Analysis on Social Impacts of Atlanta Streetcar System Emissions

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Introduction

For more than 100 years, our society have relied on internal combustion engines as the primary means to move vehicles for traveling activity. However, the widespread use of the engine technology and increasing transportation demand result in severe sustainability problems such as emissions, urban heating, urban noise, etc. In addition, our society is facing increasing environmental and political consequences from extracting and burning fossil fuels. According to U.S. Environmental Protection Agency (U.S. EPA, 2009), the transportation accounts for 29% of the greenhouse emissions of the whole country. Based on the data from Federal Transit Administration’s National Transit Database, the national average results show significant reduction in greenhouse emissions from transit (Hodges, 2010). To release the social pressure, the generation of electric transit vehicles presents one promising solution that can be part of a broader re-envisioning of our transportation system. Using electric vehicles in public transit system could contribute to reduce climate change, pollution, urban heat, urban noise and oil dependence (Electric Forum, 2011). The city of Atlanta made an investment of $98 million to rebuild the electric streetcar system. It opened on December 30, 2014 and intended to be expanded to cover and encompass economically important portions of the city, including: the primary retail district area, Piedmont Park, the Georgia Institute of Technology, and notable tourist destinations (Cleantechnica, 2015). This paper intends to assess the social impacts of Atlanta electric streetcar system by cost-benefit analysis, especially the social impact in emissions reduction from conventional fuel alternatives, and by which to provide an instance for future energy study in electric transit vehicles emissions.
Literature Review

Vehicle accidents affect millions of Americans and cause enormous economic loss every year. During 2015, roadway crashes caused 35,092 fatalities as well as large financial loss for the country (National Highway Transportation Safety Administration, 2015). In addressing roadway safety problems, the World Health Organization suggests that the countries should focus on a comprehensive approach including road environment, road users, and vehicles (World Health Organization, 2014). Intersection accident is one of the largest categories of the accidents of the nation. There are approximately 40 percent of all accidents involve intersection (AutoAccident, 2016). Crashes are more likely to occur at intersections because the vehicle activities are more complicated at intersections and have more potential in conflicts, such as left-turning and over-crossing (National Highway Transportation Safety Administration, 2015). From a city planner perspective, it is important to measure the social and economic impact of accidents. According to National Highway Transportation Safety Administration, for each fatality, the lifetime cost for society is $1.4 million, including the loss of workplace and household productivity, legal costs, etc (National Highway Transportation Safety Administration, 2010). For motor vehicle crashes, private insurers pay approximately 50% of all costs, while individual crash victims pay about 26%, third parties (uninvolved motorists delayed in traffic, charities and health care providers) pay about 14% and government accounts for 9% (Rocky Mountain Insurance Information Association, 2016).
Statistical and investment analysis have been widely used in road safety improvement studies. Mangones et al. developed a benefit-cost analysis under uncertainty using Monte Carlo simulation to assess the effectiveness of crash avoidance systems in the U.S. (Mangones et al., 2017). Niroomand and Jenkins estimated the value of fatality and injury risk reductions based on a case study in North Cyprus area, and then designed an experiment to find car drivers’ preferences for travel times, travel costs, and safety on a route (Niroomand and Jenkins, 2016). Jadaan et al. performed a case study in Jordan and investigated all parties involved in traffic safety with a best practice guide and a comprehensive road safety strategy to assist them in their initial strategic choice of cost-effective investments that aim to improve road safety (Jadaan et al., 2016). Dojutrek developed a cost-effectiveness method in multi-criteria decision-making, which could be measured in terms of the increase in security rating or the security rating after implementing the security investment project (Dojutrek, 2014).

Fatal and non-fatal damage costs make up an important part of accident costs. Damage costs include a variety of expenses such as medical treatment, material and immaterial damage, legal assistance, law enforcement and loss of time (Haight, 1994). Monetary valuation of traffic safety requires an estimate of the economic value of a statistical life (Hauer, 1994). In order to measure the value of a statistical life, De Blaiej et al. stated that monetary value of safety in public sector cost–benefit analyses should reflect the preferences of those affected by the policy measure (De Blaiej et al., 2003). So far the most widely accepted method to calculate the value of statistical life is based on the maximum utility theory (Andersson, 2007). The maximum utility theory quantifies the individual perception of the utility of safety improvements when
facing fatality risks. The theory assumes that rational decision-makers always choose the alternative with the maximum utility (Yang et al., 2016).

Large quantities of studies on value of statistical life have been conducted in various countries. Miller compared the value of statistical life estimates of 13 countries and stated that value of statistical life has positive correlation with GDP (Miller, 2000). Alberini et al. developed two contingent valuation surveys of administered in Hamilton, Ontario and a national sample of US residents to investigate if there a relationship between WTP and people’s age and health condition. They found that basically the WTP didn’t decline with poor health condition (Alberini et al., 2004). Aldy and Viscusi used the fatality data from U.S. Census of Fatal Occupational Injuries (CFOI) of the 1992-2000 period and found that value of statistical life exhibits an inverted-U shaped relationship with age. The value of statistical life of workers in middle age group is approximately 3 times to the old or young group (Aldy and Viscusi, 2006).

Estimating value of road safety is a vital part in social cost-benefit analysis of road safety schemes (Rizzi and Ortúzar). The monetary value of safety could be expressed as the aggregate of the individuals’ willingness to pay (WTP) for safety improvements or the willingness to accept (WTA) compensation for increased risk levels (Carthy et al., 1998). Beattie et al. used a contingent valuation method to estimate the WTP based monetary values of safety. In their research, the monetary value of a safety improvement could be defined as the aggregate amount that the individuals affected by the improvement would be willing to pay for it (Beattie et al., 1998). Haddak et al. evaluates the WTP for road safety improvement with a particular focus on non-fatal injuries caused by road traffic accidents. They used severity of injury as a
decisive factor in WTP and found that WTP tends to remain invariant regardless of the degree of risk reduction (Haddak et al., 2016). McDaniel et al. examined the relationship between perceived risk and WTP for increased safety from technological hazards. Their research indicated that WTP for well-defined hazards is most influenced by perceived personal exposure, while WTP for less well-defined risks is most influenced by levels of dread and severity (McDaniel et al., 1992). Jara-Diaz et al. used a social appraisal approach to calculate social prices for traffic accident reductions, where the estimation of marginal utilities of attributes and the calculation of a social utility of money are to be properly valued (Jara-Diaz et al., 2000).

Data

The input data of this study varies from different data sources. For the street network data, this study uses the ESRI North America Detailed Streets dataset. For the block group level demographics, this study uses data from American Community Survey (ACS). As for the transit data like transit stops, routes, schedules, and pedestrian transit network, the General Transit Feed Specification (GTFS) is used to build up the pedestrian transit network dataset.

GTFS is a collection of files which illustrate key properties of transit systems. Invented by Google, GTFS provides standard data form and plain text to a large quantity of transportation researchers on transit field. The flexibility of the data form makes the GTFS feeds be consumed more easily among different researchers. More importantly, the GTFS data can be ingested into database and queries, as well as ArcGIS spatial analysis, which will be utilized for this study.
Figure 1 shows the King Historic District - Centennial Olympic Park route and stations of Street Car system. The route covers 12 stations in Downtown Atlanta area. The GTFS dataset of Street Car contains 11 files, including stops, operation times, etc. The GTFS data is associated with Add GTFS to a Network Dataset tool, which allows researchers to put GTFS public transit data into an ArcGIS network dataset so you can run schedule-aware analyses using the Network Analyst tools, like Service Area, OD Cost Matrix, and Location-Allocation.

![Figure 1 Street Car Routes and Stations (Source: streetcar.atlantaga.gov)](image)

To compare the emissions generated from Atlanta electric streetcar system operation and conventional fuels, this paper proposes to make the use of several emission estimating tools. The U.S. Environmental Protection Agency (EPA) provides a state-of-science modeling system called MOtor Vehicle Emission Simulator (MOVES) for estimating mobile emissions (EPA, 2016). In addition to the estimation by MOVES, Xu et al. (2015) developed a transit Fuel and Emissions
Calculator (FEC) to compare the life-cycle emissions of multiple alternative fuels (Xu et al., 2016).

**Methodology**

First, this study builds up a highway network and pedestrian transit network via network analyst tools in ArcGIS. To apply the GTFS feed data into the network, the study uses the Add GTFS to a Network Dataset tool to generate a network capable of producing transit travel time.

By spatially joining the GTFS data of streetcar system and geocoded geography data from Atlanta Regional Commission (ARC), this study utilizes the built-up network analysis to calculate the time cost and travel distance, which could be used to calculate operating emissions of the streetcar system by MOVES and FEC model.

Moreover, this study is also interested in the social impact for the demographic context of the Street Car system. With the detailed population and household data from U.S. Census Bureau at a block group level, this study considers the accessibility range for the 12 stations of Street Car. This approach could give researchers a better sense how the electric transit system affect surrounding residents and travelers.

Next, this study will produce a cost-benefit analysis to quantify and assess the social impacts of Atlanta electric streetcar system. Cost-benefit analysis is a systematic approach to estimating
the strengths and weaknesses of alternatives. It is used to calculate and compare benefits and costs of a decision, policy or project (Wikipedia, 2017).

Results and Discussion

Figure.2 is the population distribution map for Georgia counties. The population data is on a census block group level and displayed with country boundaries. From the map, we can see that Fulton county, where the Street Car system located, is one of the most populous counties of Georgia.

Figure.3 shows the route, stops and the walk accessibility area of Street Car system. To calculate the walk accessibility, this study uses the road network we built before to generate the service area within 0.5 mile (general walk distance) for each stop. The purple polygons represent the population of census block groups. From this map, we can calculate the covered population of the walkable distance of the Street Car stops.
Figure 2: Population Distribution Map of Georgia Counties
Table 1: Distances between Stops

<table>
<thead>
<tr>
<th>Route</th>
<th>Distance (Meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hurt Park – Sweet Auburn Market</td>
<td>566.1</td>
</tr>
<tr>
<td>Sweet Auburn Market – Edgewood at Hilliard</td>
<td>348.9</td>
</tr>
<tr>
<td>Edgewood at Hilliard – King Historic District</td>
<td>209.6</td>
</tr>
<tr>
<td>King Historic District – Dobbs Plaza</td>
<td>372.3</td>
</tr>
<tr>
<td>Dobbs Plaza – Auburn at Piedmont</td>
<td>362</td>
</tr>
<tr>
<td>Auburn at Piedmont – Woodruff Park</td>
<td>617.3</td>
</tr>
<tr>
<td>Woodruff Park – Peachtree Center Street</td>
<td>212.8</td>
</tr>
<tr>
<td>Peachtree Center Street – Carnegie at Spring</td>
<td>245.4</td>
</tr>
<tr>
<td>Carnegie at Spring – Centennial Olympic Park</td>
<td>247.4</td>
</tr>
<tr>
<td>Centennial Olympic Park – Luckie at Cone</td>
<td>205.4</td>
</tr>
</tbody>
</table>

Figure 3: Walk Accessibility of Street Car System
Table.1 shows the GIS calculated results of distances between each two stops. With the route distances and operation time, this project uses the Fuel and Emissions Calculator (FEC) to calculate the life-cycle emissions for the Street Car system. The calculator makes it easier for transit researchers to assess and compare the performance of alternative vehicle technologies on the basis of purchasing, operating and maintenance costs, including energy efficiency, and the ability to reduce GHG emissions. The work flow diagram in Figure.4 shows the work strategy of the FEC.

<table>
<thead>
<tr>
<th>Luckie at Cone – Park Place</th>
<th>365.9</th>
</tr>
</thead>
<tbody>
<tr>
<td>Park Place - Hurt Park</td>
<td>287.6</td>
</tr>
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</table>
According to the Transit Ridership Report Fourth Quarter 2016 published by American Public Transportation Association, 2016 annual ridership of Atlanta Streetcar System is 371,041. The average daily weekday boarding of the fourth quarter 2016 is 700. We can assume the Streetcar system reduces the emission from 700 autos per weekday. With the data of route length and ridership, the emissions compared with conventional gasoline vehicles and hybrid vehicles are calculated using FEC. The results are shown in Table.2. In Table.2, “Parallel” means the conventional gasoline vehicles and “Series” presents the hybrid diesel electric vehicles.

From the table, the usage of electric vehicles in StreetCar system has a large positive influence on emission savings. For the transit operation (onroad), electric vehicles have zero emissions in each kind of emissions while conventional gasoline vehicles have a lot of emissions every year with the same route and ridership.

As we assume that route schedule keeps the same for every year, then the emission savings per person will increase with the increase of ridership. However, the ridership decreased sharply...
from 2015 to 2016. The ridership in 2016 is only 371,041 while the ridership of 2015 is 880,083.

One of the reason is that the system only covers very limited area in Atlanta (within three census tracts from the previous map in this paper). The working people are not willing to wait such a long time for only 150-minute walk. Overall, the StreetCar system does have a good impact on environment and emission savings, but they need to figure out a way to attract riders and therefore the social impacts would be maximized.
Reference


Retrieved November 23, 2016 from 
https://crashstats.nhtsa.dot.gov/Api/Public/ViewPublication/812318
http://www.who.int/violence_injury_prevention/publications/road_traffic/Road_safe
  ty_media_brief_full_document.pdf
- on - int
  ersection - accidents.html


[31] Hauer, E. Can one estimate the value of life or is it better dead than stuck in traffic? Transportation Research, 28 (1994), pp. 109–118
