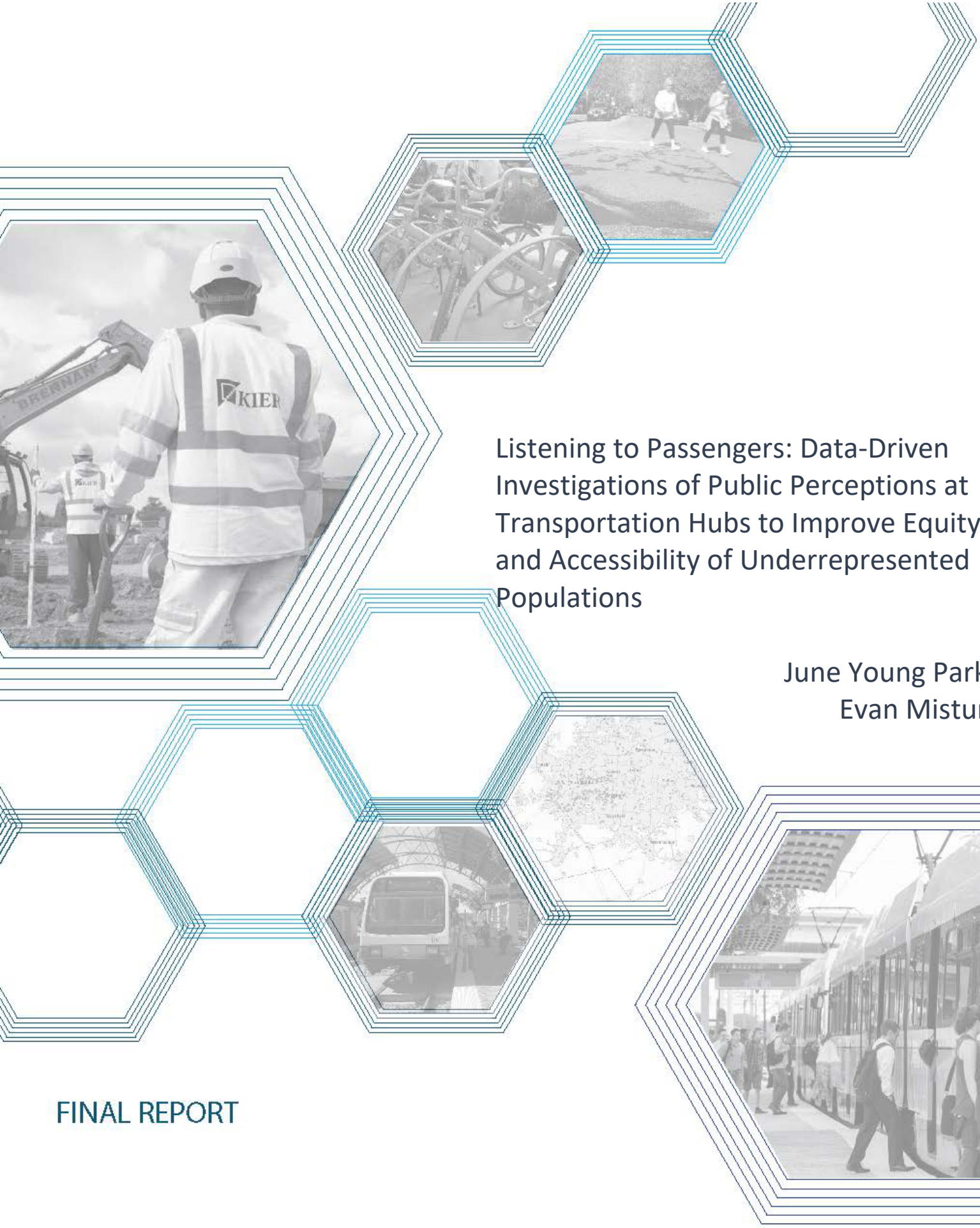

Listening to Passengers: Data-Driven Investigations of Public Perceptions at Transportation Hubs to Improve Equity and Accessibility of Underrepresented Populations

June Young Park
Evan Mistur

FINAL REPORT

CEDD
Center for Transportation Equity, Decisions & Dollars

LISTENING TO PASSENGERS: DATA-DRIVEN INVESTIGATIONS OF PUBLIC PERCEPTIONS AT TRANSPORTATION HUBS TO IMPROVE EQUITY AND ACCESSIBILITY OF UNDERREPRESENTED POPULATIONS

FINAL PROJECT REPORT

By:

June Young Park
Evan Mistur
The University of Texas at Arlington

Sponsorship:
CTEDD

For:
Center for Transportation, Equity, Decisions and Dollars **(CTEDD)**
USDOT University Transportation Center
The University of Texas at Arlington
Woolf Hall, Suite 325
Arlington TX 76019 United States
Phone: 817-272-5138 | Email: c-tedd@uta.edu

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16. Abstract

In the built environment, we have improved accessibility of people with disabilities by adopting ADA standards. For the project life cycle aspect, current efforts rather focused on the design and construction stages but lack of the consideration for the operation of transportation infrastructure. After the COVID 19 pandemic, citizens have been asked (or required) to change their behavior at public transportation hubs (e.g., airports). Consequently, new challenges for passengers with disabilities have arisen, demanding operational changes to ensure maintenance of equal access for all visitors. In the proposed research, we will identify such challenges by using a novel data mining technique on a large public perception data (64 hub airports). Then, we will apply our research findings to current guidelines as well as operation strategies at Dallas / Fort Worth International Airport (DFW). Specifically, we have developed a four-phase research method. First, we will collect location-based social media data from the Google Maps platform, which is distinct from other social media, where users share their experiences about specific locations. Then, we will apply a topic modeling technique to systemically identify public opinions of airport operations with the guidance of the Open Doors Organization, which is a non-profit focused on helping traveler with disabilities. The last two tasks will involve both professional aviation architects from Corgan and the customer satisfaction team at DFW to transfer our research findings toward practical implementation. Our innovative data-driven approach will help both designers and facility managers to make our transportation hubs more equitable and accessible for passengers with disabilities.

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Abstract

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Chapter I: Introduction

Human-centric approaches are critical for urban infrastructure systems to improve human comfort in the built environment (Park et al., 2018). This indicates that understanding human interactions should be included in the project life cycle (design, construction, and operation) of large transportation facilities to provide utmost user satisfactions while maintaining equal accessibility (Chang & Chen, 2012). The following review highlights how laws consider people with disabilities, especially in aviation facilities.

- **The Americans with Disabilities Act (ADA)** is a piece of civil rights legislation that was signed into law in 1990. The primary objective is to eliminate a wide range of discrimination against people with disabilities as well as to ensure that facilities are accessible in a non-discriminatory way. While the applied sectors are wide, it only covers a few architectural spaces in airports, e.g., accessible restrooms and service animal relieving spaces. Title III of the ADA holds air carriers accountable for ensuring the accessibility of all airport facilities, including airport shuttles within terminals and between terminals and other destinations. The legislation mandates equal access for passengers with disabilities in various areas by supports from staff, auxiliary aids, and equipment.
- **The Americans with Disabilities Act Amendments Act (ADAAA)** was signed into law in 2008. This was passed in response to prior Supreme Court decisions that adopted a rather narrow definition of disability. The ADAAA broadened the interpretations of what constitutes a disability and requires courts to focus on whether an entity has discriminated rather than on whether an individual's impairment fits in the technical definition of a disability. Its application is likely that of a state or local building code, whose scoping requirements may be contained in the local adopting amendments. It is also issued for public transportation facilities that are subject to title II, which covers various modes of transportation (bus stops and stations, rail stations, and airports).
- **The Air Carrier Access Act (ACAA)** more specifically covers the air transportation rights of individuals with disabilities. ACAA was passed by Congress in 1986 with the primary intention of addressing the variability in accommodations allowed by airlines in absence of any standards and overarching governing law at the time. It also considers airports' responsibility to ensure that passengers with disabilities can smoothly move through the airports. Lifts, ramps, or other suitable devices must be available if the terminals are not equipped with passenger loading bridges or passenger lounges for boarding and deplaning. In addition, this section covers the point that the airport operators must train personnel to be proficient in using airport owned or operated boarding assistance equipment and be knowledgeable of boarding assistance procedures to ensure the safety and dignity of passengers.

Despite the importance of disability rights laws, the positive effects associated with their implementation as a building design guideline, i.e., ADA Accessibility Guideline (ADAAG), the built environment is still not friendly for people with disabilities. At airports, the survey study of passenger complaints indicates that there are twice as many complaints from passengers with disabilities compared to those of passengers without disabilities (Major & Hubbard, 2019).

The challenge is that the adopted guidelines mainly focus on high level requirements that do not address many of the small-scale issues that airport visitors often have to deal with. Existing guidance often deals with the type of space and/or transportation modalities provided without emphasizing actual passenger interactions and experiences at airports (Titchkosky, 2011). Although the ADAAG serves as a guideline by providing specifications for building design (e.g., restroom, parking lot, doorway), the actual usability of such spaces by people with disabilities is not well evaluated.

It is important to note that the operation phase is indeed important as the design and construction phase of large facilities to provide comfortable environments for occupants (Becerik-Gerber et al., 2012). However, the evaluation of facility operation is limited largely to walk-through investigations only during facilities' design and construction phases (Welage & Liu, 2011). More recently, there has been a significant shift in airport operation due to the COVID-19 policy, which changes how passengers interact with airport systems (Park et al., 2022). However, the categories in the current standards have not been updated to correspond with these changes for passengers with disabilities. Therefore, it is necessary to comprehensively evaluate user experience from people with disabilities to identify their challenges.

The rest of this report explains our methodological approach, results, and discussion of the results. The contents of these parts are based on our previous conference presentation and publication for the American Society of Civil Engineers, International Conference on Computing in Civil Engineering. The conference was hosted by Oregon State University in June 2023.

Chapter II: Methodology: Overview

Short text clustering methods have been shown to be an effective method at discerning topics within short text documents like analyzing tweets or news headlines (Yin and Wang 2014). This method of text mining can be applied to find the topics discussed on review sites like Google Maps. Research has been performed to look at overall topics that travelers mention in online reviews a single airport or the airlines themselves (Lucini, et al. 2020) (Park, Robertson and Wu 2006). Other study focused primarily on Covid-19 measures by analyzing the posts of Google Maps to find major concern with the US airports (Park, et al. 2022).

To the best of our search, text mining approach for social media data has not been applied as to identify the disability-related inequity in the US hub airports. In this paper, we use a short text clustering and relevant text mining techniques on the scale of air transportation infrastructure, specifically aiming at the opinions from the disability community. In addition, we present our method as a framework to allow any user to acquire data for a set of buildings (e.g., airports in this case) and filter them to a specific interest group (e.g., people with disabilities) and search within that interest group to see what topics are discussed the most.

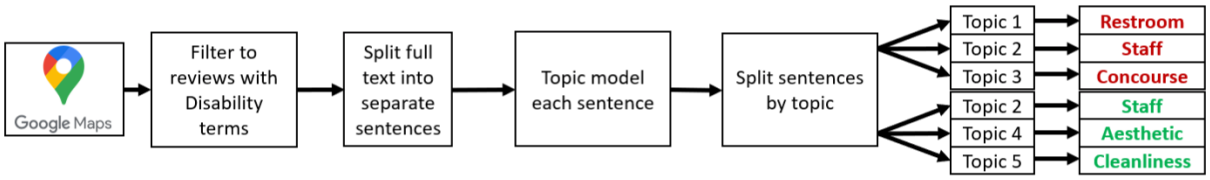
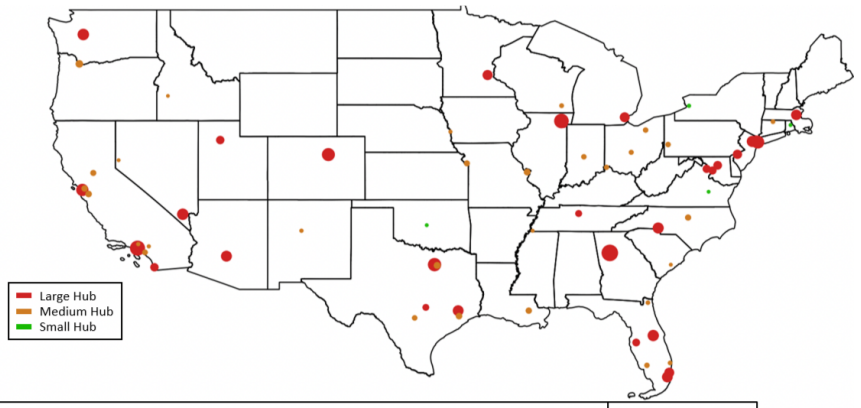


Figure 1. Methodological framework overview

The method consists of three primary components: 1) data collection, 2) data pre- processing, and 3) topic modeling. For data collection, data scraping was used for collecting Google maps reviews. Data pre-processing was done both concurrently with data collection and post collection depending on the data source used. Finally, topic modelling was performed with the GSDMM model to identify clusters of topics.

Chapter III: Methodology: Data collection

For data collection, reviews were collected for each airport business on Google Maps for 68 airports. These airports were selected based on the FAA airport role designations "P-L" and "P-M" to look at both large and medium hub airports as they consist of about 87% of the total enplanements, or commercial passenger boardings, in the US as of 2021. (FAA (Federal Aviation Administration) 2022). Of these airports, 30 large hub airports, 34 medium hub airports and 4 small hub airports were analyzed in this study. The small hub airports were selected due to the number of total enplanements being similar in size to some large hub airports. The map and table of these airports can be seen in Figure 2. Note that not all of the listed airports are not shown on the map.



Large Hub	
Atlanta	ATL
Los Angeles	LAX
Chicago	ORD
Dallas	DFW
Denver	DEN
New York	JFK
San Francisco	SFO
Seattle / Tacoma (SeaTac)	SEA
Las Vegas	LAS
Orlando	MCO
Newark	EWR
Charlotte	CLT
Phoenix	PHX
Houston	IAH
Miami	MIA
Boston	BOS
Minneapolis-St. Paul	MSP
Fort Lauderdale	FLL
Detroit	DTW
Philadelphia	PHL
New York	LGA
Baltimore	BWI
Salt Lake City	SLC
San Diego	SAN
Washington, D.C. / Dulles / Chantilly	IAD
Washington, D.C. / Arlington	DCA
Chicago	MDW
Tampa	TPA
Nashville	BNA
Austin	AUS

Medium Hub										Small Hub	
Honolulu, Oahu	HNL	Cincinnati/Covington	CVG	Albuquerque	ABQ	Sacramento	SMF	Buffalo	BUF
Portland	PDX	San Juan / Carolina	SJU	Anchorage	ANC	Kansas City	MCI	Providence	PVD
Dallas	DAL	Columbus	CMH	Ontario	ONT	Orange County	SNA	Oklahoma City	OKC
St. Louis	STL	Kahului, Maui	OGG	Omaha	OMA	San Antonio	SAT		
Houston	HOU	Milwaukee	MKE	Memphis	MEM	Cleveland	CLE	Richmond	RIC
San Jose	SJC	Hartford	BDL	Charleston	CHS	Pittsburgh	PIT		
Oakland	OAK	West Palm Beach	PBI	Reno	RNO	Indianapolis	IND		
New Orleans	MSY	Jacksonville	JAX	Boise	BOI				
Raleigh	RDU	Burbank	BUR	Fort Myers	RSW				

Figure 2. Map of target US airports

Google Maps is one of the most premiere and ubiquitous forms of mapping and navigation services available. While the number of daily active users has never been disclosed by Google, it was revealed in a 2012 press conference that they surpassed 1 billion users for Google Maps across every form of platform (i.e., mobile, web, integrated etc.). This userbase has likely continued to grow with Google's economic worth increasing continuously. As such, Google Maps holds by far the largest market share of free and accessible navigation, but it also holds a wealth of data. Businesses, public places, and even forms of transportation are represented on these maps. Several hundred thousand reviews are available for just the largest airports within the US. These reviews include a unique score information rating from 1-5 indicating how the passenger feels about their trip as well as a text description with any potential photos.

Google Maps reviews were pulled using a method of 'back-end data scraping', in which the Google database is accessed directly instead of traditional web scraping. This process has several advantages and disadvantages. When compared to traditional data scraping, this process is more reliable, faster to download and more efficient in terms of computing resources. However, this process is not near as fast as accessing the Google database through a developer account and has vague metadata (e.g., dates are given as time estimates instead of a time code and must be converted). The process has 10 reviews pulled per request, with each request being sent every 5 seconds, the data from these requests include the text, rating, and date estimate (e.g., 1 year ago, 6 months ago).

Once the data was collected from Google Maps, the reviews were then pre-processed by removing portions of the review that were copied twice, as some portions of the text repeated the first few words at the end of a review. After these reviews are searched for at least 1 disability related keyword (i.e., 'wheelchair', 'disabled'), any other reviews were discarded. Following this, each review was then split into sentences and each sentence was marked for its associated review, the airport in question, review date and its associated star rating. Additionally, corpus preparation was done by a set of python packages that removed stop-words, lemmatized, and n-gram identification. Final cleanup methods (e.g., punctuation removal, lowercase transformation) were the final steps to tokenization of the text. Sentence separation was performed to maintain accuracy with the following topic modeling method used.

Chapter IV: Methodology: Topic modeling

We used GSDMM method, specifically the "Movie Group Process" implementation (Yin and Wang 2014). Due to the nature of most reviews being short and concise, conventional Linear Discriminant Analysis (LDA) method and Term Frequency-Inverse Document Frequency would not be able to perform nearly as accurately as GSDMM would. However, there is a potential for larger reviews to 'poison' the GSDMM with an abundance of subjects. As such a simple process is used to split the reviews into separate sentences using punctuation as a marker. An example of a review with multiple subjects, both considered positive and negative regarding the airport, is shown in Figure 3. This example could poison the results giving only 1 of the 3 total topics given when that is not the case.

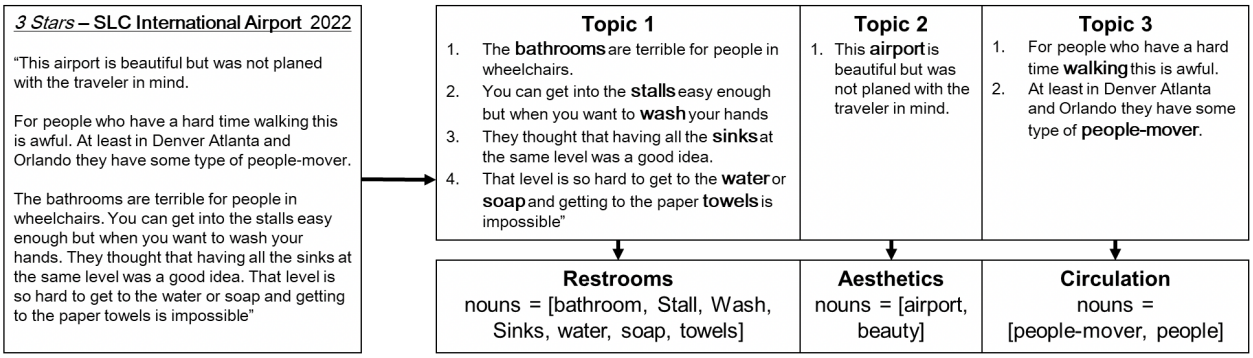


Figure 3. Sentence based modeling for GSDMM in this research

Since the sentences are considerably shorter than the entire review, GSDMM provides a more accurate representation within the review with mixed feedback. This proves to be helpful for reviews that are not 1 dimensional (i.e., 1 Star or 5 Star reviews). However, the inference as to if a topic is negative or positive still needs to be manually done. GSDMM, unlike LDA does not need a set number of topics to be defined beforehand, and can be inferred intuitively, however through tuning extraneous topics can be combined with other similar and relevant topics. When the number of topics is too high, the topics themselves become extremely isolated and hyper-focused, some generalization is needed to be able to provide insight. The maximum number of topics tested was 140 and through analysis of the number of documents, scores of relevance per documents were referenced to find the ideal model.

Chapter V: Results

Reviews for 68 airports were collected, those with the FAA designations of P-L, P-M and a select few P-S airports based on location. 553,430 unique reviews were scraped from Google Maps to be analyzed. Of these reviews, only 331,301 had textual response, the remaining reviews were star ratings only without any feedback. The filtered data set comprised of just 3,720 reviews that held keywords related that had a high likelihood of being related to disability terms. Review distributions nationally shift towards lower star ratings with this effect being exaggerated in certain airports more than others as shown in Figure 4. Especially, Dallas – Fort Worth (DFW) airport has overall a good score in their Google Maps rating system. However, when it comes to disability-related reviews, the proportion for the lowest rating (1) takes a significant portion, almost half of the total number of reviews. This general trend in disability-related review results suggests a deeper investigation of these reviews by topic modeling analysis.

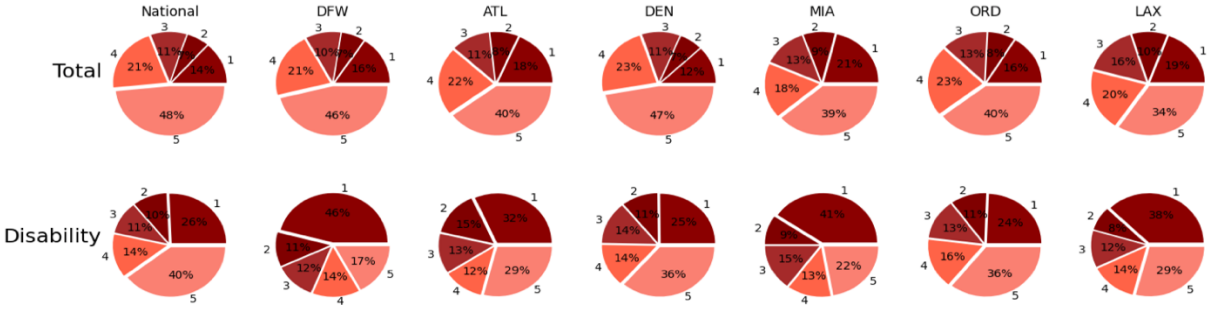


Figure 4. (1-5) Star reviews for all reviews and disability related reviews

The K number in GSDMM controls the number of clusters and topics within this model. Cohesiveness is a score that the process gives each document on a scale of 0-1. Topics with a high average score and low cohesiveness have a higher level of accuracy and consistency of its representative topic. Taking a K number of clusters to be 10 held the highest number of possible topics with a tight cohesiveness. Taking K<10 allowed too many topics to aggregate together, and topics could not be as easily identified even though the score values were high. Taking K>10 allowed for more concise topics, the average group score and deviation increase by nearly 5% and 2% accordingly when moving from K=10 to K=11 topics and this trend. Taking K to be too high would not make for an efficient grouping process for analysis and the deviation. Taking $\alpha = 1$ and $\beta = 0.1$ allowed the number of clusters to consistently stay populated. The α variable controls how likely a document is to join an empty topic on a scale of 0-1, a high value in this case means that empty topics are almost guaranteed to be filled. A low β however will attempt to balance this to make topics stay close to related topics. The average cluster cohesiveness scored 70% with a standard deviation of 28%.

Table 1. Topics represented by each cluster

Cluster 0	Cluster 1	Cluster 2	Cluster 3	Cluster 4
Staff Pushers	*Staff* Deboarding	*Space* Entry	*Staff* Airline	*Staff* Boarding
Cluster 5	**Cluster 6**	**Cluster 7**	**Cluster 8**	**Cluster 9**
Space Checkpoint	*Space* Baggage Claim	*Staff* Security	*Space* Tenants & Restrooms	*Staff* Amenities

The clusters (topics) in Table 1 are represented by the most representative words for each cluster according to the GSDMM model used. These words are shown in Figure 5 for the count of words within each topic. Cluster 3 has the highest cohesiveness with the word service appearing over 400 times.

Through sampling of reviews and analysis of most representative keywords, generalized subject titles were derived for analysis as shown in Table 1 and Figure 5. The method of deriving these titles was based on choosing a synonym for the most representative word in addition to review sampling to determine the actual topics. This allowed clarification for some topics boarding and de-boarding. Of the topics derived 4 topics were space related categories and 6 topics were staff and operations related categories. 2,829 reviews were related to the 4 space topics within the airport, the largest category within space was the baggage claim. Staff Reviews consisted of the remaining topics, the majority of these are related to security and online staff. Looking at Space related topics, “Tenants and Restrooms” have reviews relatively distributed across all 5 ratings. Baggage Claim in comparison has considerably lower 5 Star reviews and more 1 and 2-star reviews, Security checkpoint scores even lower with an increase in 5-star reviews and a reduction in almost all other star ratings.

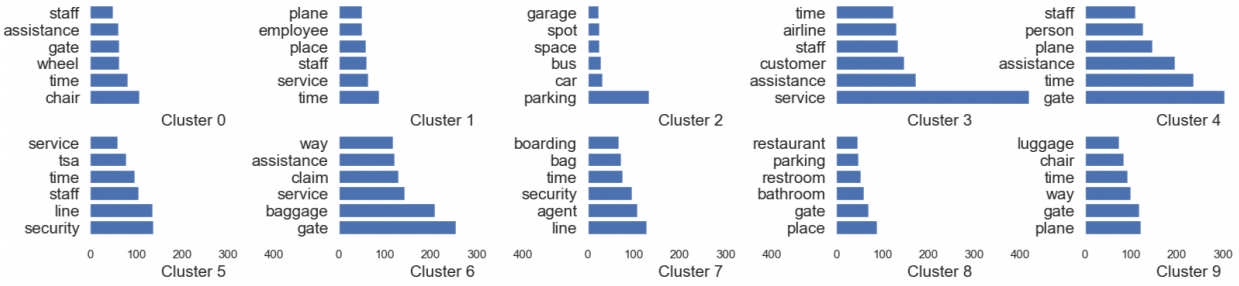


Figure 5. Most representative words for each topic

Lastly, Figure 6 shows the distributions of the reviews per modelled topic can be seen to have higher review scores for airline staff with the highest percentage of 4 and 5-star reviews. The lowest scoring topic in Figure 6 appears to be for Security Staff with 43% of the reviews consisting of just 1 star reviews alone. Space review distributions appear to have a more even distribution over each rating compared to the staff reviews.

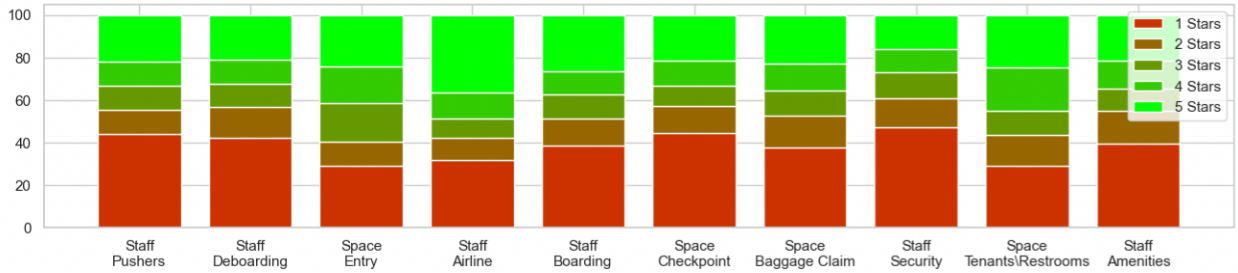


Figure 6. Review rating distribution across topic clusters

Chapter VI: Discussion

It appears that most of the reviews that disabled passengers leave are typically an extreme positive or an extreme negative. This can suggest that a single bad issue or experience can cause that traveler to leave a 1-star review. Extreme positives seem to focus more on staff exclusively while extreme negatives are broader in subject but include space issues as well. It is expected for many samples to be related more towards staff than functional design and operations as reviewers are motivated to promote positive feedback. However, it is important to reiterate that the strongest motivation for travelers to write reviews is to provide concerns and warnings for other travelers with disabilities (Yoo and Gretzel 2008). This means that they are more likely to leave informative reviews to assist other disabled travelers or inform airport facilities about the issue. Expanding on this, it is possible that disabled passengers that leave low scoring reviews regarding the space and design to spur facilities staff to fix the issue or just to warn other travelers. This can be seen further in cluster 8 with a lower scoring but prevalent term being 'suggest'. Low scoring reviews regarding staff seem to provide less helpful feedback, especially in the context of the TSA and security.

Sampling low scoring reviews in cluster 8 yields some interesting results with issues of reach within the restrooms of certain airports, one such example was shown earlier in Figure 3. Perhaps this is an indication that some ADA guidelines are being missed. This would require the further improvement of ADA for future needs of disability community. One potential theory is changes of scope that occur late in the construction or renovation process, since most construction mismanagement occurs from last minute site changes (Chester and Hendrickson 2005). Another proposed observation is that many of the original airport designs are not able to properly accommodate passenger volume with the current security requirements implemented after the September 11th 2001 terrorist attack. According to Figure 5, 1 star reviews are the most prevalent in all categories including the aforementioned space topics.

Interestingly, the level of low scoring (< 4 star) reviews disproportionately increases with larger airports. This is overloading with a total number of passengers creating too much traffic within the concourse, crowded restrooms with lengthy lines. Several sampled reviews specifically mentioned not enough wheelchair access stalls, most of these samples lie within clusters 6 and 8, relating to the space of the airport. The aggregated review data could be further analyzed to provide a detail modeling process to innovate Building Information Modeling (BIM) of airport facilities, incorporating potential issues if the flaw is similar enough to a known design pattern.

The limitations of this study include discerning the experience within these topics that are mentioned. Some topics can be considered a negative or positive experience regardless of the review rating. Also, the context of nearby sentences is not considered. Investigation on sentiment based on surrounding sentence and adjectives in a building context should be done. Another limitation is that the other reviews for the tenants within the airport spaces are not considered as they are left on a separate review page for said businesses. Review bias can be a factor as well, Lastly, filtering reviews is a lossy process, many reviews that could have been disability related were dropped in lieu of removing non-relevant data. In addition to this, nearly half of the

collected reviews had no textual data, leaving a considerably large amount of ambiguity in the reviews without text. It is possible that many of those reviews could be disability related as well.

Travelers with disabilities leave more negative feedback for airports across the US, indicating that barriers and agitators still exist for those with disabilities. Using text mining, cohesive topics within the reviews were identified. These topics separated by 4 space-related and 6 staff-related topics. The most complaints were found in the airport spaces such as baggage claim areas, bathrooms, inter-terminal transportations and areas around the entry including parking. Our analysis suggests that designs and operation may require further improvement of ADA guidelines to fully accommodate travelers with disabilities.

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Appendix A: Technology Transfer

An Appendix should be included in this final report to document the Technology Transfer activities conducted during the project term, accomplishments towards T2 adoption and implementation by relevant stakeholders, as well as any relevant post-project T2 plans.

We conducted activities supporting technology transfer throughout the project, culminating in a series of meetings where we will present our findings, along with recommendations for implementation, to stakeholders from the public, private, and nonprofit sectors (Table 2).

Table 2. The list of stakeholders for technology transfer

Sector	Nonprofit	Private	Public
Organization	Open Door Organization (ODO)	Corgan Design Architects	DFW Airport
Objective	Topic modeling results to scrutinize the results from the disability perspective	ADA review results and potential barriers to implement from architect perspective	potential usage of the proposed method to improve accessibility of airport
Meeting detail	March 2023 via MS Teams	March 2023 via MS Teams	November 2023 at DFW HQ

We engaged a large team of stakeholders on this project. First, we worked with Laurel Van Horn, the VP of Programs at the ODO, where their non-profit efforts on many projects aimed at improving equitable access in public spaces and are interested in incorporating our results as they can be used to help achieve that goal. They were critical in helping us appropriately design our topic modelling methodology to identify challenges for airport users with disabilities. They provided useful insight in setting up the methodology and improve the construct validity of our inputs by providing expert perspectives for triangulation. Full implementation of our tool in airports may be difficult for them to achieve since they do not have any direct control over facilities. They have a wealth of knowledge and experience working in and with disabled communities and will provide us much needed contextual information and understanding of these topics that will ground our analysis at different stages of the project.

We also presented our results to Corgan Design Architects: Jonathan Massey, the Aviation Sector Leader and Managing Principal, Scott Gorenc, the Aviation Director, and Samantha Flores, the Director of Research and Innovation. Corgan is one of the world's largest architecture firms engaged in various aviation projects. Their work portfolio includes designs public transportation facilities around the country and is invested in finding new ways to deliver high-quality designs that meet their clients' needs. They were very interested in our results because they will shed light on how airport spaces are used and accessed by different groups, common issues that arise from building design and management, and how end-users perceive different design options in the context of COVID-19. These results may help them innovate new ways to integrate equal access into their designs to serve this clientele. In addition, our evaluation of ADA guideline provides interesting discussion to think about the future of accessibility design standard as a national level. These stakeholders are in prime position to incorporate our findings

into the firm's practice. They will contribute to our project by providing critical insight into the building elements that influence user outcomes in airports, the feasibility of different design changes, and the context of airport design.

Finally, we engaged John Han, the Senior Manager of Research and Analytics at DFW, in our project. He is currently in charge of customer satisfaction at one of the major airport hubs included in our study and may be able to directly implement both our findings. His team are responsible for ensuring equitable access to airport users maintaining high facility standards and resolving issues at DFW airport using state of the art technologies and are interested in our findings as they will help identify problems and solutions for underrepresented groups more effectively, increasing management performance at DFW airport. Their feedback was critical for accomplishing field implementation of our research findings. They were extremely interested in our methodology and showed their interest of utilizing social media data to understand passenger satisfaction. At the same time, they were considered regarding the reliability of social media data in general, which opens another research theme for our team. John Han provided important information and context into airport management and customer relations in major transportation facilities and feedback on how to best develop our research products for implementation as well as reviewing our final results.

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C-TEDD@UTA.EDU CTEDD.UTA.EDU @UTACTEDD @ C__TEDD @ CENTER FOR TRANSPORTATION, EQUITY, DECISIONS AND DOLLARS 817.272.5138