Evaluating the effect of Weather and Socioeconomic Factors on Transit Ridership in the Twin Cities, Minnesota

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Presentation Layout

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Motivation (1/1)

- To study the effects of weather and socioeconomics on transit ridership in Minnesota: how do Minnesotans react to different weather conditions?
- Do people have different mode choices according to the weather?
  - If yes, how?
- Do socio-economic factors like gas price and employment affect ridership?
- Goal: to determine the significance of weather and socioeconomic effects on ridership
  - Is it worth investing in mitigation strategies?

Assumptions (1/1)

- Ignore effects of service area expansions
  - Limitation of route-based data instead of stop-based data
- Climate parameters measured at Minneapolis-St Paul (MSP) airport is applicable everywhere
- Assume weather effects to be constant throughout the day

Methodology (1/1)

- Analysis using Ordinary Least Squares (OLS) regression
- 5 models: 4 seasonal models (spring, summer, fall, winter), 1 combined model
  - Separate models to see if the overall trend is different according to the season
  - To determine whether seasonal ridership data differ
    - Hypothesis test (F-test for variance)

Null: $\mu_{sp}=\mu_{su}=\mu_{fa}=\mu_{wi}$
Alt : $\mu_{sp}\neq\mu_{su}\neq\mu_{fa}\neq\mu_{wi}$

F-val = 11.80054 >> 1 (seasonal data differ)

->Create 4 seasonal models

Data: Acquisition (1/5)

- Metro Transit service area, Twin Cities, Minnesota
  - Adjusted APC 2008-2016 route-based daily ridership data (Metro Transit) (~8 years)
  - Did not keep track of route changes, a lump sum analysis is done
  - Weather data w.r.t. Minneapolis-St. Paul (MSP) (Minnesota Department of Natural Resources (MNDNR))
    - Average temperature
    - Dew point
    - Wind speed
    - Precipitation/snow fall depth
  - Weekly gas prices (U.S. Energy Information Administration (EIA))
  - Employment data (U.S. Bureau of Labor Statistics (BLS))

Data: Weather (2/5)

Parameter	Notes
Weather	
Average temperature	Comfort, mode choice
Relative Humidity (dew point)	Comfort, expectation of weather
Wind speed	Comfort
Precipitation/snow depth	Comfort, mobility, mode choice

Data: Temporal/Events (3/5)

Parameter	Notes
Day events	
Weekend/holiday or weekday	Boolean {0,1} (Dummy) Potential trips change during breaks
Season	
Spring, Summer, Fall, Winter	Boolean {0, 1} (Dummy) Uses the meteorological definition for range in months (March, April, May); (June, July, August); (September, October, November); (December, January, February).

Data: Socioeconomic and Other Factors (4/5)

Parameter	**Notes**
Socioeconomic	
Unemployment rate	
Workforce	
Other Events	
Green Line opening	Boolean {0,1} June 14, 2014 as starting date of operation
Weekly average gas prices	

Data: Relative Humidity (5/5)

- Calculate RH using Magnus Formula for dew point, solve for RH

$$RH = 100 * \exp\left(\frac{bT_{dp}}{c + T_{dp}} - \frac{bT}{c + T}\right)$$

For constants, use approximation for $-30°C \leq T \leq +35°C$, $\xi\,(T_{dp}) \leq 0.1\%$

b = 17.67 and c = 243.5^{o}C (Bolton, 1980)

OLS model

$$Ridership = \alpha_0 + \alpha_1 WK + \alpha_2 SP + \alpha_3 SM + \alpha_4 FA + \alpha_5 GL + \alpha_6 T_{avg} + \alpha_7 \mathrm{RH} + \alpha_8 SF$$
$$+ \alpha_9 P + \alpha_{10} WSavg + \alpha_{11} GP + \alpha_{12} U + \alpha_{13} WF + \xi$$

Variable	Description
α_0	Intercept value (captive riders)
α_i	Coefficients
WK	Weekend and holidays or weekdays
SP	Spring
SM	Summer
FA	Fall
GL	Green line presence
$Tavg$	Average daily temperature

Variable	Description
RH	Relative humidity
SF	Snowfall depth
P	Precipitation depth
WS_{avg}	Average wind speed
GP	Average gas prices
U	Unemployment rate
WF	Work force
ξ	Random variable with a mean value of 0

Results: Combined model Coef. and Statistics

	Coeff.	Std. Error	F-value (|F|>1.96)	P-value
Intercept	38434.05	70965.35	0.54	0.59
RH	-117.22	44.05	-2.66***	0.01
Snowfall	-1921.57	739.13	-2.60***	0.01
Precipitation	-6504.55	2132.59	-3.05***	0.00
Average Temperature	-77.58	41.45	-1.87*	0.06
Gasoline Price	40390.95	1230.08	32.84***	0.00
Unemployment Rate	1366.23	740.71	1.84*	0.07
Spring	-1256.31	1919.24	-0.65	0.51
Summer	-19597.45	2771.01	-7.07***	0.00
Fall	6855.53	1980.72	3.46***	0.00
Weekend	-136173.16	1090.03	-124.93***	0.00
Green Line	25093.53	2382.23	10.53***	0.00
Wind Speed	-132.57	144.80	-0.92	0.36
workforce	0.05	0.04	1.30	0.19

Adjusted R^2	**0.848 (decent fit)**
Observations	3133

***** represents results are significant at 99% confidence level**

**** represents results are significant at 95% confidence level**

*** represents results are significant at 90% confidence level**

Results: Seasonal Model Coef.

increase

decrease

Independent Variables	Fall	Summer	Spring	Winter
	Coefficients			
Intercept	1032546.579	42831.737	159865.25	151235.07
Weekend	-147299.054	-21367.564	-138849.17	-138009.91
Green Line	9415.771	34628.075	25730.408	23161.711
Average Temperature			-327.428	514.077
Relative Humidity		-200.119		-236.976
Snowfall				
Wind Speed				
Precipitation	-9523.488		-11516.562	-37792.675
Gasoline Prices	45238.583	52022.601	32911.680	33319.155
Work Force	-0.471			
Unemployment Rate	-9946.475	4628.234		
Adjusted R^2	0.896	0.870	0.874	0.800

Conclusion

- Transit ridership respond to changes in weather and socioeconomic events

	Effects on ridership
Intercept	
Rel. Humidity	Decrease
Snowfall	Decrease
Precipitation	Decrease
Average Temperature	Decrease
Gasoline Price	Increase
Unemployment Rate	Increase

	Effects on ridership
Spring	Not significant
Summer	Decrease
Fall	Increase
Weekend	Decrease
Green Line	Increase
Wind Speed	Not significant
workforce	Not significant

Observed trends from Combined Model

Conclusion

- Transit users behave differently by season
  - Seasonal expectations or activities
- Rain events affect ridership negatively significantly more compared to snow
  - More inconvenient or uncomfortable?
- Gasoline price increments positively affect ridership
  - e.g. transit waiting time outweigh fuel costs?
- Railway transit is a positive investment

Recommendations

- Waiting facilities with better weather shielding (cost vs profit?)
- Consider investments in railway transit
- Additional considerations that could be made
  - Variation in user behavior according to geography

  (do riders behave significantly different in locations of similar climate?)
  - Trip purpose

  (work and school trips are affected less compared to optional trips)

Future considerations

- Analysis with route-based data
  - To identify the routes which are susceptible to change in the ridership due to weather conditions
  - Does not capture service area expansion
  - Does not reflect spatial effect of impacts (e.g. unemployment)
- Consider population or network growth

End.