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Project 1 (First Draft)

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1 Introduction

New York City (NYC) would like to implement a fleet of autonomous vehicles (AV) by 2020 as part of a larger initiative of establishing itself as a world leader in smart city infrastructure. Because of the novel nature of AV technology, there is a considerable amount of uncertainty regarding the impact from its implementation on traffic issues including safety, congestion, energy consumption and environmental impacts. City officials wish to determine the effect of each alternative, while considering uncertainty, on these outcome and optimal strategies moving forward with AV technology within the NYC fleet of vehicles. This study will focus on the alternatives available to implement this technology from AutoMerge, Inc. (AM) specifically in NYC's 40-passenger transit buses. It will compare different alternative strategies by performing a Benefit Cost Analysis (BCA) to assess how these different options impact the general population of NYC, which are the main stakeholders in this issue. Among the factors to be included in the analysis are: safety, energy consumption, air pollution, GHG emissions, weather conditions and traffic flow. Section 2 presents a detailed description of the problem and the alternatives analyzed. Section 4 presents the analysis of each alternative and the results found. In section 5 a sensitivity analysis is performed for some inputs. Section 6 discusses the results of the analyses and section 7 presents the conclusion and recommendations of this study.

2 Problem Description

2.1 Alternatives

Broadly, NYC must consider the following three alternatives.

Alternative 1: Do not implement AV.

This is the reference alternative. AV is not implemented and the benefits and costs are the ones already incurred to the population. There is relatively little uncertainty associated with this outcome because there is historical data to project the effect of this alternative on outcomes.

Alternative 2: Implement AV in the NYC bus fleet.

In this alternative, the city implements the AV technology in the bus fleet directly (without performing any pilot tests). Because this is an emerging technology, it is unclear how AV will perform in each outcome so uncertainty analysis will help determine the expected value for each outcome using the risk information currently available.

Alternative 3: Perform a pilot test with an amount of n buses before deciding to implement AV.

In this alternative, the city performs a pilot test with a predefined amount of n buses. The pilot test has an associated cost directly proportional to n . The potential benefit of running a pilot study is the additional information gained on risks associated with congestion and other outcomes. It will be necessary to calculate the value of imperfect information for each n for this alternative.

2.2 Benefits, Costs & Uncertainty

Although public transit systems are essential to any urban area, they also incur several costs to the general population. Implementing AM in the bus system will impact these costs in different ways.

1. **Capital and Operating Costs of implementing AM.** The most obvious costs are the capital and operating costs of implementing and operating the AM system in the buses. Ordinary capital and operating costs related to the bus operation will not be considered in this analysis since they will be incurred in all alternatives.
2. **Traffic Congestion.** Being a part of the transit system, buses have an impact in the traffic congestion of NYC. This traffic congestion results in longer commutes and wasted hours for the general population, which can be interpreted as a cost. The use of AM can have an impact in the traffic flow and in these implicit costs.
3. **Fatalities & Injuries.** Another cost are traffic related injuries and fatalities. Using AM in the bus system can have an impact in traffic safety and change these costs.
4. **Emissions.** Another major external cost of the bus system is the one related to the emission of air pollution gases and greenhouse gases. These emissions result in major health hazards for the general population and can affect future climate. Implementing AM can have an effect of changing these emissions by improving traffic flow.

Table 1 summarizes these different costs. In addition to the costs listed above, there is also the specific cost of doing a pilot test to assess the benefits of implementing AM.

In addition to the costs listed above, there are also uncertainties associated with the implementation of AM. One of the uncertain factor is what will be the effects of AM in the

Table 1: Costs associated with implementing the AV technology in NYC buses

Capital costs of installing AM system in buses
O & M costs of AM system
Cost of building simulator facility to train drivers
Traffic fatalities
Traffic injuries
Traffic Congestion
Emission of air pollutants
Emission of Greenhouse gases (GHG)
Cost of potential pilot test (*)
(*) only applicable to alternative 3

congestion and safety of NYC transit system. Another source of uncertainty is how bad weather will affect the operation of the AM system. These two types of uncertainty are included in our analysis.

2.3 Assumptions

1. The number of riders using each mode of transportation will remain stable for all three alternatives.
2. Changes in congestion will affect motor vehicles (buses, cars, light duty vehicles, and trucks) but not bicycles or walkers.
3. All travel minutes across persons and modes of transportations are worth the same and includes fuel costs, \$22 per hour per individual.
4. Weather patterns remain consistent.
5. Any travel time, even fast ones, incurs a time cost. This means that for each alternative, there will be a time cost added which is associated with it.

3 Methods

For this analysis, we use a decision tree with standard expected values to assess alternatives one and two and the value of imperfect information to assess alternative 3. Figure 1 shows our decision tree for the first two alternatives. This same paradigm will be used to compute the expected value of imperfect information.

Each cost listed in Table 1 was estimated using data from different sources:

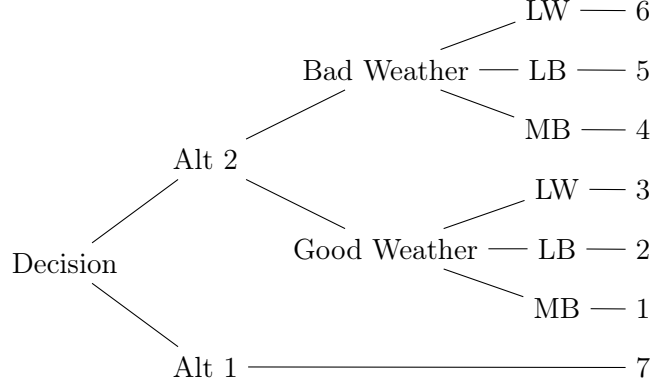


Figure 1: Partial decision tree

1. **Congestion.** To calculate congestion costs, we only consider buses, cars, light duty vehicles, and trucks. While walkers and cyclists do experience travel times, we do not believe that they will change with the different alternatives and do not need to be included for comparison purposes. Thus, for any single mode of transportation, we calculate cost as follows:

$$\text{Cost} = \text{daily person trips} \times \text{average trip hours} \times \text{Cost per hour per individual.}$$

From our assumptions above, only average trip hours will change under differing alternatives, weather conditions, and AM performance.

2. **Emissions.** Because at this point we have emission data available only for buses, we focused our emission cost estimate only on buses. Emission factors for buses differ for when buses are in movement and when buses are idle. For buses in movement we have emission factors (ef_m in g/mi). For idle buses we have emission factors (ef_i in g/min). Using these factors, the marginal cost of each type of gas emission (mc_g in \$/ton), the total vehicle travel time (T in minutes), the total vehicle distance (D in miles) and an estimate of the share of travel time that the vehicle is idle (s_i in %) we can compute total emission costs.

$$\text{Cost} = \text{Cost}_{\text{run}} + \text{Cost}_{\text{idle}} = D \times ef_m \times mc_g + s_i \times T \times ef_i \times mc_g$$

We assume that improvements from AM will only affect emissions as a result of idle time (i.e., as congestion decreases, vehicles spend less time in idle status but still travel the same distance).

3. **Fatalities & Injuries.** The cost of each death is estimated using the standard Value of Statistical Life (VSL). The cost of each injury was estimated using data from CDC.

Using historical data for transit accidents in NYC, we computed total cost of traffic fatalities and injuries.

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4. **Capital and O&M Costs.** Estimates for capital and O&M costs for the AM system were informed in a per bus basis, conditioned on the age of the bus. We used this data to compute these costs.

4 Analysis and Results

4.1 Alternative 1: Don't Implement AV

4.2 Alternative 2: Implement AV

4.3 Alternative 3: Pilot test

Figure 2 presents the resulting NPV for each alternative. For alternative 1 we can observe that the component that results in the largest cost is air pollution.

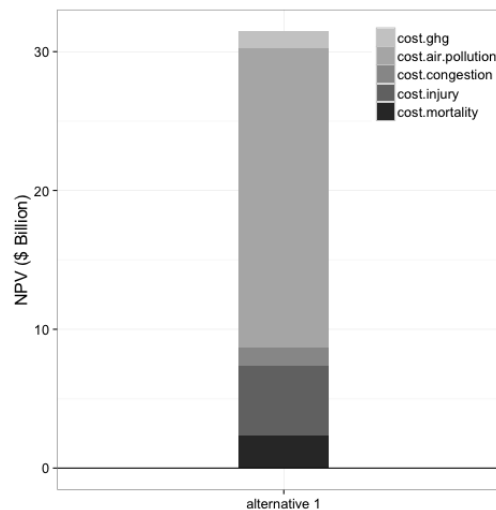


Figure 2: Expected NPV (in Billion \$) computed for each alternative (at the moment only alternative 1 is computed)

- 5 Sensitivity Analysis
- 6 Discussion
- 7 Conclusion & Recommendations