GTFS-enabled Spatiotemporal Analysis of Transit Services

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Transit Accessibility

- How easy it is for an individual to reach a desired destination using public transit?
- Public transit feasibility as a travel choice is affected by
  1. spatial coverage
  2. temporal coverage of transit services
- Applications
  1. Evaluation of the existing services
  2. Travel demand forecasts
  3. Decision making related to transportation investments and land use development

Transit Accessibility Measures

- Travel Time Discretionary:
  1. Local Index Of Accessibility (LITA)
  2. Transit Capacity and Quality of Service Manual (TCQSM)
  3. Time of Day

- Travel Time Dependent:
  1. Cumulative Measures (Vickerman, 1974)
  2. Gravity (weighted) Measures (Hansen, 1959)
  3. Utility-Based Measures
  3. Constraints-Based Measure (Wu & Miller, 2002)
  4. Composite Measures (Harvey Miller, 1999)

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Cumulative Accessibility Measures

- Counts the number of potential opportunities that can be reached within a predetermined travel time window(or distance):

$$A_i = \sum_{j=1}^{J} B_j * a_j$$

A_i- Cumulative Accessibility Measure at point *i* to potential activity zones *J*

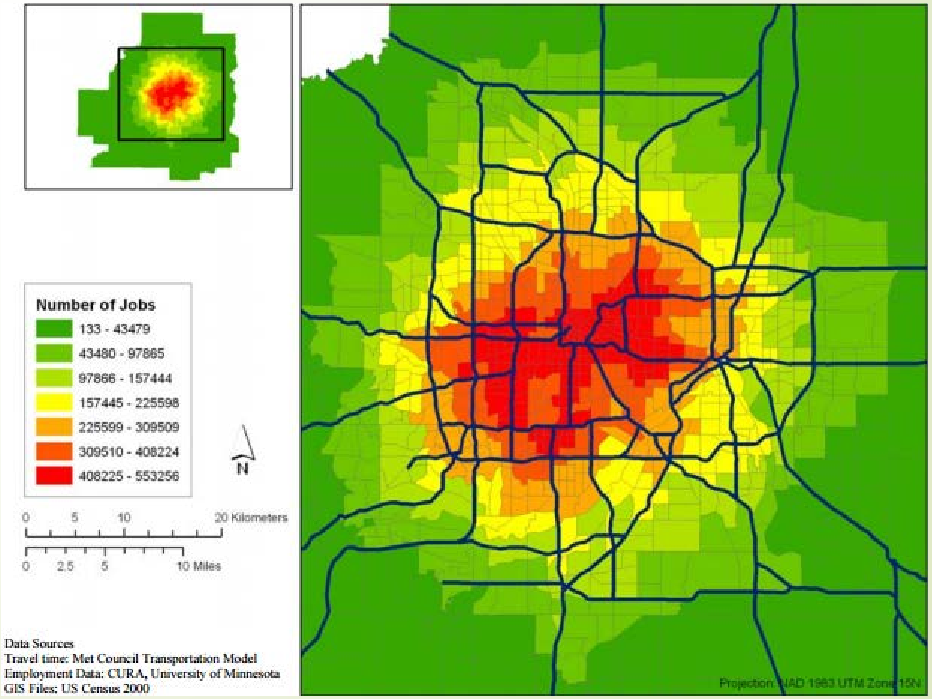
B_j- A binary value equals to 1 if zone *j* is within the predetermined threshold and 0 otherwise

a_j- Opportunities in zone *j*

Cumulative Accessibility Measures

- Number of jobs within 10 minutes of travel time by automobile during the morning peak in 2000

Adopted from El-Geneidy & Levinson, 2006.



Gravity Accessibility Measures

- Weights the number of potential opportunities that can be reached based on impedance or cost function (e.g. time, distance):

$$A_i = \sum_{j=1}^{J} O_j * f(C_{ij})$$

A_i- Gravity Accessibility at point *i* to potential activity at point *j*

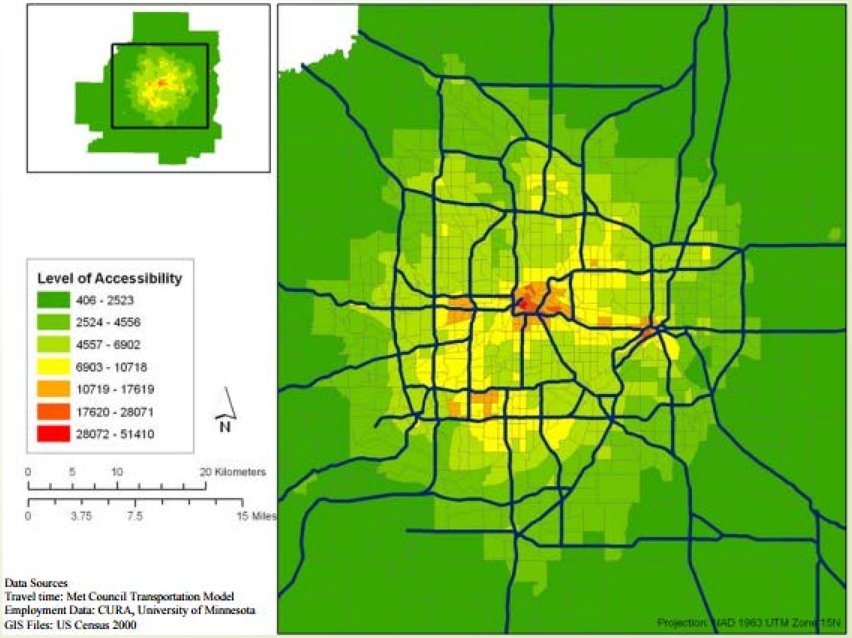
O_j- The opportunities at point *j*

$f(C_{ij})$- The impedance or cost function to travel between *i* and *j*

Gravity Accessibility Measures

- Gravity-based accessibility to jobs by automobile during the morning peak in 2000 using the $\frac{1}{tt_{ij}^2}$ as impedance function

Adopted from El-Geneidy & Levinson, 2006.



Weighted Average Travel Time Potential Accessibility

- Weighted Average Travel Time (WATT)

$$WATT_i = \frac{\sum_{j=1}^{J} O_j * tt_{ij}}{\sum_{j=1}^{J} O_j}$$

$WATT_i$- WATT for station *i*

tt_{ij}- Travel Time between station *i* and station *j* using public transit

- Potential Accessibility (PA)

$$PA_i = \sum_{j=1}^{J} \frac{O_j}{tt_{ij}}$$

PA_i- PA for station *i*

Limitations

Previous studies do not consider:

- Temporal changes in transit service throughout the day and day of week
  1. Neglect the transit-dependent population
  2. Neglect the daily fluctuation in transit services

- Unclear Visualization

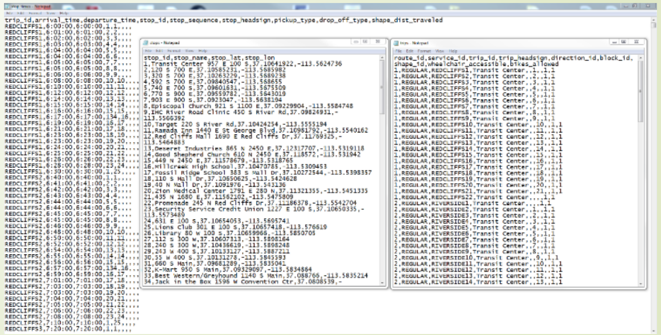
- Hard for agencies to implement the method
  1. Computation extensive with ARCGIS (60 days for Salt Lake City transit)
  2. Challenging to find transit service data
  3. Importing the raw data is challenging

Our Contribution

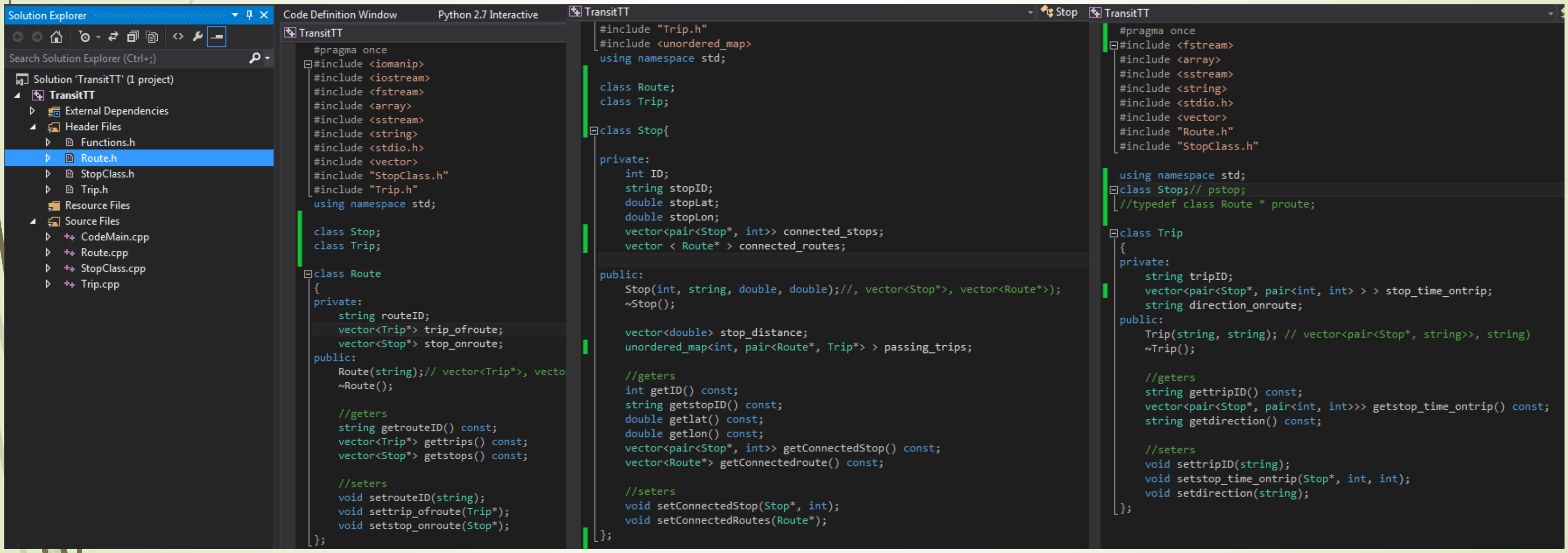
- Develop a user-friendly efficient tool to calculate PA and WATT for every minute of the week and provide a clear visualization of results
  - ✓ Use open source databases (GTFS and Census data)
  - ✓ Develop a travel time calculation algorithm from GTFS data
  - ✓ Use C++ to improve the computational efficiency
  - ✓ Filtering the results based on socioeconomic characteristic of station coverage area

GTFS

- General Transit Feed Specification (GTFS) was created in 2005 by Google and TriMet to Represent agencies' schedule, trip, route, stop data, etc.
- Zip file consists of several plain text files which been formatted as Comma-separated Values (CSV).
- Potential applications:
  1. Transit Operation performance measures
  2. Ridership performance measures (combined with APC)
  3. Transit Accessibility Measures



GTFS in C++
Stops, Routes, Trips



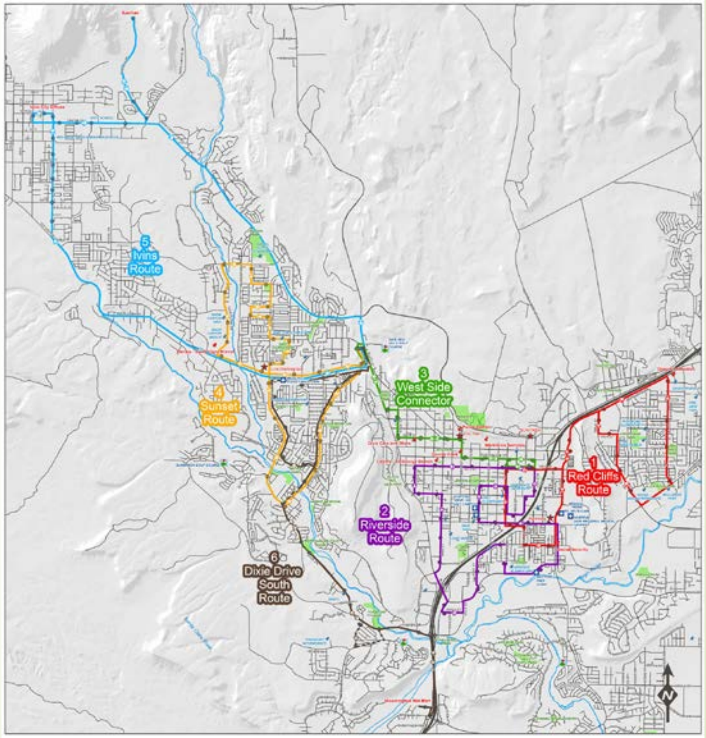

```cpp
#pragma once
#include <iomanip>
#include <iostream>
#include <fstream>
#include <array>
#include <sstream>
#include <string>
#include <stdio.h>
#include <vector>
#include "StopClass.h"
#include "Trip.h"
using namespace std;

class Stop;
class Trip;

class Route
{
private:
    string routeID;
    vector<Trip*> trip_ofroute;
    vector<Stop*> stop_onroute;
public:
    Route(string);// vector<Trip*>, vecto
    ~Route();

    //geters
    string getrouteID() const;
    vector<Trip*> gettrips() const;
    vector<Stop*> getstops() const;

    //seters
    void setrouteID(string);
    void settrip_ofroute(Trip*);
    void setstop_onroute(Stop*);
};
```

```cpp
#include "Trip.h"
#include <unordered_map>
using namespace std;

class Route;
class Trip;

class Stop{

private:
    int ID;
    string stopID;
    double stopLat;
    double stopLon;
    vector<pair<Stop*, int>> connected_stops;
    vector < Route* > connected_routes;

public:
    Stop(int, string, double, double);//, vector<Stop*>, vector<Route*>);
    ~Stop();

    vector<double> stop_distance;
    unordered_map<int, pair<Route*, Trip*> > passing_trips;

    //geters
    int getID() const;
    string getstopID() const;
    double getlat() const;
    double getlon() const;
    vector<pair<Stop*, int>> getConnectedStop() const;
    vector<Route*> getConnectedroute() const;

    //seters
    void setConnectedStop(Stop*, int);
    void setConnectedRoutes(Route*);
};
```

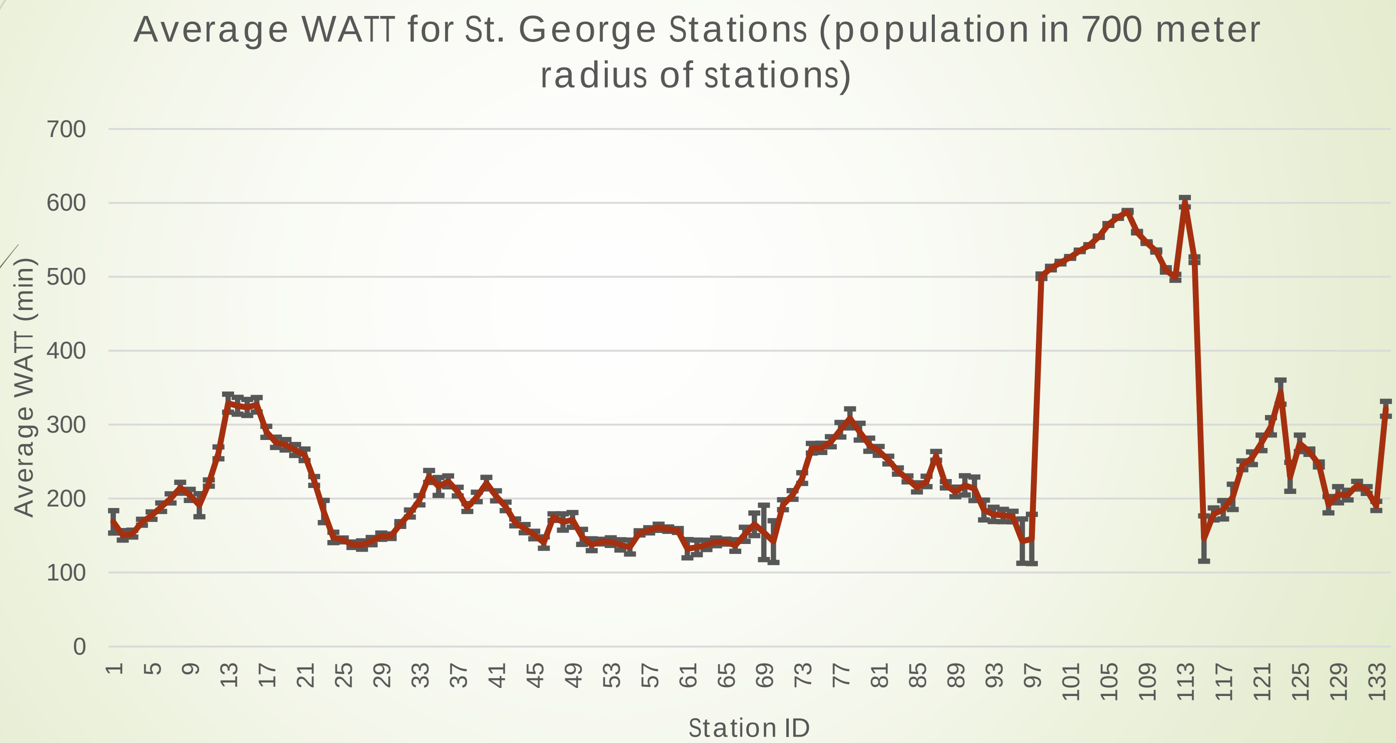
```cpp
#pragma once
#include <fstream>
#include <array>
#include <sstream>
#include <string>
#include <stdio.h>
#include <vector>
#include "Route.h"
#include "StopClass.h"

using namespace std;
class Stop;// pstop;
//typedef class Route * proute;

class Trip
{
private:
    string tripID;
    vector<pair<Stop*, pair<int, int> > > stop_time_ontrip;
    string direction_onroute;
public:
    Trip(string, string); // vector<pair<Stop*, string>>, string)
    ~Trip();

    //geters
    string gettripID() const;
    vector<pair<Stop*, pair<int, int>>> getstop_time_ontrip() const;
    string getdirection() const;

    //seters
    void settripID(string);
    void setstop_time_ontrip(Stop*, int, int);
    void setdirection(string);
};
```

ST. George Transit Map SUNTRAN

- 6 bus routes
- 134 transit stops
- Fixed Headway of:
  1. 40 mins
  2. 80 mins
- City Population: 76,817

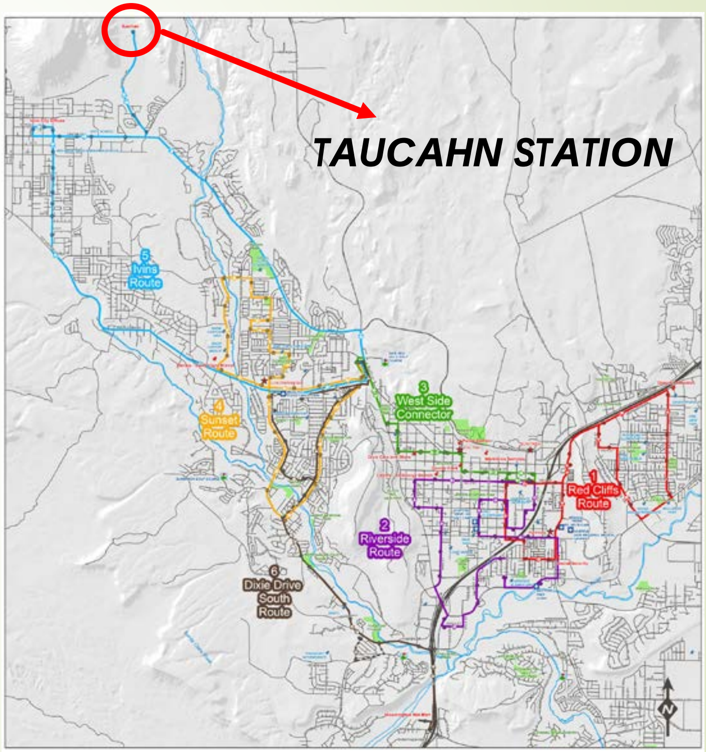


St. George Stations WATT Run Time = 4 mins

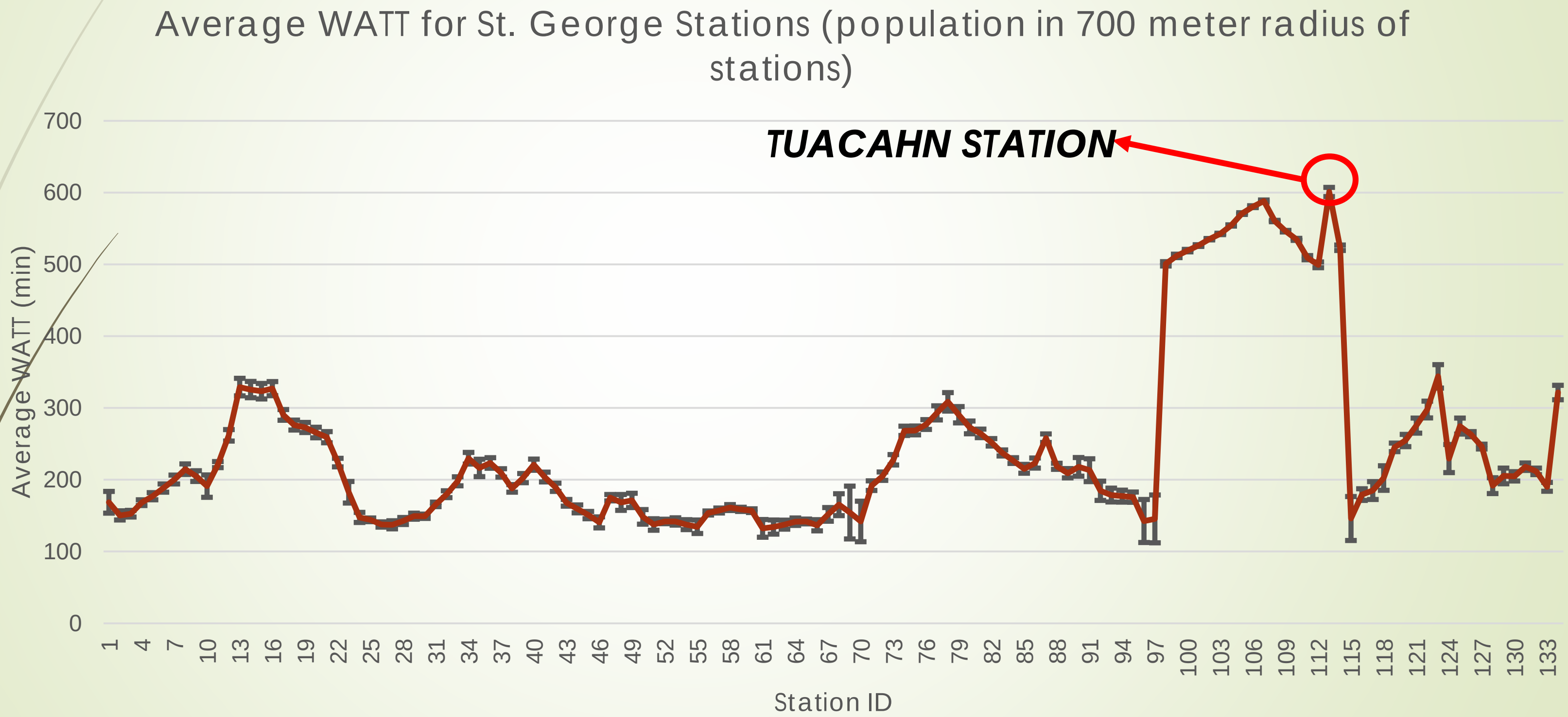


ST. George Transit Map TAUCAHN Station

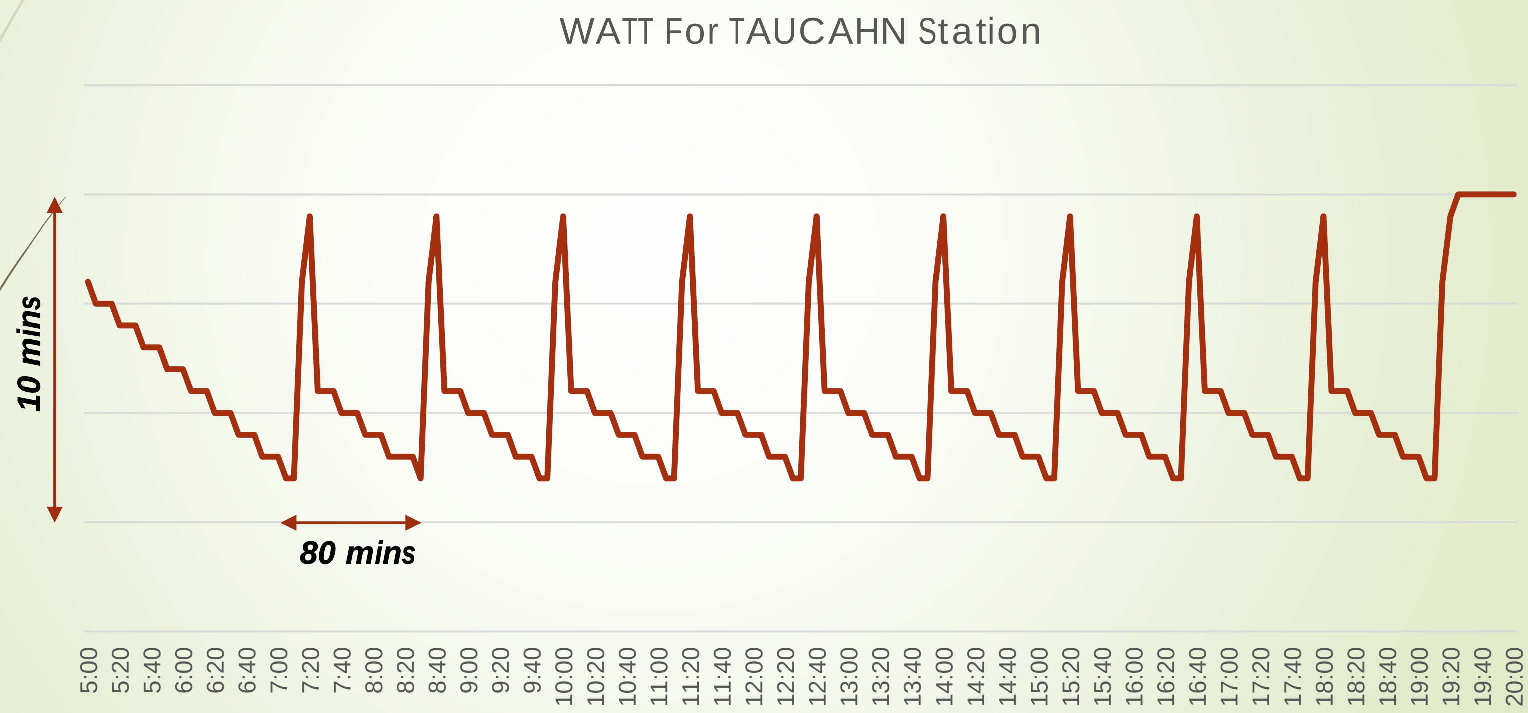
- Recreational Station
- Route 5 is the only passing route
- Headway : 80 mins
- Population around the station is about 20 people



Tuacahn Station's WATT

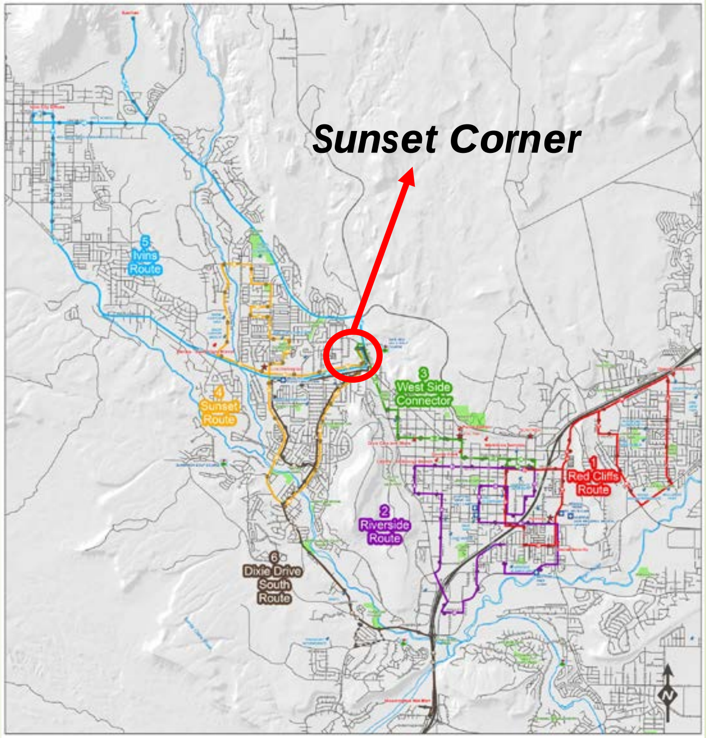


TUACAHN Station WATT

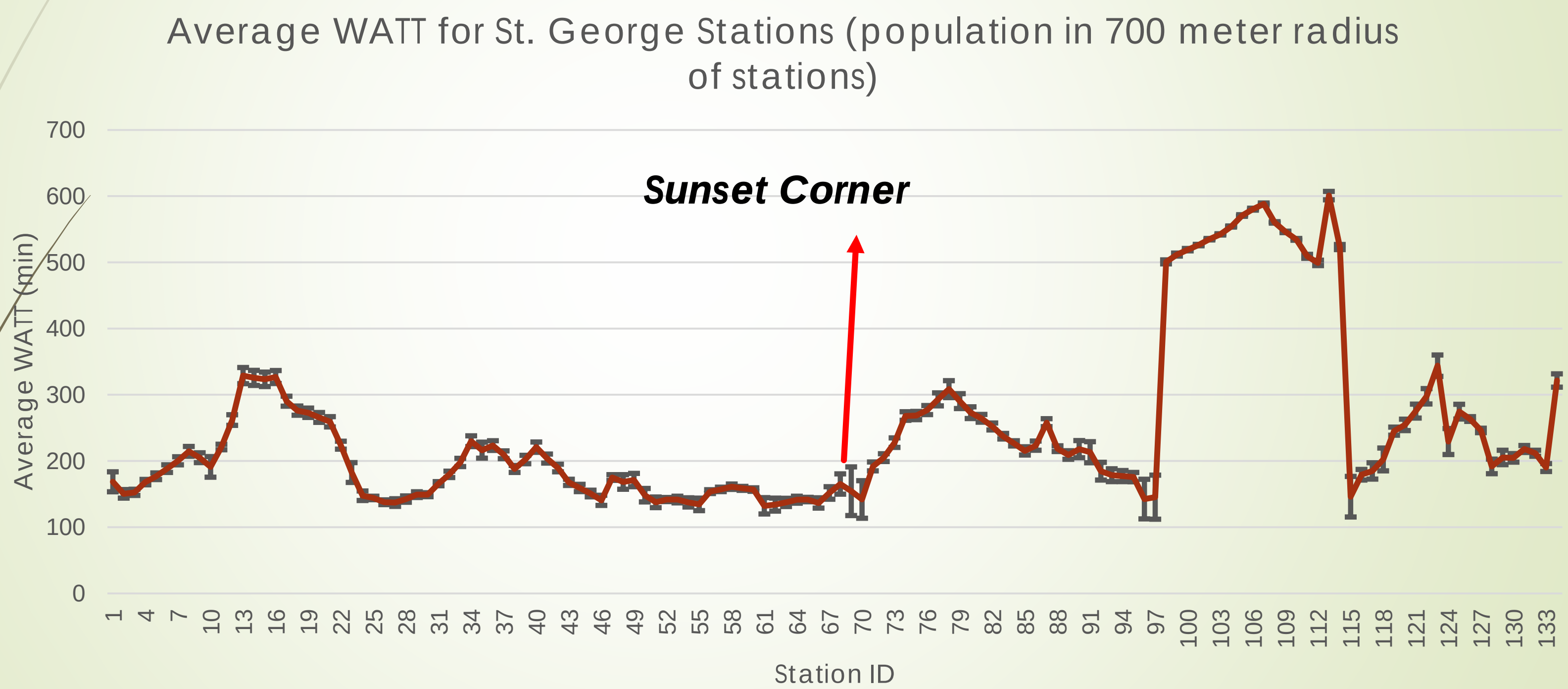


ST. George Transit Map
Sunset Corner Station

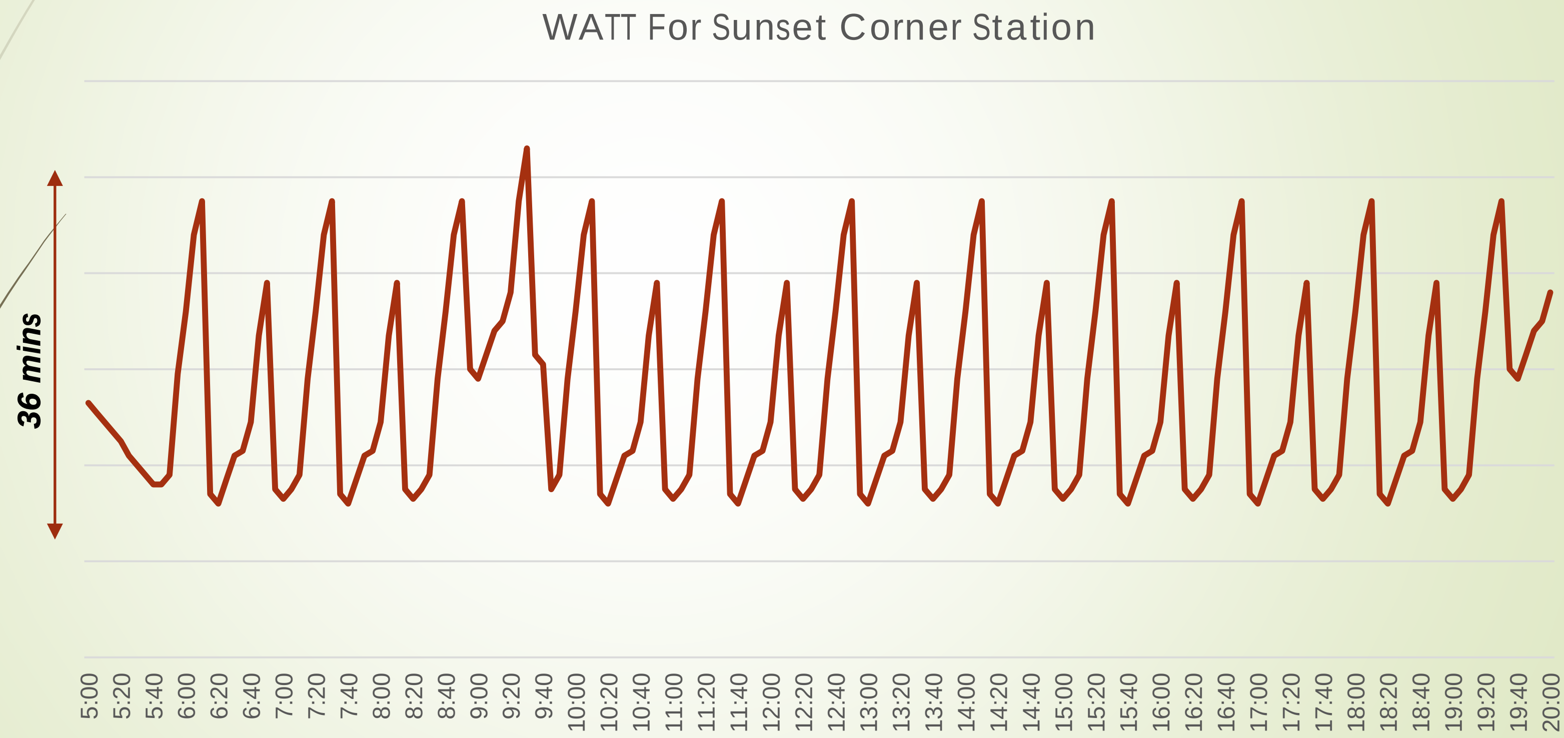
- Close to shopping Centers
- Routes 3, 4, 5, and 6 are passing this station
- Population around the station is about 1600 people



Sunset Corner Station's WATT

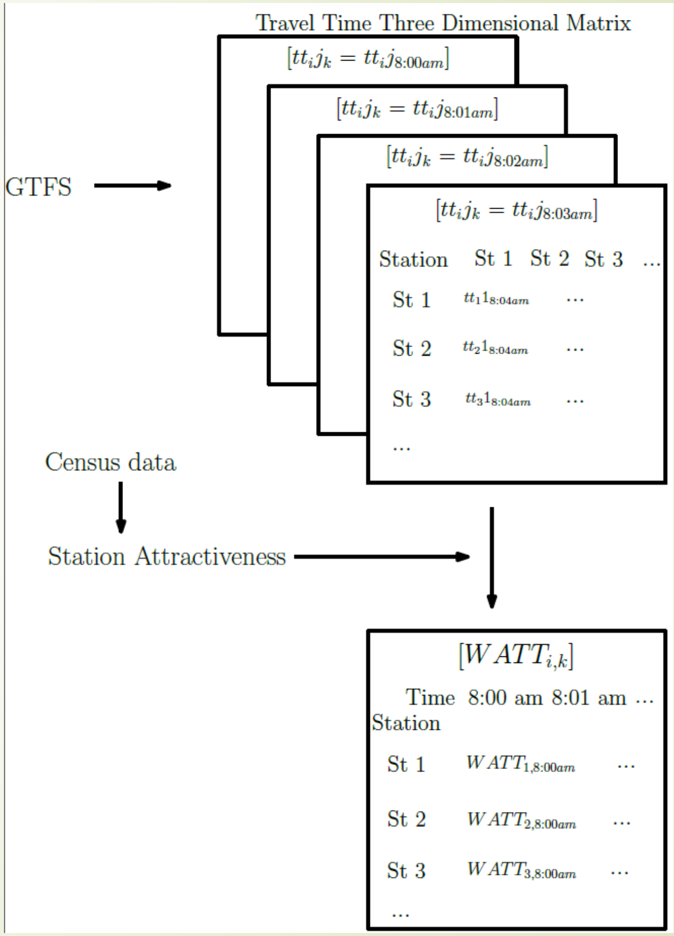


TAUCAHN Station WATT

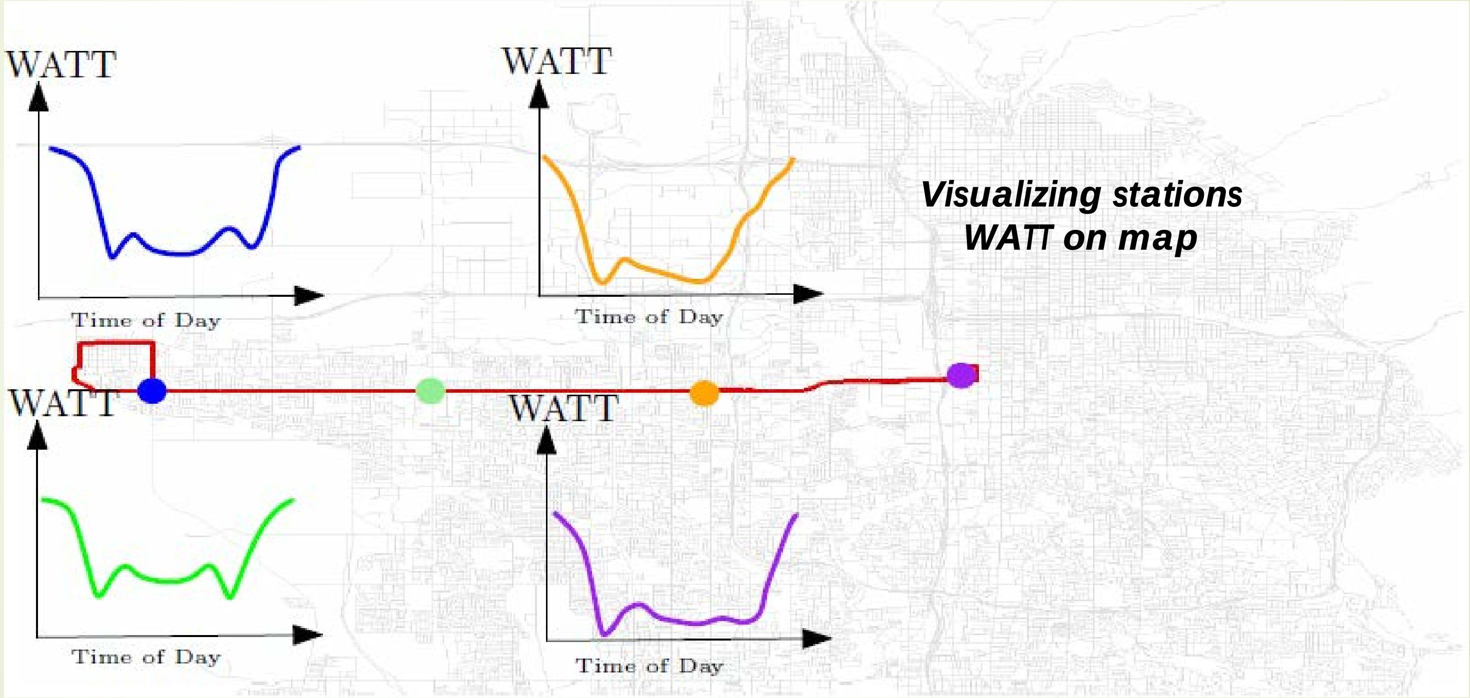


Conceptual Framework

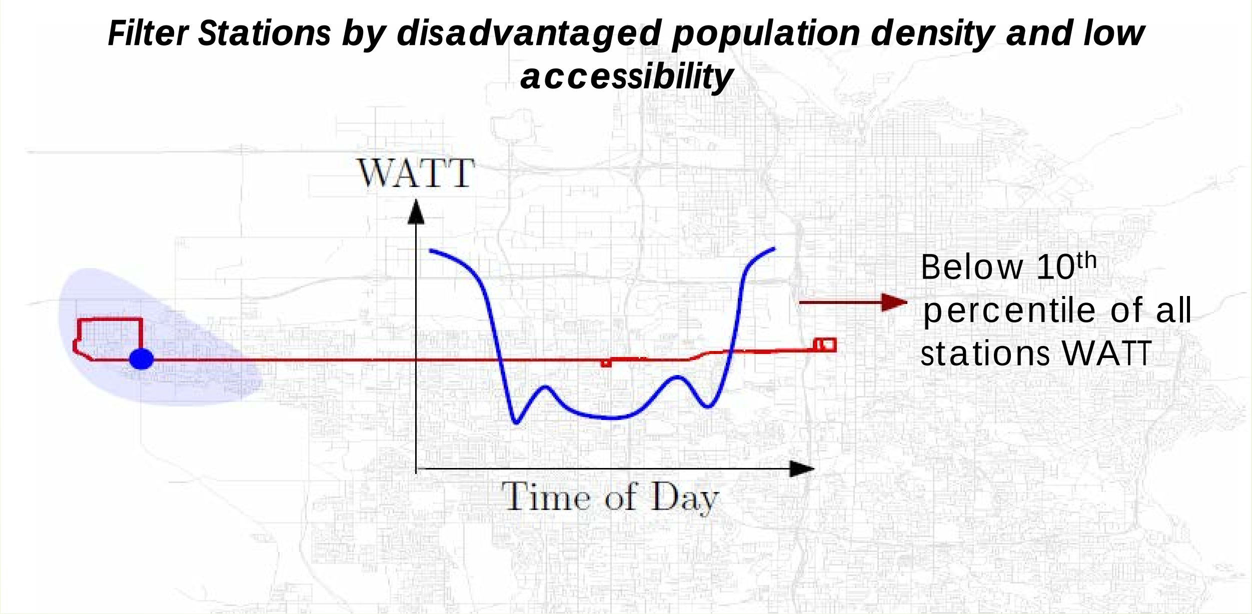
- Using GTFS the travel time between all stations for each time-of-day is calculated
- From census data, station attractiveness is calculated (number of jobs)
- Using the results of previous steps, WATT for each station and time-of-day is calculated



DATA Visualization



Data Visualization



APC and AFC Study

- Using Genetic Algorithm to prepare the APC/AFC dataset (noise cancelation)

$$GA: \text{minimize } (abs(\, DT_{estimated_i} - DT_{actual_i}))$$

- Combining Linear Regression with GA to analyze the fare payment structure of bus routes

$$GA: \min[abs\,\{(\beta_{B_{CTVM}} * B_{CTVM_i} + \varepsilon_i) - \left(\alpha_{B_{Cash_i}} * B_{Cash_i} + \alpha_{B_{TVM_i}} * B_{TVM_i}\right)\}]$$

R-squared =	0.9011			
Adjusted R-squared =	0.9009			
F(12, 7712) =	5852.9 9			
Prob > F =	0.00			
DT	Coefficient	Std. Error	t	P>|t|
Weekend *	1.087	0.173	6.30	0.000
B-EFC *	5.279	0.081	65.57	0.000
B-TVM *	1.803	0.025	73.03	0.000
B-Cash *	6.917	0.033	211.6 8	0.000
A-EFC *	2.020	0.206	9.79	0.000
A-CTVM *	1.611	0.037	43.40	0.000
Door-Cycle *	1.509	0.097	15.60	0.000
Fair-Mall stop indicator (Magna dir.) *	2.116	0.192	11.00	0.000
3575 W stop indicator *	-2.588	0.259	-9.98	0.000
3955 W stop indicator *	1.617	0.204	7.92	0.000
Fair-Mall stop indicator (TRAX dir.) *	3.432	0.277	12.40	0.000
1685 W stop indicator *	2.287	0.225	10.15	0.000
Constant*	2.026	0.143	14.15	0.000

Future Work:
WATT and APC/AFC data

Modeling the joint impact of WATT on ridership (APC) and fare payment (AFC) can help answer these questions:

- Dwell Time Analysis to improve GTFS travel time
- Transit service (fare, service coverage, etc.) vs. social equity
- Does higher accessibility encourage higher ridership?
- If yes? How?
- What are the externalities affecting ridership?

THANK YOU!

REFERENCES:

- Scheurer, J., & Curtis, C. (2007). Accessibility measures: Overview and practical applications. *Department of Urban and Regional Planning, Curtin University*, *52*.
- El-Geneidy, A., & Levinson, D. Access to destinations: Development of accessibility measures. 2006. *Minnesota Department of Transportation: Minnesota*, 124.
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- Fayyaz, S., Kiavash, S., Liu, X. C., & Porter, R. J. (2016). A Genetic-Algorithm and Regression-Based Model for Analyzing Fare Payment Structure and Transit Dwell Time. In *Transportation Research Board 95th Annual Meeting* (No. 16-4815).