Impacts of Inclement Weather on Transit Ridership:
A Minneapolis, MN Case Study

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I. Introduction

The Metropolitan Council of the Twin Cities Metropolitan Area, not unlike Metropolitan Planning Organizations (MPOs) throughout the country, has published arguably lofty transit ridership goals in its 20 year comprehensive plan. Especially since it has not been deliberately researched before in the region, it seems appropriate to ask how much ridership is affected by the primary non-confrontational conversation starter throughout Minnesota: the weather. The following analysis will work toward answering that exact question.

The analysis of this research will begin with a discussion of the temporal-based psychology research, in addition to industry research and surveys regarding methods to mitigate a negative temporal perception of passenger journey times, and other opportunities for ridership improvements. Additionally, a related econometric study completed on the weather impacts on the Chicago Transit Authority system in 2008, which is used to provide the methodological framework for the statistical analysis, is discussed.

Following this discussion of research that can lead us to insights and considerations for improvements for transit riders that may subsequently influence their choice to use transit in the future, or even to induce new riders, an econometric model and additional techniques tests whether a relationship exists between Metro Transit weekday, regular service (excluding reduced and holiday service) bus ridership, and independent variables such as average monthly temperature, precipitation, snow clearance times, gasoline prices, etc. Through this, the study seeks to uncover statistically significant relationships between the dependent and independent variables.

Finally, following the discussion of the modeling results, which will also address data collection and quality conflicts, multiple policy opportunities for Minneapolis, the Twin Cities Metropolitan Area, and other urban areas seeking to improve ridership or transit management practices related to inclement weather will be addressed.

II. Literature Review

A. Psychology of the Transit User

The conventional study of travel behavior, similar to other fields of consumer behavior, groups the traveler's types of evaluations of a transit experience, which include monetary and temporal (time-related) categories, into a generalized cost, which assumes that a tradeoff between the two is equal in value (Li, 2003). Alternatively, assessing the monetary costs and the temporal aspects as unique pieces of the transportation experience across the entire journey may yield useful results that can inform the planning and shape of transit systems and transportation policy.

Although a void in the temporal research of a user across a journey exists, the concept of time perception itself has a long and significant tenure in psychology research. Of the multiple time-perception concepts imagined during its 200 year history in psychology research that are applicable to commuter perceptions, perhaps most important is Fraisse's 1984 definition of time perception, which "implies that time in perception bears no straightforward relationships to physical time"(Li, 2003, p. 43). Hornik's 1992 research gave an interesting insight about the influence of one's mood on temporal judgment; the state of one's mood makes the individual more prone to draw from memories of a similar mood when analyzing an experience (Li, 2003, p. 45). Finally, Boltz's 1998 research reveals that an uncertainty likely results in a longer perceived trip time (Li, 2003, p. 50).

B. Qualitative Oversights

Similar to the conventional study of travel behavior, conventional planning also its oversights; the importance of the quality of service is usually overlooked, and instead, only quantitative measures such as operating costs, revenue, speed, and incidence rates are considered in efforts to identify planning problems and assess potential improvements (Littman, 2008, p. 44). The narrow inclusion of quantitative factors inherently undervalues the significant aspects of comfort, convenience, and security, all of which can positively influence the temporal experience of commuters (Littman, 2008). Increased seat comfort can help stabilize one's mood and draw from these positive memories when evaluating the ride, while additional marketing efforts can simultaneously enhance notions of security (for example) and manage expectations of ride length during periods of construction or event congestion; both of these outcomes assist in reducing the temporal perception of travel time (Li, 2003, p.50).

In addition to the potential benefits that would be enjoyed by existing passengers, changes in these qualitative factors may also induce new riders, which hold the potential for broad societal benefits, as well as the ability to generate a positive feedback loop that creates more revenue for the transit system and ultimately, further increases in ridership. However, because public transportation is provided as a fundamental public service, these extras associated with convenience and comfort are not able to be automatically funded (Littman, 2008). Instead, improvements to service quality are made "only if planners are to demonstrate their value" (Littman, 2008, p.44).

C. Wait for Service

Another significant aspect of the transit experience that would potentially see ridership increase as a direct result of improvement is the wait a user may incur for service. Compared to any other segment of the transit experience, users often value the duration of their wait for service at nearly two to three times the time-cost attributed to travel time spent in a vehicle (Krizek and El-Geneidy, 2007, p. 75). As opposed to the activities a commuter may be engaged in throughout the ride, the likely presence of unoccupied time during the wait may direct the commuter's attention toward the unfulfilled goal of travel and other indications of the passage of time, and may influence an overestimation of the individual's judgment of expended time (Li, 2003, p.48).

Increasing the frequency of a transit service, while holding all other factors constant, or *ceteris paribus*, is an obvious mechanism to increase the demand for transit; greater frequency means less of the costly wait time for the traveler. Although the relative increases in demand vary widely between markets, geographic, and demographic factors, an example of evidence is an analysis of Portland, Oregon's elasticity of demand for public transportation with respect to travel time resulted in a calculated elasticity of -.129; *ceteris paribus*, a 10 minute reduction in transit travel time would yield a 1.29% increase in ridership (Littman, 2008). Of course, the mitigation of a commuter's wait time is not often as simple as increasing the frequency of the service due to factors like additional operating costs and other inefficiencies related to an improper increase in headway and capacity (Deskalakis & Stathopoulos, 2008)**.**

Alternatively, although the cost of investment is large, providing transit users with real-time route information at stations is a tested mechanism to mitigate negative temporal perceptions caused by the uncertainty of arrival times during a commuter's wait. A survey study performed in 2005 for the commuting population in the city center of Dublin, Ireland, which was a case where no central source of information for the region's major bus network, two light rail lines, or heavy rail network was available at the time of the surveying. Analysis of the Dublin survey data returned an inverse relationship between the availability of information and perceived wait time, similar to a 2003 study in London that estimated a 26% reduction in perceived wait time, as well as a 2007 study on a tram line through The Hague, Netherlands, which reduced rider's perceived waiting time by 20% (Caulfield and O'Mahony, 2009, p. 3).

As mentioned, the costs of providing real-time information are not insignificant, according to Caulfied and O'Mahony, and analysis shows user price sensitivity toward paying for real-time information from both the SmarTraveler system in Boston, Massachusetts, in 1997 and in a 2003 study for the TavInfo transit information system in San Francisco, California (Caulfield and O'Mahony, 2009). However, the significant growth in market penetration of smart phones since 2009 provide less costly opportunities for large and small transit organizations to provide similar types of real-time information to commuters through an application. Aside from infrastructure costs associated with reporting the data, and the capital costs to develop the appropriate applications for a user's smart phone platform, the benefits of testing the local perception of a real-time data system to inform users, decrease perceived wait time, increase certainty regarding arrival and departure times, increase commuter satisfaction, and decrease signage costs seem clear (Cantwell, Caulfield, & Mahoney, 2009). Service on Manhattan Island, New York and throughout Chicago, Illinois exemplify successful and applicable case studies that created smart phone applications for retrieval of real-time route information, and the use is widespread in each city's commuter-via-transit population.

D. Built Environment

Aside from time-perception improvements for the commuter, the quality of the environment for pedestrians around transit stations is another relevant opportunity for improving ridership of public transportation systems. Public health officials began exploring changes in the physical structure of a city after realizing the difficulties in encouraging individuals to lead active lifestyles, and advocates for giving significant attention to the land-use include New Urbanists, who advocate that the “street environment is a crucible for effective civic engagement,” researchers who have noted the impact of an area’s walkability on the quality of social relationships, and many others (Frank & Ryan, 2009, p. 42).

Frank and Ryan recently tested this compelling environment, hypothesized that a (positive) relationship would exist between increased transit ridership and walkability measures, and found statistically significant results that supported a positive relationship between walkability and increased transit use in San Diego, California. Ultimately, the transit level of service, which was calculated by dividing the number of bus routes by the average wait time, was the strongest predictor of bus ridership in Ryan and Frank’s modeling. The regression analysis also coupled socioeconomic data such as median household income, percentage of Caucasian households, and the percentage of work-force eligible adults (Frank & Ryan, 2009).

The potential benefits from creating a physical environment that supports non-motorized forms of travel, such as walking or biking, are likely apparent to transit and land-use enthusiasts. Certainly, those outside the professional realm of planning or land-use design may quickly defer to this second model’s lack of significant explanatory power over a model that found an expected positive relationship between transit level of service, certain demographic factors, and transit ridership, the study still contributes positively to the academic and professional realm. In addition to a statistical framework for cities outside of the San Diego metro area, the adaptation of this tool has the potential to assess the impact (and applicable fees) of a new development on the pedestrian environment. Planners may also find opportunity in the walkability index as a planning tool when a transit agency is considering alternatives when expanding transit service, or use the results or framework as an incentive for local governments to aggressively employ smart growth land use tactics (Frank & Ryan, 2009).

E. Non-User Transit Preferences in the Twin Cities

Last, but certainly not least important, those who do not use public transportation undoubtedly warrant some attention to acquire a better understanding of their habits and preferences. In an analysis of Metro Transit surveys of transit users and non-users throughout the Minneapolis and St. Paul market, the non-users represent a significant share of the market; furthermore, an estimated 53% of the non-users are defined as potential-riders. Additionally, Minneapolis – St. Paul’s ratio of captive riders to choice riders is significantly higher than other major transit organizations throughout the country, which signifies a substantial possibility for growth in Metro Transit Ridership (El-Geneidy & Krizek, 2007).

El-Geneidy & Krizek focus on the “area to market transit services,” which is the group of individuals that can be classified as choice riders or potential riders. The two groups actually share quite a few similarities: individuals in the groups often prize reliability, travel time, type of service, and comfort (El-Geneidy & Krizek, 2007, p.88). Apart from this list, potential riders are notably also looking for greater service coverage. Of this group seeking more extensive coverage, and since many of these potential changes were addressed previously, perhaps the major outstanding question is centered on measuring the unmet demand of the non-user potential riders. Excluding the results of the non-user survey, Chicago faced a similar question in regard to the unknown demand for services along the Orange Line. Post-hoc analysis found that 25% of riders were those who were new to transit and had previously used an automobile to complete their commutes (El-Geneidy & Krizek, 2007, p.73). Continued analysis of non-user populations throughout the Metro Transit service area to appropriately anticipate and plan for the latent demand is seemingly optimal, as opposed to an analysis after the 2014 opening of the Green Line (Central Corridor), or the light rail corridor’s potential 2017 southwestern extension, colloquially known as the Southwest Corridor.

F. Weather Impacts on Chicago Transit Ridership

To date, existing research on the issue of weather and transit ridership is limited, at best. To date, the only evidence of a body of research addressing this combination of issues is a June 2001 – August 2003 daily study of the weather impacts on ridership within the Chicago Transit Authority’s system. This graduate level research confirms that temperature, rain, snow, and wind all affect transit ridership in the expected direction, although to different extents depending on the mode, season, and day of week. Generally, good weather tends to increase ridership, while bad weather tends to reduce it. However, the authors note that it is still possible that extremely bad weather, such as fog or a blizzard, may increase ridership because some drivers are likely to switch to transit in these situations. Although the Hiawatha (Blue) Line ridership was excluded from this study due to the availability and quality of data, among other potential biases that may be present in its ridership, the CTA analyses also show that bus ridership is more sensitive to weather than is rail (Guo, Wilson, & Rahbee, 2008).

An important element discussed in this research and adopted in this analysis' statistical study is the level of analysis. The authors describe four criteria for an appropriate measure that ultimately lead to the selection of daily analysis, including:

1. Allowance for sufficient variation between units in weather and ridership to achieve a statistically robust analysis;
2. Minimal intrinsic fluctuation between units in terms of both weather and ridership; a month is a bad unit of analysis because there is systematic change in weather from March to April, for example;
3. Easy representation of weather by a specific variable; and
4. Unit of analysis should reflect the real decision-making context.

III. Data collection

Closely following the statistical model used in the Chicago Transit and Weather study, the analysis strives to econometrically estimate the relationship between regular weekday service bus ridership on the Metro Transit routes that travel to, from, or through Minneapolis, Minnesota, and hypothesized independent variables such as temperature, weather events, road conditions, and other external economic indicators. The raw data used to prepare the model for testing, as well as the data sources, include:

- Daily Metro Transit bus ridership – Minneapolis routes (Metro Transit)
- Monthly average MnDOT time to bare lane on super commuter segments (MnDOT)
- Monthly total MnDOT expenditures on snow clearance labor hours, equipment, and material usage on super commuter plowing segments (adjusted to 2011 USD) (MnDOT)
- Metropolitan area average price of gasoline (weekly average) (BTS)
- Metropolitan area monthly unemployment (no seasonal adjustments) (BLS)
- Metropolitan area average monthly household expenditures on transportation (BTS)
- Daily average, high, low temperatures – MSP Airport (NOAA)
- Daily snow accumulation – MSP Airport (NWS)
- Daily total snowfall, precipitation – MSP Airport (NOAA)
- Daily heating degree days (base of 65 degrees F) – MSP Airport (NWS)
- Daily cooling degree days (base of 65 degrees F) – MSP Airport (NWS)
- Daily average wind speed – MSP Airport (NWS)
- Daily sustained peak wind speed – MSP Airport (NWS)

IV. Methodology

In addition to the type of data collected and the disaggregation to the daily level suggested by the Chicago study, a careful analysis of ridership drop-offs was conducted to ensure that the appropriate service days were included in the analysis. Metro Transit's provided data did included a variable that designated whether the service day was a weekday, weekend, holiday, or reduced, but did not designate holiday such as Veterans' Day, Martin Luther King Day, or President's Day. These, along with Inauguration Day (January 19th), Good Friday, and the week following Christmas and New Years' Day, were all subsequently removed from the service days included in the analysis; a visual representation of the impacts of these outlier ridership days can be seen in comparing the differences between Figure 1 and Figure 2 in the Appendix.

Additionally, the University of Minnesota ridership, although extremely challenging to accurately remove from the analysis, is also a source of seasonal variation. One of the clearest ways to remove this variation due to the beginning and end of academic terms was to eliminate the 100 numbered routes designated as University of MN oriented limited stop routes from the daily ridership sums.

Following the analysis of variance (ANOVA) test and resulting F and p statistics that led to the ability to reject the null hypothesis, a time-series log-linear regression model using the ordinary least squares method of parameter estimation was completed. In order to effectively eliminate tested coefficients that did not result in a p-value falling under the .05 significance threshold, the reverse pair-wise functionality within the SPSS software was used.

Once these pair-wise tests were completed, further tests for collinear relationships and autocorrelation on promising and potentially significant coefficient estimates were completed to ultimately ensure an appropriate and robust set of model coefficient estimates. These tests included artificially moving one of the independent variables to the opposite side of the equation to test for linear relationships and the calculation of the Durbin Watson statistic.

An example of the equation form tested throughout this process is as follows:

Equation 1.1:

Natural Log (Y) = $B1 + B_2 (X_2) + B_3(X_3) + B_4(X_4) + \ldots + B_n(X_n) + e_d$
Where:

Yd is the Metro Transit bus ridership on the ridership day *d;*
B1is a constant term;
B2 –B_n are the 1st through nth statistically significant coefficient estimates; and
e_d is an error term, which is assumed to be normally distributed with a mean of zero.

V. Results of Econometric Modeling

Although the results of the modeling are not packed with explanatory coefficients beyond the understanding of those who specialize in the study of transportation and public transit fields, the statistically significant outcomes represent one of, if not the, first tested models on the Twin Cities data, and specifically in application to the City of Minneapolis. Results of the final regression are listed below.

Table 1: Regression Results

	df	*SS*	*MS*	*F*
Regression	5	1.076	0.215	34.820
Residual	821	5.077	0.006	
Total	826	6.154		
	Coefficients	*Standard Error*	*t Stat*	*P-value*
Intercept	12.004	0.017	722.339	0
Daily Precipitation	-0.056	0.011	-5.081	4.641E-07
Avg. Weekly Gas Price	0.047	0.005	9.420	4.431E-20
Avg. Temp Departure	0.003	0.000	6.809	1.902E-11
Heating Degree Days	0.002	0.000	10.140	7.592E-23
Snow Depth	-0.009	0.001	-8.057	2.750E-15

Due to the nature of the estimated log-linear model, the combined effects of the coefficients represent the amounts that contribute to a 1% increase in weekday, regular-service-day ridership on Minneapolis based bus routes. Interestingly, despite the seemingly intuitive nature of these results, only the average (non-leaded) gas price out of the five coefficients is self-explanatory; combined with the other coefficients, a $0.04 weekly average increase in the price of gasoline can reasonably explain an approximate 1% increase in ridership.

Table 2: 2000-2004 Snow and Rain Traffic Impacts on Arterial Roads

Snow Category	Snow Intensity (Inch/ hour)	2000 Highway Capacity Manual Capacity Reduction Estimates	2000-2004 Twin Cities Study - Capacity Reduction	2000-2004 Twin Cities Study - Speed Reduction	Rain category	Rainfall intensity (Inch/ hour)	2000-2004 Twin Cities Study - Capacity Reduction	2000-2004 Twin Cities Study - Speed Reduction
None	0				None	0		
Trace	<=.05		3%-5%	3%-5%	Trace	<.01	1%-3%	1%-2%
Light	0.06-0.1	5%-10%	6%-11%	7%-9%	Light	0.01-0.25	5%-10%	2%-4%
Moderate	0.11-0.5		7%-13%	8%-10%	Heavy	>0.25	10%-17%	4%-7%
Heavy	>0.5	25%-30%	19%-27%	11%-15%				

Source: TRB 2000 Highway Capacity Manual; Agarwal, Maze, & Souleyrette, 2005.

The significance of the coefficients for precipitation, which includes a measurement for snow and rain, and standing snow depth are interesting to analyze. Despite the ability for falling snow to reduce travel times more significantly that rain alone, as displayed in capacity and speed of traffic impacts table below, it seems that a mix of rain, freezing rain, and snow, in combination with existing snow from previous days, tells a more complete story. Perhaps the significance of the precipitation variable (for which .05 also measures as .5 inches of snow) over the falling snow variable even speaks to the decreased amount of predictability of travel times in a one's personal vehicle.

Finally, the average temperature departure and heating degree day coefficients are also interesting. The first represents the temperature departure from the 39-41 year historical average temperature for that calendar day; the latter is an indirect and relative measure of fuel (heat) costs, and is simply the absolute difference between a day's average temperature and the base for the National Weather Service's HDD standard, 65 degrees Fahrenheit. As the difference between a winter average daily temperature and 65 degrees lessens (or as the temperature increases), ridership, in combination with the average departure and previously mentioned coefficients, is likely to increase. The interesting aspect is that the average, low, and high daily temperature data points were all ridden with problems; the first two were noticeably volatile between model iterations, which is a major red flag for collinear variables, and the residuals of the third were not randomly distributed, which was reflected in p scores between .12 and .18 in various model iterations.

Design flaws and areas for improvement in future research are present in nearly any research piece; major opportunities for increasing the span, complexity, and precision of this model undoubtedly exist. Added years of ridership data from Metro Transit, which suffered major accuracy and collection problems prior to January of 2008, will be the most helpful data point to advance this model. The following data points, which were also unavailable at the time of this research, may also contribute to future research:

- On-time bus performance percentages
- Average operating speed of busses
- Count of heated/enclosed transit stops (no construction year available, so time-series measurements are not useful)
- Date and budgetary expenditures on snow emergencies declared by the City of Minneapolis
- Count and local traffic incidents related to weather
- Average parking cost – no measure to gauge average, city-wide parking costs, or costs of parking in private lots or ramps in Minneapolis

In addition these variables, the lane miles data of major divided highways and bus priority lanes was unavailable from MnDOT. However, if staffing (and therefore data accessibility) were to improve, the variation in lane mile data would interesting to monitor on a specific segment of road in comparison to the major bus service serving the same segment of road, and perhaps in coordination with the MnDOT hours to bare lane and snow removal data (see Figures 3 and 4 for graphs of the current level of disaggregation of these data points). Unfortunately, it is very difficult to get these 3-5 data pieces correctly disaggregated in order to properly compare them. Instead, there is likely to be a mismatch between the length of the road segment served by transit compared to the segments applicable to the MnDOT data. Additionally, the loop detector and traffic counting technology is often disabled at or near MnDOT construction sites, so incomplete data for a time-series analysis is likely going to be a persistent problem.

VI. Policy Applications and Insights

El-Geneidy and Krizek's 2007 analysis, in combination with the other market research previously discussed and the outcomes of the statistical analysis, seem to collectively provide a wealth of opportunities for improvement of both users and potential future riders that are currently non-users. Although the focus of this study is narrowed to the weather impacts of ridership, the benefits of added convenience, comfort, and predictability to a transit trip and system are highly applicable in an effort to increase ridership.

A. Real Time Information and Feedback Systems

Multiple policy opportunities actually work to improve all three of these key aspects of the user experience. Minneapolis and Metro Transit are well on their way to full bus and rail implementation of one of the key suggestions in transit psychology research: dissemination of real-time arrival and departure information. Through the USDOT's Urban Partnership Agreement, Metro Transit, through the Metropolitan Council, received a grant to develop and launch the agency's "NexTrip" information system, which has already been launched on the Marquette and 2nd Avenue contra-flow bus facility, multiple Park and Ride facilities in the region, and through a set of internet and smart phone applications. Access to the information is crucial while passengers are waiting for arrivals, and especially while waiting to transfer, and the installation of new LCD display screens, as well as the retrofitting of screens on the Hiawatha line will be delivering this information on a wider scale by the end of 2012 (Siqveland, 2011).

Although this project is already partially executed and is planned for full implementation in approximately one year, many lower cost technology oriented improvements for the City of Minneapolis and Metro Transit should not be ignored. Although it is more applicable to zonal or distance-based fare structures, the opportunity for a commuter calculator mobile application or online tool would be an excellent strategy to manage user perceptions of both convenience and predictability. The tool could use a combination of averaged decreases in speed and capacity along a travel route with a specified origin and destination due to weather events, free-flow travel time estimates, and the Texas Transportation Institute's reliability multiplier to calculate travel (time) costs for personal automobiles and public transportation. This expanded version of travel time by mode information systems could be an easy mechanism to show the time, fuel efficiency, and emissions saving opportunity present in choosing transit for choice commuters in the Twin Cities.

B. Snow Removal Policy and Infrastructure Design

Improvements in the prevention of unnecessary travel mobility delays following weather events is another group of opportunities that may go a long way in creating a more navigable pedestrian environment that will increase convenience and ease in accessing transit stops, as well as an increasingly efficient traffic operation to support reliable travel times for transit. Increased dissemination of snow emergency and plowing information in Minneapolis, for example, works to keep residents prepared and cars off the street for faster snow clearance. A location-based application for the City's snow emergency, for example would provide users the necessary deadlines to avoid towing, based on their home or current location.

Increased sidewalk clearance enforcement, paired with a social awareness media campaign idea like WalkBoston's that frames an un-shoveled sidewalk as an act equally unacceptable to littering, would additionally create a more accessible pedestrian network after inclement weather that currently suffers from home and property owners that do not abide by the City's clearance requirements (Snow/Sidewalks, 2008). In addition, a shoveling deadline reminder could be incorporated into the location-based snow emergency application. These policy shifts, paired with smart sidewalk design standards that incorporate ides like wide boulevards for snow storage, curb ramp angles optimal for snow clearance from pedestrian traffic islands and transit stops will help keep people on their feet instead of in a private automobile when completing part of their commuting trip.

C. Transit Industry Best Practices Research

On a broader level, continued research and compilation of transit management and planning best practices for inclement weather is a necessity. Minimal information exists in this subject area, and the development and transfer of knowledge of practices to increase reliability during inclement weather events or seasons could be very beneficial. Strategies that could potentially be included in this type of research may range techniques to disseminate information to plowing schedule optimization to transit schedule run cutting during weather events or seasons to reduce probabilities of late arrival and low reliability and subsequent user dissatisfaction.

King County in the Seattle metropolitan area, for example, uses their website trip planner tool as an opportunity to notify users of weather-based service warnings, for example. Although the Twin Cities do not face the type of terrain and natural barriers present in the Seattle system that may warrant pre-announced service warnings, the concept of disseminating real-time transit arrivals, departures, and significant delays is reinforced. Additionally, the application is becoming increasingly applicable for future years, as the frequency of large precipitation events increases with climate change (see Figure 4) (FTA Office of Research, Demonstration, and Innovation, 2011).

D. Land Use, Work Force Composition, and Commuter Habits

Finally, a 2011 unpublished study of the geography of commuters by University of Maine economist and professor Todd Gabe leaves a few additional thoughts that are both relevant for future study and a good reminder of the importance of the basics discussed in this analysis' literature review. In this case, he makes the argument that, above all, land use determines commuter habits. Factors such as the share of housing constructed between 2000 and 2006, which is a somewhat relative measure for continued sprawl, remain highly relevant to the equation; this share is negatively associated with the use of bicycles or transit as a means of transportation to work. Somewhat similarly and undoubtedly important to realize, within the inner city, the length of the commute (based on a city's average commute time) shows a positive relationship with the likelihood of commuters to use transit instead of walking or bicycling (Florida, 2011).

Gabe also notes an additional interesting relationship found in his study between the *type* of workers in an urban area; the share of workers in the creative class, including scientists, engineers, techies, innovators, and researchers, as well as artists, designers, writers, musicians and professionals in healthcare, business and finance, the legal sector, and education, is positively associated with the percentages of people who take public transit or walk or bike to work. Of course, the connection between all of these measurements and weather is also noted by Gabe; weather and climate do play a role, he insists, as walking, bicycling, and public transit use are all greater in drier climates. However, relative to those with very warm temperatures and wet weather, places with colder January temperatures also are more likely to have a greater share of transit users (Florida, 2011).

VII. Conclusion

Through the careful exploration of a hypothesized relationship between public transit ridership in Minneapolis and external factors such as weather and gas prices, a statistically significant relationship has been uncovered. Through a combination of the temporal-based research, these quantitative results, and the policy application set forth at the end of the analysis, the City of Minneapolis and the Metropolitan Council can clearly implement changes to the public transportation system. Additionally, the acquired knowledge of weather impacts should assist in the city and Met Council for strategic transit and weather management programs in the future that have the potential to drastically increase ridership toward the goals set forth in the 2030 planning documents.

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