GREATER TORONTO AREA

INTELLIGENT TRANSPORTATION SYSTEMS

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Executive Summary

As the population increases in the GTA, transportation, traffic and commuting times will become significant factors in the lives of residing citizens. An increase of travel time comes an increase of traffic, pollution and stress resulting in an overall lower quality of life. With several hotspots for traffic in the GTA, such as the Gardiner Expressway, the need for intelligent systems to organize congestion is at an all-time high. The use of Intelligent Transportation Systems (ITS) incorporates hardware and software of Information Communication Technologies to collect data from a variety of sensors including Vehicle-to-Vehicle (V2V)and Vehicle to Infrastructure (V2I), both of which have several categories and types such as intrusive and non-intrusive. Through research on ITS, it can be seen that current applications are used in context of local projects such as Sidewalk Labs in Toronto.

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1. Introduction

The purpose of this technical research report is to find efficient and safe solutions of transportation within the Greater Toronto Area (GTA) through the use of Intelligent Transportation Systems (ITS). With a growing population in the GTA, individuals are required to commute from outside of the downtown core resulting in increased traffic congestion, carbon dioxide emissions and vehicular accidents. By analyzing ITS through sensor systems and GPS tracking, this research looks forward to reliable transportation solutions for GTA residents.

1.1 Traffic Impact

Increasing population growth combined with inflating housing costs in Toronto, forces individuals to commute from outside of the downtown core, which results in heavily congested traffic, increased carbon dioxide emissions and increased gas prices (ITS Canada, 2019). In 2010, commute times to work within Toronto averaged 33 minutes by car and on average 44 minutes by public transportation (Statistics Canada, 2016). It was also reported by Statistics Canada that the dissatisfaction of commuters in areas populated with 1 million citizens or more increased with the growing rate of transportation congestion (Statistics Canada, 2016). Furthermore, in 2018, 41 pedestrian and 5 cycling deaths were reported on city roads in the GTA (Spurr, 2018). Overall the need for safe infrastructure impacts quality of life in addition to safety.

1.2 Structure of Report

Included at the beginning of this report are list of figures, tables and glossaries in order to actively aid the general reader with unfamiliar topics. The structure of this report will follow a problem and solution sequence with focus on in-road and in-vehicle sensors as they are related to ITS. It will also include parts and process of sensors, methodology, and feedback on how the issue of traffic within the GTA can be improved. The end of the report will feature current uses of ITS specifically with developments in Toronto Sidewalk Labs.

2. Traffic Congestion

An essential aspect of infrastructure, the problem of traffic congestion can occur through several facets. Common causes can include: overcrowding of cars in comparison to roadway allowances, obstacles causing blockage, and structural design of roadways (Rosen, 2013). Whether the source of congestion is due to lane closures, lane merging, utility work or accidents, a balanced transportation system is vital for metropolitan areas with larger populations.

2.1 GTA Traffic Insight

With almost 2.7 million working commuters within the Toronto area (Statistics Canada, 2019), a prominent highway for drivers is the Gardiner Expressway. Constructed in 1956, the Gardiner Expressway "runs for about 20 kilometres from the foot of Highway 427 and the Queen Elizabeth Way in the west to the Don Valley Parkway in the east (Waterfront Toronto, 2019)." Carrying approximately 200 000 vehicles daily westbound, and 120 000 daily eastbound (Waterfront Toronto, 2019), this highway acts as a fundamental location for thousands of commuters. With high volume and limited number of lanes, any disruptions or obstacles on the highway can cause significant delays to travel time.

2.2 A Closer Look: The Gardiner Expressway

In a journal article written by professors at the Civil Engineering Department at the University of Toronto and Cairo University, the authors discuss volume, speed and spread of congestion across areas such as the 401 Highway, Lake Shore Boulevard and the Gardiner Expressway (Kamel et al. 2016). By generating a model simulation based off of travel demand data, the study analyzes the differences between the simulated and observed speeds of vehicles on the Gardiner Expressway. With varying volume on weekdays, seasons and peak hours, the simulation calibrates to account for appropriate changes. It can be seen in Figure 1 that in comparison to simulated data, the observed data of highway speeds on the Westbound Gardiner can range from approximately 80kph to 30kph during hours of congestion (Kamel et al. 2016).

Figure 1: Gardiner Westbound Observed and Simulated Speeds (Kamel et al., 2016, p 451)

3. Intelligent Transportation Systems (ITS)

In order to combat reduced speeds during peak congestion, the use of ITS can be used to collect data in an attempt to coordinate traffic and enable commuters to make informed decisions while driving (Sawyer and Hancock, 2012).

3.1 What is ITS?

The use of Intelligent Transportation Systems focuses on managing traffic flow through four aspects: "sustainability, integration, safety, and responsiveness (Guerrero-Ibáñez et al. 2018)." By collecting real time in-vehicular, and infrastructure data through the use of sensors and Information Communication Technologies (ICT), the process of ITS provides drivers with up to date information in order to make informed decisions. In order to make the best possible choices, ITS aims to provide drivers with suggestions that address and optimize issues such as "high fuel prices, high levels of CO2 emissions, high levels of traffic congestions, and improved roads (Guerrero-Ibáñez et al. 2018)."

3.1.1 Information Communication Technologies

Consisting of hardware such as Global Positioning Systems (GPS) and software such as carsharing apps, ICT plays a vital role in communicating with drivers to provide accurate up to date information on behalf of ITS (Guerrero-Ibáñez et al. 2018).

3.1.2. Categories of Sensors

With an average of 60-100 sensors on current car models, the process of ITS can use data from both Vehicle-to-Vehicle (V2V) and Vehicle to Infrastructure (V2I) communications in order to effectively use ITS (Guerrero-Ibáñez et al. 2018). Such categories of sensors include the following:

- Safety Sensors
- Diagnostic Sensors
- Traffic Sensors
- Assistance Sensors
- Environment Sensors
- User Sensors

(Guerrero-Ibáñez et al. 2018).

3.1.3. Vehicle-to-Vehicle (V2V) Sensors

In order to enhance the driving experience, Figure 2 depicts current Vehicle to Vehicle sensors that are applied to alert drivers of any warnings within the car itself. The incorporation of ITS would use the data collected from sensors such as RADAR to alert the driver of potential danger in situations such as changing lanes, thus reducing vehicular accidents and causes of traffic congestion (Guerrero-Ibáñez et al. 2018).

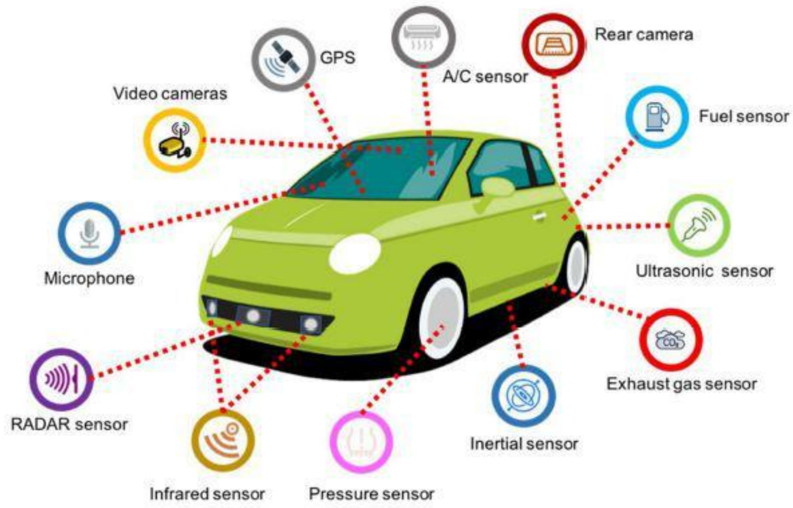

Figure 2: Various types of in vehicle sensors (Guerrero-Ibáñez et al., 2018, p3).

Applications of in-vehicle sensors for safety purposes include the following:

- Tire pressure monitoring
- Proximity, ultrasonic and electromagnetic sensors for distance safety
- Radio Detection and Ranging (RADAR) alerts or activates brakes if detects emergency situations
- Gyroscopes determine vehicle speed and positioning to improve GPS accuracy
- Light Detection and Ranging (LIDAR) enables autonomous self driving by measuring depth information through the use of lasers (Guerrero-Ibáñez et al. 2018).

3.1.4. Vehicle to Infrastructure (V2I) Sensors

In order to collect data from mass amounts of vehicles the use of on-road sensors can be classified into two categories: intrusive and non-intrusive. With intrusive sensors, installation is directly on paved surfaces which can be associated with higher maintenance and installation costs.

Figure 3 shows the types of intrusive sensors which can be implemented to provide data to ITS processing units such as Embedded magnetometers, Pneumatic tube sensors and Inductive loops.

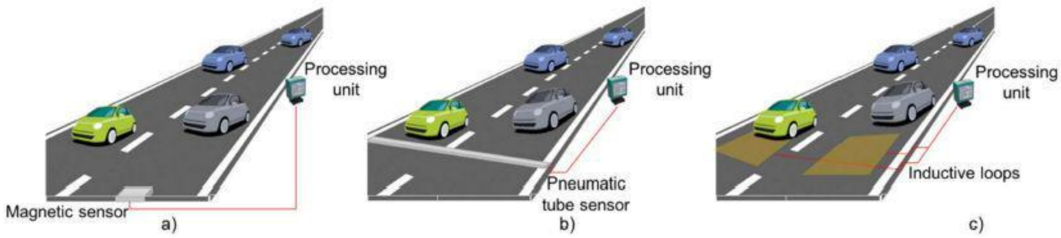

Figure 3: Intrusive on-road sensors (Guerrero-Ibáñez et al. 2018, p5)

Non-intrusive sensors, such as radar, camera and laser beam sensors, are located either above or nearby roads, as seen in Figure 4.

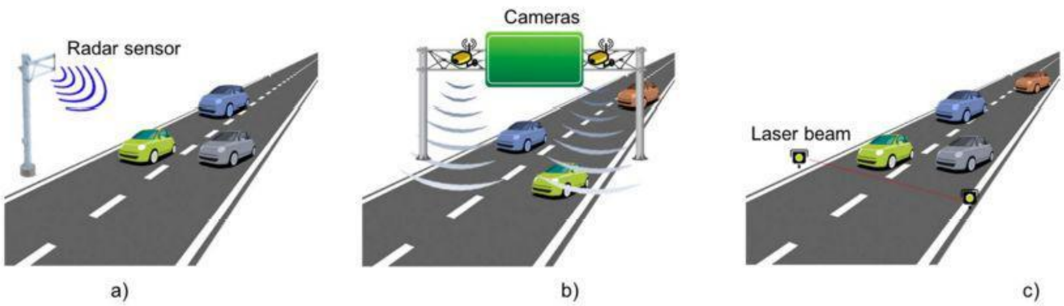

Figure 4: Non-intrusive on-road sensors (Guerrero-Ibáñez et al. 2018, p6)

4. Conclusions and Future Developments

Overall, by analyzing solutions within the context of Intelligent Transportation Systems, this research proposes an alternative to solve the issue of congested transportation within the Greater Toronto Area. By integrating data from in-vehicular and on-road sensors, in addition to communication technologies, the congestion and overall safety in locations such as the Gardiner Expressway can be reduced by informing drivers of smart decisions while driving.

As a current development, Sidewalk Labs in Toronto aims to use ITS through building a complex system of smart mobility by gathering data and analyzing patterns of city movement from the smartphones of individuals. Simulations are created for each individual based on collected data in order to predict traveling behaviors (Sidewalk Labs, 2018).

With the use of ITS, roads and general infrastructure have the capacity to be better managed, organized and safer for everyone.

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