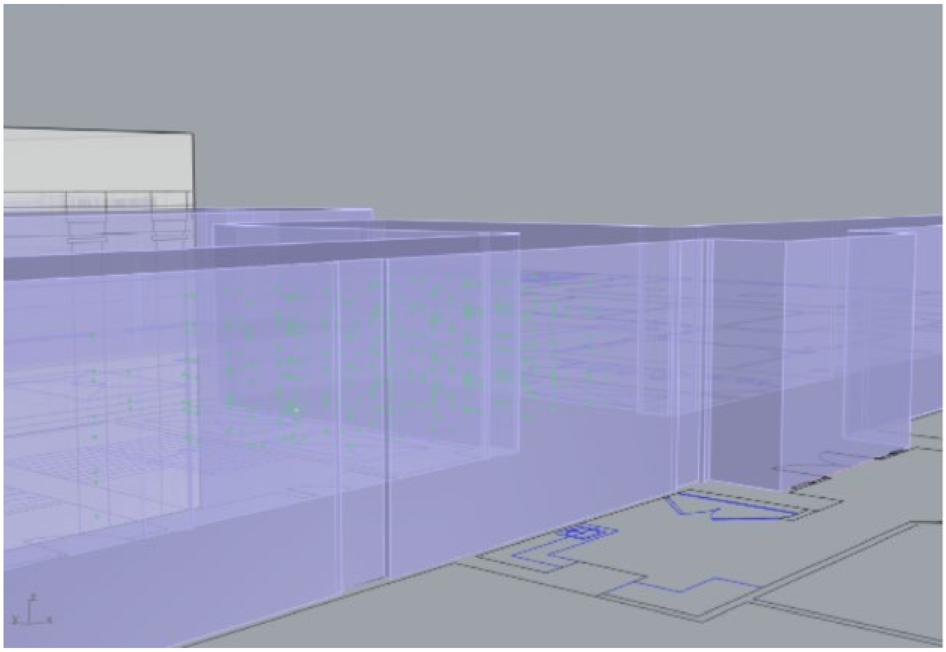

FIGURE 1.7

Digital model of Great Northern Building and Galtier Plaza / Cray Tower with illustration sound particles within the building

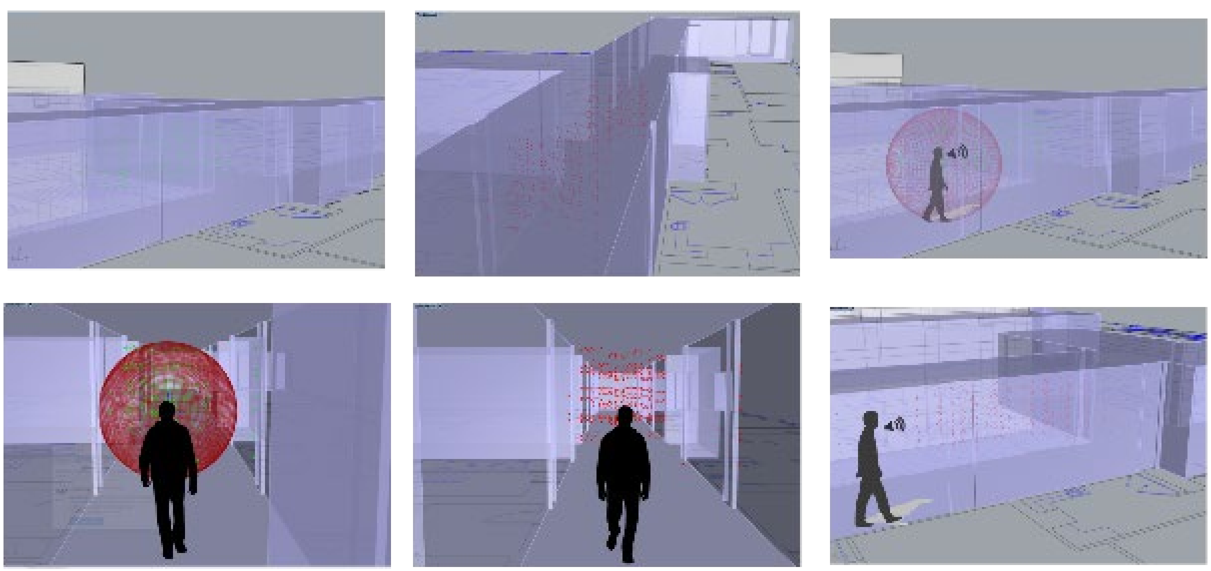

FIGURE 1.2

Digital model of three-dimensional sound representation in three-dimensional digital model. The green dots and red dots represent the random distribution of sound particles in the air. The red circle net is representing where there is an active sound source. In this graphic, the black silhouette person is talking and transmitting sound waves.

2. 5 Analysis of skyway user feedback

There are several things that have changed after the skyway system was implemented in St. Paul. Many small businesses that cater to downtown workers (coffee shops, lunch restaurants, convenience stores, dry cleaners, etc.) have migrated into the skyway, leaving the streets and sidewalks sparsely populated.

The skyway caters more to the needs of residents and locals than visitors. Different external factors have to be considered in the feasibility of a skyway. People can wander in the skyway to different historical buildings and explore places they might not have explored before. During the pandemic, more changes occur. There is heavy traffic during business hours; circular ventilation circulates air breath out by pedestrians to all skyway users. If all retail stores and resources move to the upper level in the buildings, the skyway space will become constrained because of the increased target user. This will be difficult for users to maintain a six foot distance and viruses will spread easily. Below we look into the comments from 2011 to 2020 about the Lowertown St. Paul Skyway system on TripAdvisor and categorize it to create a pie chart from 52 user's comments from this website. ("St. Paul Skyway," 2007)

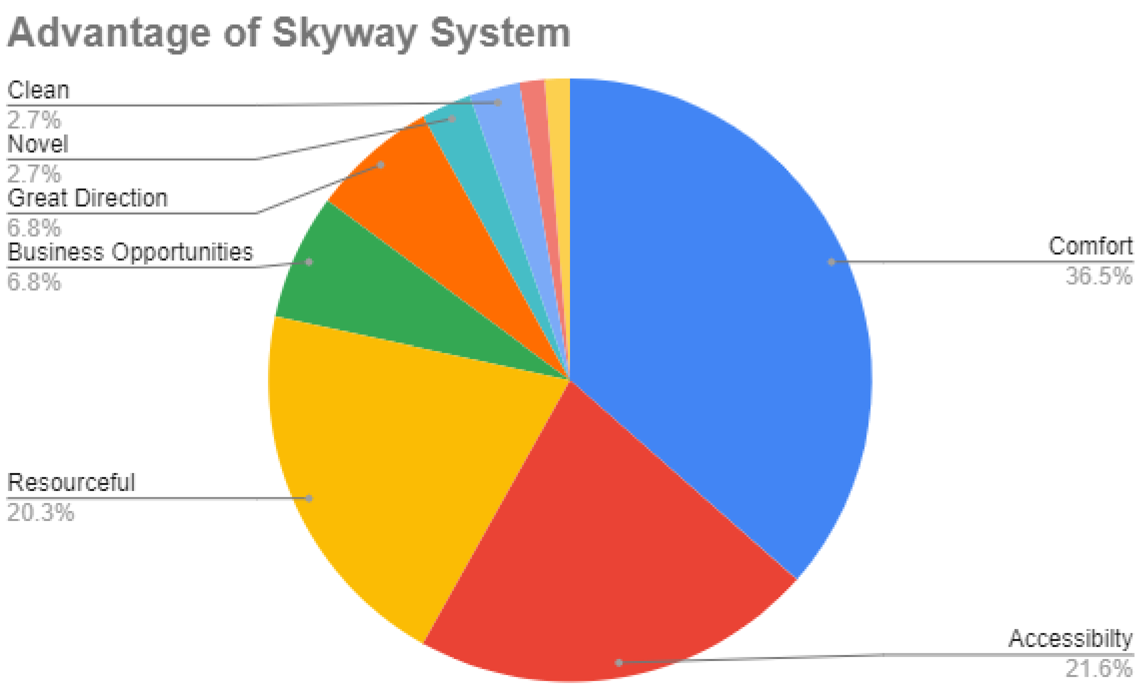

Figure 1.8 The advantage of skyway system pie chart Advantages of Skyway System:

I. Clean: Sanitary issues

II. Novel: Novity of the space

III. Great Direction: Good directions sign and navigation to spaces

IV. Business Opportunities: Great opportunity and customer flow

V. Resourceful: Many utilities in the skyway

VI. Comfort: The design within the skyway is comfortable

VII. Accessibility: The entrances and exits are easy to access in different time frames

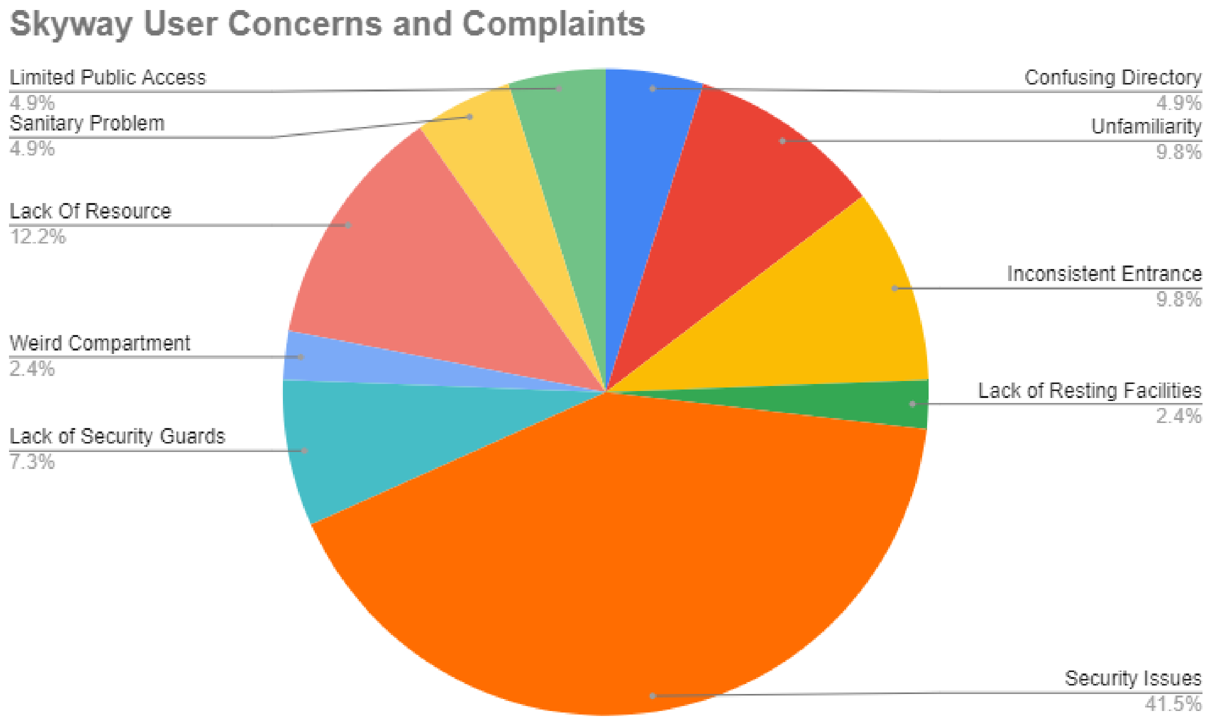

Figure 1.9 The disadvantage of skyway system pie chart Disadvantages of Skyway System:

I. Limited Public Access: The skyway only operates in business hours

II. Sanitary Problem: Not clean and bad sanitary conditions

III. Lack of Resources: Not enough resources and shop to satisfies customer needs

IV. Weird Compartment: The business and entertainment shops does not have a distinguish separations

V. Confusing Directory: The signs and navigation systems are not sufficient to assist users in navigating.

VI. Unfamiliarity: People are not familiar with the system

VII. Inconsistent Entrance: Frequent changes of accessibilities hour in entrances

VIII. Lack of Resting Facilities: There is not enough resting facilities for walkers to take break in between travels

IX. Security Issues: there are security concerns from user feedback.

3.0 Discussion on findings and methods of sound representations

The findings of this research will help create a prototype of sound visualization for later development that can be widely applied to many architecture models. We examined the drawing sections and construction of the St. Paul Skyway system including its buildings in closer detail using Rhino software. These analyses will bring us closer to understanding the separation of people and identify strategies for breaking and blurring boundaries within the system. The tools that we develop through the research could be used toward other similar questions in the future, creating more possibilities for further research.

During this research project, we will explore how architecture's sound visualizations, connection to individual and collective possession, usefulness or utility fieldwork, ownership, and accessibility of the transit flows within the skyway affect our perception of the representation of buildings from Christenson's work. Sociology approaches to these questions allow us to explore the underlying causes that change society's value and balance.

As we were examining the skyway within the buildings in Rhino using a three-dimensional Isovist view, we expanded on the possibilities of reproducing sound representations visually outside of the vision area from the viewer and considered how sound penetrates part of the mezzanine. If the perception area is widened, part of the skyway could see into the ground floor from the second floor. The sounds spread from the ground floor from the second floor, and vice versa, affecting the vibrations of the sound. The definition of the skyway is shifting as the sound reverberation and space changes. As the skyway is connected to stores and shops and an open hall mezzanine, sound reverberation is changing. The sound visualization reverberation can then identify a space purpose and re-define the space. We focused on the transmission of sounds and had an idea for a model representing sound transmission. Sounds reflect the remaining vibrations differently depending on the absorption properties of the material. If we want to know how the vibration of the sounds transmit through space, we need a two-dimensional and three-dimensional model of sound representations.

3.1 Exploration of sound visualization previous studies

The prototyping idea on the functionality of the sound representation model is based on the physics of sound production image. We first looked at the Chladni pattern, where two-dimensional standing wave patterns are created by frequency produced as the violin bow drags on the edge of the metal square (UNSW School Of Physics, n.d.). The kernel on the large metal square formed unique patterns from random distressed kernels as the violin bow dragged on the edge of the metal square. The dot (kernel) comes together on a certain part, creating a unique shape, and the pattern the kernel forms helps visualize the visual representation of vibration and frequency. These assist in bridging the connection of physics movement to architectural design use.

FIGURE 1.10
This is an image of a pattern on a Chladni plate created using a violin bow (Whipple Museum of the History of Science, n.d.)

Then, we looked into Rudolph Koenig's work Manometric flame, which shows the changes in sound frequency through flames (Whipple Museum of the History of Science, 2009). First, he uses a tubular collector to collect air to create resonance to the tube. If there is a periodic change in gas, there will be periodic changes in flames as the air particles vibrate around it from the frequency of the sounds. Hence, sounds are visualized as it shows the changes in flames. The changes in these air particles might help people visually understand changes in vibrations. The sounds create different frequencies, forces, and vibrations that could impact the construction of the buildings (University of Southampton, n.d.).

The consideration of feasibility design will change the comfort of the inhabitants in addition to the material construction of the system, focusing on user experiences of the skyway system design and sustainability of the structural design. If we are proposing a skyway as an inhabitable model in urban representation, we have to think about the reverberation and sound frequencies in its nearby location outside and inside. We look into how shock waves are deduced from the distortion of the background pattern resulting from the changes in the refractive index due to density gradients (Merlin, 2015). This led us to consider what the appropriate way is to translate this energy-generated by vibrations of air molecules to visual demonstrations. Two PHD researchers at Department of Architectural Engineering, Hanyang University have conducted a parametric study into the influence of height-to-width ratio on sound fields considered pressure level (SPL), reverberation time (T30), and early decay time (EDT). Their method of computer simulation techniques "based on a hybrid method combining ray tracing and image source modeling [...] and an omnidirectional sound source", can be used as a reference for the development of surround sounds simulation models depending on user preference in the future(Lee & Kang, 2015). These insights are guidance to question material and height relations that impact the makeup of the skyway. At the same time, the material chosen has to fit the environment of the skyway system. For example, the St Paul Skyway eliminates the need for pedestrians to venture out in cold weather and move directly to the place they want to reach, all within a heated area. Minnesota is characterized by cold temperatures ranging around "12°F (−11°C) in January to 74°F (23°C)

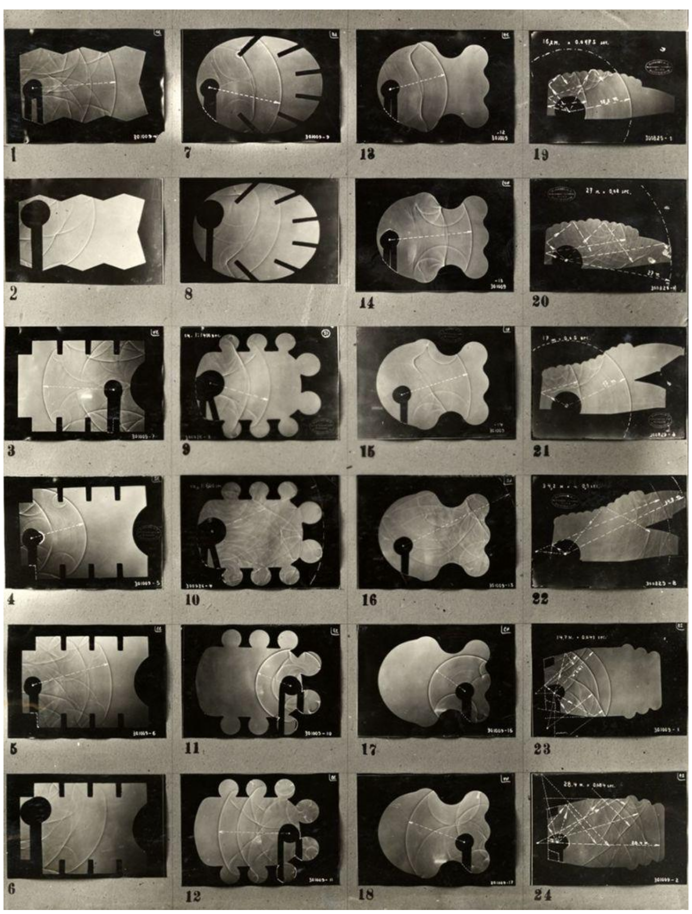

Figure 2.1: Franz Max Osswald, contact print of sound photographs in architectural models, from Osswald's applied acoustics laboratory at ETH Zurich, 1930–33 (Image Archive, ETH Library Zurich, http://doi.org/10.3932/ethz-a-000986437). (Osswald, 1930-33, as cited in Fischer, 2018)

in July for Minneapolis - St. Paul" ("Climate in Minnesota for international students," n.d.).

Then, we looked over Osswald's previous work on architecture acoustics, Figure 2.1 showing his shadowgraphs visualizing the movement of air (Osswald, 1930-33, as cited in Fischer, 2018). His work demonstrated the superposed pressure wavefronts imprinted on the photographic paper as gray lines and tone; shimmering streaks capture a moment of sounds passing through space (Fischer, 2018). He looked at the visible movement in the water employed to explain the invisible movement in the air. He observed a variation of density in the air caused by candles, electric sparks, and shock waves from gunshots and created drawings of what he had seen. His work references physicist Arthur Foley's photographic image in Figure 2.2.

He mentioned that there is a difficulty in controlling the interval between the first spark to set off a sonic pressure wave and the second spark to expose the photographic plate. His photographs depicted "sound waves propagating, reflecting, and diffracting in sectional models of various geometries" (Fischer, 2018). His work translates sounds into gray shadows, challenging our understanding of sight and hearing relations to physics and the environment. Sound no longer appears invisible and intangible but is transcribed in graphic representation. The models and ideation used to study "acoustics of spaces expose the material stakes involved in simulating architecture" are crucial for communicating environmental phenomena such as the movement of air, temperature, and sound (Fischer, 2018).

These examples of capturing sounds in graphic and digital representation sparks ideas on how sounds propagate through spaces and possibilities of visualizing its development of ideations, using dots as particles to represent the sounds energy waves that can be visualized in an enclosed space with motions. This can be used towards Christenson's proposal as a device for reading local particularities in the skyway. He suggested that skyway as a translucent architecture interface, as it "acts of omission and highlighting and are never fully transparent"; this allows us to closely examine cross-disciplinary factors, such as changes in the dynamics of ethnographic and sociology behavior, as people

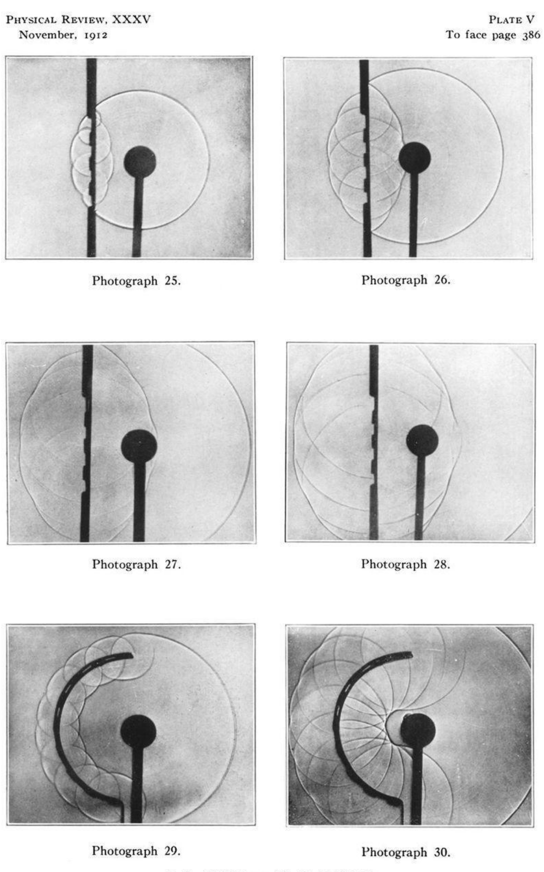

Figure 2.2: Arthur L. Foley and Wilmer H. Souder, experiments with schlieren photography in enclosed geometries, 1912 (Arthur L. Foley and Wilmer H. Souder, "A New Method of Photographing Sound Waves," Physical Review 35, no. 5 [1912], plate V). (Foley & Souder, 1912, as cited in Fischer, 2018)

interact with skyway in the city. The skyway is part of the modes of city street elevated in space, incorporated into the buildings. Its uniqueness in capturing a system in a constrained space, shifting as an "analogous city" (simulation of city) is presenting many issues of the "first city" (original city) problem addressed in Christenson's interpretation of Burn's perspectives (Boddy 1992, Christenson 2020). It allows us to have a more constricted space examining societal problems such as constraints of perception of the city. "The skyway can be seen to result from a hypothesized act of extrusion, as if the system takes its form by extruding a rectangular cross-sectional shape through the city, along lines of travel" (Christenson 2020). The compounded amalgam of spaces in the skyway can be viewed as restricted space to observe perceptions, values, beliefs, cognition, emotions, cultures, views and design of architecture skyway.

3. 2 Development of ideations

We looked over a Grasshopper definition that could visualize frequency waves with a sheet of z-direction dots with Grasshopper components using the plugin from Firefly. This guided me in thinking we could use randomly distributed dots as air particles and create movements to represent changes in sound frequencies as we change the spacing between each dot. The air particles are an idea borrowed from the kernel vibrating from the Chladni pattern to produce a set of unique frequency patterns. The idea of movement changes is from Rudolph Koenig, as he records frequency of the sound's thoughts as particles' periodic changes in flames. The same way can be done in Grasshopper as the change in dots represented by air particles moves as affected by sounds. Osswald's shadowgraphs inspired our direction on how visualization of sound is similar to isolvist view in a perceptible range from its viewpoint. Foley and Souder experiments with schlieren photography gave insights to us: we can have two options of sound visualizations, radial and longitudinal waves. Sound sources transmitting through air particles change in one color, and reverberation as another, the remaining are unchanged. The sound visualization ideation model should be developed into a three-dimensional model with a moveable sound source and adjustable particle density with detailed information available for each group of particles. Users can see the changes in air density that represent sound frequencies in the selected area that can be wider than visual perception range. The air particles randomly distributed in the spatial bounded area should ripple out as the sound source is activated from the previous placement of the dot. Users can import any source of their preference and hover their mouse to different parts of the area to view sound information. Users can change the sound sources with the plug in, simulating how the sounds would transmit within the skyway to understand user experience and indoor construction designs.

If we use this prototype model to understand how air particles and sounds spread, we can track down how air circulates to different ventilation mechanisms within the buildings. This allows us to use visual sound travel to differentiate spaces and adjust the material applied to certain space construction to enlarge and conceal sounds when necessary. The ventilations transmitting disease on the analyzed captured virus is too low for disease transmission indoor, however some researchers researching on

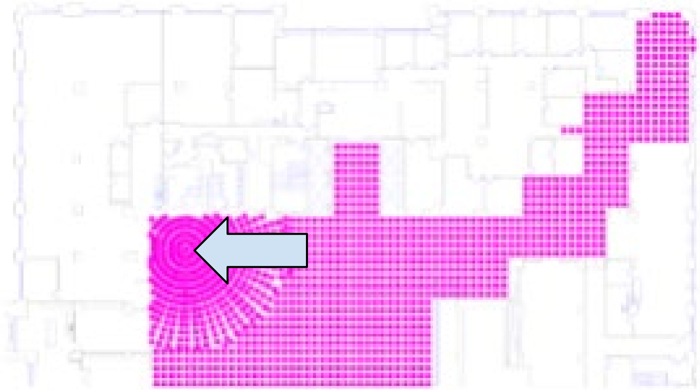

FIGURE 2.3
This is a digital model of two-dimensional sound representation in two-dimensional floor plan The arrow is where the user can click to simulate sound source emitting from the pointed locations

HVAC systems think it is too early to draw this conclusion ("Community, work, and school," 2020). World Health Organizations suggested one way to improve central air filtration is to increase high air filtration and "generate clean-to-less-clean air movements by re-evaluating the positioning of supply and exhaust air diffusers and/or dampers and adjusting zone supply and exhaust flow rates to establish measurable pressure differentials and have staff work in "clean" ventilation zones that do not include higher-risk areas such as visitor reception or exercise facilities (if open)" ("Coronavirus disease (COVID-19): Ventilation and air conditioning in public spaces and buildings," 2020).

3. 3 More considerations on functionality of these sound visualizations

The visualizations of sounds connect to each point of the user feedback we analyzed earlier. After we have looked into some user feedback, we think that these sound visualizations can allow designers to spot the feasibility problem of the skyway in various ways. The widespread use of skyway passages within buildings boosts the interactions between people in those buildings and advances our conveniences in accessing the buildings. We must consider its user feedback to ensure the skyway system's sustainability and feasibility in the near future.

3.4 New definition of Indoor Space and user comfort

Skyways with enclosed walls create isolated spaces for pedestrians, and a skyway with an opened section wall creates a less dense space for sound to travel to the pedestrian ear, also meaning it sounds and feels more "open." Everyone's perception of the space between the skyway and street is different, and what we could hear outside on the skyway is limited compared to the street. There is no clear separation of business space and shopping area, so how do we redefine recreational areas and business areas when they are within the same buildings? The sounds of people chatting in the mezzanines could vibrate to the second floor business room. Occasionally, the mezzanine hall redecorates into wedding venues, with voices vibrating and revolving around the area, changing the definition of space utilization. If the designers are designing for a big conglomerate who wants to incorporate a skyway system, they have to beware of these unclear boundaries of space when they design their space allocations to fortify the purpose of the space, preventing blending of utilizations. They could also enhance these multifunctional spaces for other space development and increase flexibility of the company. The software could help them to control the sound reverberation of the space and determine the size of the room. Such a business room should fit 10 people, lower the transmission of the sounds and auditorium might fit more than 100 people and maximize its transmission of the sounds in a large space with original construction materials. These materials can be incorporated in the three-dimensional Rhino model and check its sound vibration impact within the enclosed space for the safety of public hearing.

This will potentially change the perception of streets and separate the traffic flows to grade up and grade down in a grade separated system as suggested in Christenson's paper. The upward development of pedway and downward development of underground tunnels can "impact the vivacity of street activity", and the city street will be desolated as people utilize the skyway and underground tunnels (Robertson, 2004, as cited in Christenson, 2020). This might affect our capitalism and free democracy society as we are moving previously existing public and semi-public functional spaces into privatized compartments away from the ground floor with restricted access. He suggested that the critical position of the development context of the skyway systems is similar to the United States and Canada expansion of suburban areas in the 1950s and 1960s period, where it comes with a wave of demographic changes around the urban cores. The skyway "operate to segregate occupants by race and class, and in particular that they cater heavily to mostly white, middle- and upper-class, commuting, suburbanites, just as they fail to serve people of color or those who walk, bike, or use transit"(Christenson 2020). The changes to skyways will create a new form of systematic problem, such as racial inequality and changes in human behaviors, whether we view it as multilateral insertion, new impositions, or layering of the pre-existing sites (Burns, 1991, as cited in Christenson 2020). As Willensky mentioned, there are many pre-existing questions in the city we are in now, skyway development might not be a solution to these problems, but it puts the questions in a framed context where we can closely examine it and have more control on understandings of the area (Willensky, 1985, as cited in Christenson, 2020).

The development of a city with the skyway or other form might be inevitable as the modification needs to fit the ever-changing needs of the society. The best we can do is to evolve the skyway to be a more inclusive space than exclusionary space, no matter how we define spaces. The developers and designers of the skyway have to understand that the behavior of social homogeneity is a pernicious influence to society. Social homogeneity is latent in the segregation rules that will apply to its users with how space is constructed without volatile languages thrown at users to alert them. The worst outcome would be as Minneapolis architect Bernard Jacob "posits skyways as a form of violence to which citizens have become desensitized", if the designers and developer abuse the power of spatial construction or designing

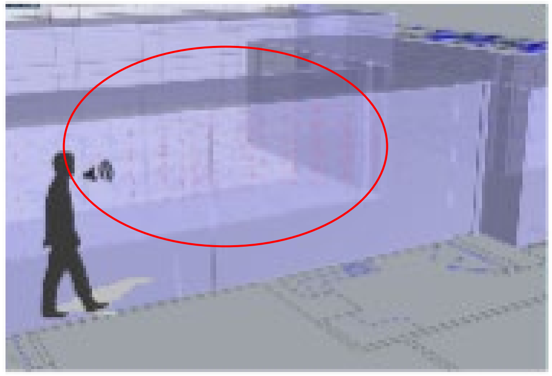

FIGURE 2.4
Digital model of three-dimensional sound representation in three-dimensional digital model The red circles are the air particles that we can look at on ventilation systems

without understanding of these underlying social implications (Jacob 1985, as cited in Christenson, 2020). Christenson believes that drawing sections does not result in resolution to existing problems, but it provides an analysis of data shifting the context to issues that can be closely examined such as their local particularities. This is the same way with sound visualization representation; it is a tool to explore skyway construction as an architecture interface to frame some questions in the existing society.

3. 5 Accessibilities problem and security focus

When the areas are locked due to a private event, people can no longer come in through the skyway. If one junction is closed due to an event, users of the skyway must enter through another entrance of another building to get to their destination indoors. This would create inconveniences, if the user does not have a mobile app to update them, this current changes in terms of accessibilities. Designers can look at the sounds map distribution to see where the sounds are most condensed and redesign the structure of the skyway to maximize its use. They can consider if there is any part that is not fully used and look into that area to focus on the cause of various problems such as hygiene, sanitary problems, and security problems.

3.6 Ventilation and air particles within the skyway system

This two-dimensional and three-dimensional software can simulate the flow of air. The space within the skyway is much smaller than in an open area on the street, and people have more in-person connections and interactions, even with strangers. This brings the communities closer together, but it is also detrimental during a pandemic. It is in an enclosed space for ventilation, and the spread of COVID-19 through suspending aerosols is very probable, making fresh air even more essential. This sound visualization software can simulate the air circulation flow as users walk within the building and see how the air is circulated and its impact on infection rate of the virus.

However, in our location, we need heat in indoor space, especially during the winter. It would be a waste of energy and money to have both heating and constant ventilations on, as we need to heat up the cold air from outside frequently instead of preserving the indoor heating. The best practice to use the skyway safely is to wear a mask because your chance of exposure to respiratory viruses such as COVID increases while in the skyway (Monroe County Department of Tourism, 2019). The little air circulation within the crowded settings at closed in-setting like skyway will increase the spread of virus in suspended aerosols. With people condensed in the conjunctions to get to another place, it shrinks the distances between pedestrians with its frequent use.

3. 7 Other problems concerning the feasibility of the skyway

The skyway system could be new to many people located in areas which have not incorporated skyways before. There will be a problem when people are not adjusted to these new rules. They will need an alternative solution to stay. Options would include them remaining on the street. These will change some individual perceptions and feelings on accessibility, as people are blocked from the outside because of their dress code and lack of financial resources to stay.

Skyway is a connection junction with a constricted space, so it is not as wide open as the street. The space within the skyway during its prime work time is used to walk by pedestrians. If there are homeless people lingering and occupying space in the skyway, it could slow down the pedestrian traffic of the pedestrian. From the user feedback, there was an incident where the security guards came in and took them away, only to find them complaining about the unequal treatment they get. The indoor space of the skyway has added more constraint to the definition of existing public space, where the public space within the skyway has rigorous rules to follow, such as user dress code and behavior code. If users want to enter the skyway, they have to abind to these codes when using the skyway. This is different from the public space on the streets, where most people do not have dress codes and behavior codes; barely any security would regulate people on the street, in contrast to the high number of patrols within the skyway system. To apply skyway into urban representation, we have to make users accustomed and familiar with the underlying rules.

The skyways are a relatively new thing for them compared to the public street in the perspective of spaces and rules they follow when they access it. People who use the street think there are fewer security guards and more spaces for visual perceptions. Homeless people may stay wherever there’s less pedestrian traffic, as long as it does not interfere with pedestrians using the street. However, the skyway is a relatively constricted and confined public space, as it is only public for a certain time and must be cleared after the set time.

4. 0 Conclusions

In conclusion, we generated an idea of sound visualization ideations that could serve as a device in exploring architectural space and the skyway system’s local particularities, leading us to identify some social, political, topological contexts of the skyway as Christenson suggested. The skyway as an inhabitable mode of urban development could be our future urban development trajectory. Using sound visualization applications as a tool to understand the skyway as an architecture interface is crucial. We examined the location of the buildings and the structure of the building, modern architectural acoustics, and prototype ideas to visualize the physical phenomena of sounds. This allowed us to look into acoustic architecture models that assist us in understanding the viability of the skyway in urban representation on a larger application scale. We first examined the locations of the Great Northern buildings and architectural constructions within it using various maps and navigated the floor plan to locate the skyway system within the buildings interconnected with others. Then, we used Rhino and Grasshopper definitions along with building models constructed in Rhino to examine the spatial distributions of the areas within. These programs were used to analyze sociological questions, and look into the viability of the skyway in urban representations. We looked into how the visualization of sounds within the skyway could assist in understanding its feasibility and constructed different two-dimensional proposals on sound visualizations that could be executed in a three-dimensional model.

This model can help us incorporate architectural acoustic elements into our skyway model, looking over areas of the skyway, courts, offices, plaza and halls. The model can give us visual cues to work on the exclusion of undesirable or extraneous sounds or amplified unwanted sounds causing negative user experiences in a constructed space. We can locate where the noise distribution is within the building to improve noise control, along with precautions and safety measures within the buildings. Expanding on the occluded desirable or wanted functional sounds from both exterior or perimeter and interior of the buildings in various points of views. The sound and space can then define the space and maximizes its intended purpose. Sound travels through all matter; for this research we focused on how air particles are affected by the frequencies of the sound waves distributed from limited sound locations. This allows us to generate prediction analytics and forecast probabilities of future events and outcomes to visualize how materials would change the vibration of the sounds, as it creates a different physical sensation to the people in it with these underlying societal factors. There are many unclear expectations of how users will perceive the skyway as an urban inhabitable mode of living, so we have to explore the idealized form of society and the fluctuating changes in our city as the environment and buildings are interdependencies related. In the future, there could be a potential for visual analysis of sounds within architecture to understand the acoustic architectural aspect of the skyway, as suggested in the analysis of the two-dimensional drawings, and development to construct sound visualization applications with the three-dimensional (spherical) analysis, mapping quantifiable aspects of sounds perceptions for sounds analysis.

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