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THE USE OF FLOATING CELLULAR TELEPHONE DATA FOR REAL-TIME TRANSPORTATION INCIDENT MANAGMENT

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LIST OF EXHIBITS

LIST OF TABLES

ACKNOLEDGMENTS

Many industry experts contacted for the purpose of this paper are employees of the IBI Group in Toronto, Ontario. Discussion pertaining to this paper was often informal, without adherence to any formal interview structure. Proper citation has been provided in places where discussion pertained directly to text or information contained here in.

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1. INTRODUCTION

1.1 Intelligent Transportation Systems Overview

Traffic congestion is an increasingly important problem for metropolitan areas worldwide. As automobile ownership and usage continues to increase, transportation managers have been forced to implement new strategies and tactics in order to keep traffic moving. Due to concepts such as 'triple convergence' and tightening government budgets, the past strategy of simply increasing roadway capacity to accommodate new demand is no longer feasible. It is not possible to simply 'build out of congestion'[1].

Consequently, provincial and city agencies responsible for network operations are turning to the field of Intelligent Transportation Systems (ITS) in increasingly greater numbers. This area of traffic management relates to the application of technology to transportation and includes field equipment, central software and hardware connected through a communications network. In the field, the use of dozens of electronic technologies such as Variable Message Signs (VMS), Variable Speed Limit Signs (VSLS), Closed Circuit Television Cameras (CCTV) and vehicle detection stations are commonly seen, while at central software applications for device control and event management are deployed. ITS can effectively increase the capacity of existing roads by facilitating better decision making by motorists, improve emergency response times and improve information sharing between roadway agencies.

ITS typically consist of three components; each designed to accomplish a different task:

- Information Gathering – The acquisition and organization of the relevant transportation data. This is typically done automatically through the use of field hardware such as inductive loop detectors, automatic license plate recognition, infrared detectors and video detection. Data

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[1] Downs, Anthony (1992*). "The Triple Convergence*." Retrieved from http://www.walkablestreets.com/triple.htm on August 11th, 2007

collected can vary by type (traffic volume, lane occupancy, vehicle speed, vehicle classification) or by time (real-time vs. historical).

- Information Processing – The transformation of the gathered data into a digestible format. This information is then used by the operating agency in order to help manage the network. Depending on the type of information gathered, the processing methodology could range from input into a complicated computer model for the generation of macroscopic congestion maps, through to the CCTV confirmation of reported incidents. The biggest component to a central system is the event management function. For each minute of lane blockage there is a corresponding 6 minutes of delay[2]. Therefore, the quicker events are cleared, the less delay is experienced on the highway.
- Information Dissemination – The relay of processed information to the public for their use in trip planning. This can be accomplished through on-road systems such as VMS and Highway Advisory Radio (HAR), through pre-trip avenues such as web-based congestion maps, or through hand-held and on-board systems.

Although these three elements form the basis of any ITS, the manner through which these tasks are accomplished can be quite different depending on the system in question. As mentioned, there are dozens of ITS technologies, each with its own strengths and weaknesses. Consequently, each ITS will vary in the complexity of the system, types of information relayed to the public and its effectiveness in regards to congestion reduction.

1.2 Purpose

The purpose of this paper is to inquire into the feasibility of using Floating Cellular Data (FCD) for the purpose of real-time incident management. Under this scenario, FCD would be used in

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[2] Bullock, Mara. Personal Interview. September 4th, 2007

conjunction with a dynamic transportation model for the purpose of providing a real-time estimate of the traffic conditions across the entire roadway network under consideration.

1.2.1 STATUS QUO AND THE NEED

This kind of traffic management system would represent a revolutionary approach to traffic management systems. Currently, the most commonly used approach to traffic management is a system centered upon the collection of real-time data through field equipment installed by the operating agency. This field data is then run through pre-determined software algorithms, which are intended to detect incidents on the roadway through comparison of received data to historical conditions and through the use of comparative algorithms. Once an incident is detected, a system operator is typically alerted, and confirmation is achieved through the use of CCTV cameras.

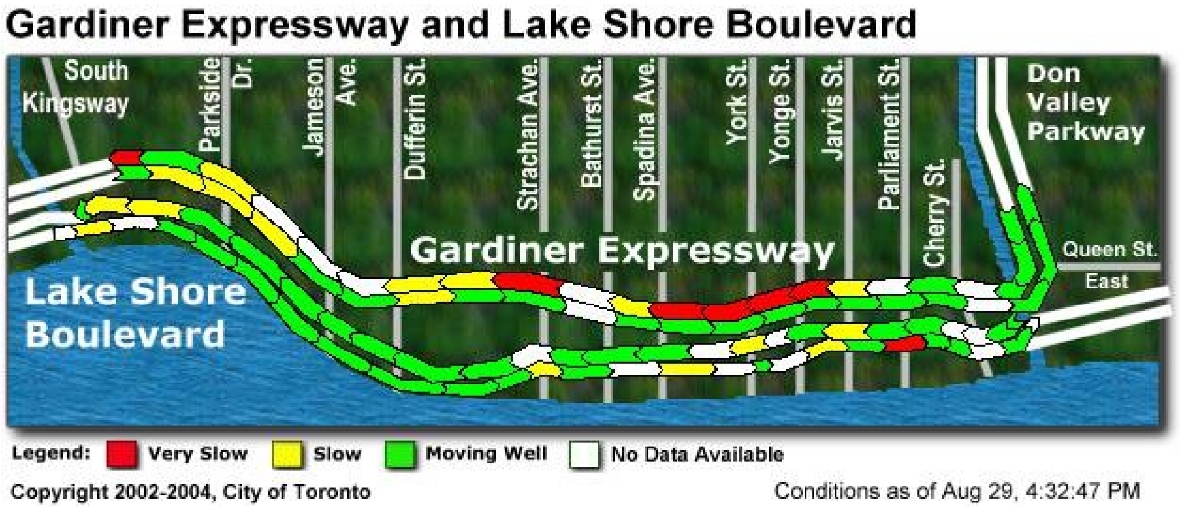

Exhibit 1-1 – Typical Transportation Management System Output (Public)[3]

If a traffic incident is confirmed to have occurred, the system operator will contact the emergency services and proceed with the implementation of a response plan. Typical response plans can include implementing a lane closure, updating on-road dissemination avenues such as VMS, totally closing a roadway or in some cases, doing nothing. Although trained operators can greatly reduce

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[3] City of Toronto (2004). "City of Toronto: RESCU Traffic Cameras". Retrieved August 29th, 2007 from http://www.toronto.ca/trafficimages/rtis.htm

the impact of a traffic event by implementing an effective response plan, there is no way for him or her to fully anticipate the impact of any changes made.

This issue becomes especially worrisome as the complexity of the event in question increases. A system of this nature can typically mitigate a small or medium scale transportation emergency, but what of large events such as the full closure of a major freeway or the evacuation of an area following a natural disaster?

These large-scale events are currently planned for through the development of specified plans. Such plans typically rely on static transportation models, which use historical traffic data to predict what may be the most efficient evacuation route[4]. Although certainly better than having no pre-defined plans, the use of static transportation models does not take into account variables such as current traffic conditions or roadways that may be under construction.

Even in small or medium scale transportation incidents, the current approach of collecting field data for incident detection comes with several areas of concern. Firstly, the installation and maintenance of field equipment can be quite costly. The use of inductive loops, the most commonly applied detection device, requires invasive roadway work in regards to installation. This is highlighted in Exhibit 1-2. Plows and other snow-removal equipment can also damage these loops. Many other detection technologies such as infrared and microwave have issues pertaining to the accuracy of data that can be expected.

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[4] Rontiris, K. and W. Crous. "EMERGENCY EVACUATION MODELLING FOR THE KOEBERG NUCLEAR POWER STATION". Retrieved August 20th, 2007 from http://www.inro.ca/en/pres_pap/asian/asi00/EMME2Asian.pdf

Exhibit 1-2 – Induction Based Traffic Loop Installation[5]

Further, the coverage area of standard traffic management systems is typically restricted to freeways. Although certainly the most important roadways in regards to regional transportation incident management, incidents occurring on major arterial or collector class roadways can have destabilizing effects on traffic flow as well.

However, perhaps the most pressing criticism of current traffic management systems arises from the lack of predictive capabilities. As mentioned, system operators and traffic engineers currently have limited quantitative estimates regarding the projected impacts of selected diversion strategies or plans. This leaves the evaluation of strategy, comparison of available plans and the ability to correct errors, especially in real time, to be lacking.

1.2.2 APPROACH

Consequently, there are several areas in which current traffic management systems could improve. The follow list provides an overview of criteria identified as being elements that the next generation

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[5] City of Richmond (2007). "Traffic Signal Maintenance". Retrieved August 28th, 2007 from http://www.richmond.ca/services/ttp/signals/maintain.htm?PageMode=HTML

of traffic management systems should possess. This list was based upon various elements as outlined in Version 6 of the U.S. Department of Transportation's National ITS Architecture:

- Improve coverage capabilities to include arterial and collector roads
- Easier to install and maintain
- Provide continuous traffic data, rather than isolated point data
- Provide ability to adapt to current roadway conditions
- Develop automatically and suggest various contingency plans
- Provide predictive traffic information

Therefore, this paper will evaluate whether the use of FCD, in conjunction with a dynamic transportation model, would support a system that delivers the criteria outlined above. The last three points indicate that a dynamic transportation model will be required in order to maximize the utility of FCD. What a dynamic model is, as well as an overview of why this is required, is provided in Section 3.2.

If feasible, a system of this nature would use FCD in order to approximate the position of vehicles on the roadway, allowing for an unprecedented level of detail and coverage area in regards to traffic modelling. The use of a dynamic transportation model would then facilitate the prediction of future traffic conditions on a short term basis (15 or 30 minute intervals) in order to allow transportation engineers, or the associated transportation model, to develop contingency plans in anticipation of future traffic conditions.

The use of FCD and dynamic models could allow a system to automatically detect an incident on the roadway (collision, lane closure etc), and then use existing traffic volumes to predict what the impact of the detected event will be on the roadway network by producing estimates of future conditions on short-term intervals. These predicative traffic volumes can then be used in order to develop more efficient contingency plans in regards to mitigating the incidents anticipated impact on the road network.

In order to accomplish this feasibility inquiry, this paper will examine and connect several sections of study:

- A comparison between the existing technologies in the area of information acquisition and FCD in order to evaluate the potential new applications for FCD.
- Inquiry into privacy concerns relating to the use of FCD, which is often the most pressing criticism of this technology[6].
- An overview of dynamic modelling in order to relay its necessity in regards to real-time incident management.
- A worldwide scan of the current applications of dynamic modelling in order to verify its capabilities.

Throughout this paper, special consideration will be given to the current government policies being enacted in this area, as well as recommendations pertaining to future policy development in this area. As traffic management systems almost always fall under the control of a government agency, the application of appropriate policy is important.

Overall, this paper will strive to provide an evaluation regarding the potential integration of FCD and dynamic modelling for the purpose of real-time incident management. A system of this nature has not yet been implemented anywhere in the world, making an inquiry into the feasibility of implementation a unique matter of research.

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[6] Larkin, Gary (2006). "New Privacy Threats". PC World. Pg 20-22. June 2006

2. OVERVIEW OF FCD

2.1 Introduction

With increasing frequency, the use of Floating Cellular Data is being viewed as an emerging alternative to the current status quo in regards to transportation network management. Currently, there is heavy reliance on the use of fixed sensors, such as inductive loops, for the purpose of collecting real-time traffic data. The alternative is the use of probe vehicles this is a new term for me, typically they're talked about as probe technology as the agency doesn't 'own' the sensors but is tracking probe vehicles], such as FCD. However, there is currently some uncertainty regarding the capabilities of mobile sensors. The usage of mobile sensors is not as well established as that of fixed sensors, with "probe vehicles [having] seen little field application in incident detection or traffic management"[7]. Table 1 provides an overview of the known capabilities of the two sensor types.

Table 1 - Fixed vs. Mobile Sensor Overview[8]

Application	*Purpose*	*Desired Time Frame*	*Fixed Sensors*	*Mobile Sensors*
Incident Detection	Alert the road operator to an incident to enable incident response plans to be activated	Instantaneous or near to instantaneous	✓	?
Response Plans	Enable the road operator to implement controls (signal timing, ramp metering, etc.) to improve transport system performance	Instantaneous or near to instantaneous	✓	? or ✓
Information Dissemination	Facilitate informed decisions by travellers or shippers about route, mode, destination and trip-timing decisions	Near real-time	✓	? or ✓
Performance Monitoring	Enable the road operator to quantify the performance of the network over time and the extent of variation in performance	Historic	✓	✓

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[7] Rose, Geoff (2006). "Mobile Phones as Traffic Probes: Practices, Prospects and Issues". Transport Reviews. May 2006

[8] Ibid

Fixed sensors are typically used to collect data on an entire traffic stream, such as a roadway, but can provide that information at isolated points in the roadway[9]. "In contrast, probe vehicles provide a sample of data rather than a census, [providing] data more continuously as they move over the network and, therefore, have the capability to provide a richer insight into network performance"[10].

Within the field of mobile traffic probes, there are two further divisions. The first is the use of probe vehicles that are sampled at a fixed location. This type of system utilizes electronic tags or other identifiers on vehicles that can be read as they pass by sensors, and is commonly used for generation of travel time information. The second option is to use an approach such as FCD in order to establish a system where vehicles are randomly sampled while traveling on the roadway[11].

In this regard, the use of mobile phones to collect traffic data is often viewed as practical as it would make use of existing infrastructure. The vast majority of major urban centres already have extensive cellular networks, so the additional infrastructure required would be minimal. "This has intuitive appeal because on the surface it would suggest that the data could be made available in a more cost-effective way…"[12] than through traditional means.

2.2 How FCD Works

Government agencies are increasingly considering FCD in order to gather real-time traffic data. "This approach entails recording traffic data from a sample of vehicles, which 'float' with the traffic and provide a proxy of current road traffic conditions"[13]. This data can be used as an alternative to information obtained from infrastructure-based sensors, providing a cheaper and less intrusive method for collecting this data.

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[9] Ibid
[10] Ibid
[11] Ibid
[12] Ibid
[13] ITS International (2006)." *Beyond Real Time". November 2006.*

FCD works by passively tracking the location of powered cell-phones relative to the closest communication towers. "As the car moves, so does the transmission from the mobile phone. Using triangulation, the location of each mobile signal can be identified in terms of the road network and thus the position of each car on the network in real time"[14].

FCD is typically collected by the telephone company, and then sold to a third-party for the purposes of generating relevant transportation information. By sampling the location of vehicles at a pre-defined interval, these third-party companies are able to generate information relating to items such as traffic density, average speed and incidents. Once this information has been generated, it can then be sold to a government agency responsible for traffic management for assistance in overseeing the roadway network.

2.3 Outstanding FCD Issues

2.3.1 TECHNOLOGY ISSUES

Despite the high level of sophistication involved in using cellular phones as traffic probes, there are still outstanding issues regarding the level of accuracy one can expect from using FCD. As FCD relies on using the position of the vehicle at two points in time, and then calculates speed based on the time elapsed between captures, the accuracy of the position data is of the highest importance. The level of error present in these position estimates can have a significant impact on the level of accuracy[15].

The relationship between location data and accuracy was shown in 2001 during a field test in Lyon, France. During this test, inductive loops were used to provide base data against which the data obtained from FCD could be compared. Although this test confirmed that FCD could be used to

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[14] Ibid

[15] Rose, Geoff (2006).

obtain traffic data, there was still enough error present to degrade the quality of data obtained[16]. Although the use of data screening to remove obvious outliers (someone walking along the side of the road) and the aggregation of data into hourly averages improved data quality to some degree, this test showed that there still remains room for improvement[17].

A similar test in Finland undertaken in 2002 also presented concerns regarding the level of accuracy that FCD can deliver. In this test, "the level of error in the position fixes on the phones [undermined] the quality of resulting speed data"[18][19] In the subsequent report, the author concluded that the most probable cause for observing accuracy problems is that the position of the cellular phone towers were not likely to be best suited for the gathering of traffic data[20].

There are several methods by which cell phone location can be calculated. Of these, the use of triangulation is considered to be the most accurate. Using this method, location accuracy of 50-200 metres can be achieved[21]. Exhibit 2-1 provides an overview of the triangulation method.

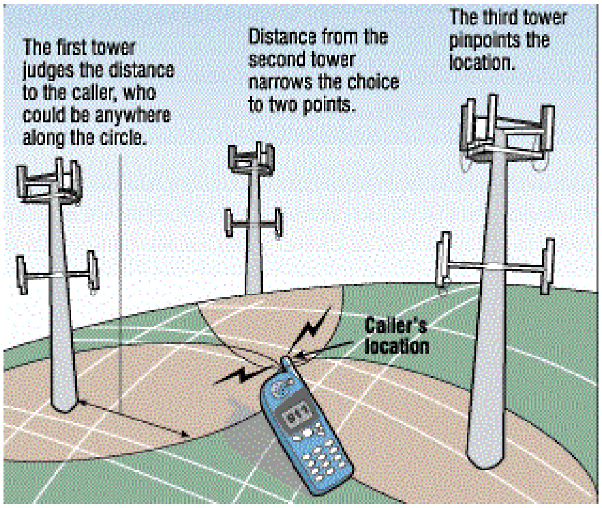

Exhibit 2-1- Cell Phone Triangulation

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[16] Ibid
[17] Ibid
[18] Ibid
[19] Kummala, J. (2002). Travel Time Service Utilizing Mobile Phones. Report No. 55/2002 (Helsinki: Finnish Road Administration)
[20] Ibid.
[21] Rose, Geoff (2006).

However, even given the minimum error of 50 m, this can result in significant error. Assuming a capture interval of 20 seconds (common for inductive loops[22]), and an actual travel speed of 100 km/h a car would only travel 555 metres. If an error of 50 meters were applied to either end of this figure, the measured travel distance would increase to 655 metres. Maintaining the 20-second capture assumption, this would translate into a computed speed of 117.9 km/h, or an error of 18%. Assuming larger inaccuracies in position estimation would obviously increase this error quotient considerably.

As this is a purely technical issue, the only manner in which policy could impact the accuracy of FCD would be through the allocation of government research funding for companies and academic institutions involved in this area.

2.3.2 SAMPLING CONCERNS

Also of concern is the issue of the sample size and characteristics required in order to properly model a roadway network. Some estimates have suggested that a sampling of 3000-5000 vehicles would be required as a minimum in order to approach an accurate image of current roadway conditions[23]. However, even with sample sizes in this range, there is still concern regarding the potential for bias:

> Arterial roadway segments are generally controlled by traffic signals at intersections. The variability in travel time that vehicles experience on an arterial roadway segment is largely determined by the amount of delay experienced at the downstream signal. Delay at signals is largely a function of the arrival time with respect to the signal cycle. Thus if probe vehicles represent a biased sample with respect to their arrival time distribution, then even when data are available from many probes, the mean travel time will not tend to the population travel time[24].

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[22] Ibid

[23] Ibid

[24] Hellinga, B. R. and Fu, L. (2002) "Reducing bias in probe-based arterial link travel time estimates". Transportation Research Part C.

There are also concerns regarding the impact of demographics on the FCD sample. “There are differences in the availability of a mobile phone depending on gender, vehicle type and driver’s age that could all have implications for the representivenss”[25][26]

Matters pertaining to sample size can be further complicated by the fact that identifying unique vehicles on the roadway can be challenging. The aforementioned field-test in Lyon, France indicted that there were on average 102 phones per 100 vehicles sampled, despite the fact that 23% of all recorded vehicles had no phone at all. “From the perspective of representivenss, there is…an obvious difference between having four phones samples from one vehicle as opposed to four phones sampled from four different vehicles”[27].

Overall, there are three factors that affect the sample size of FCD collection:

- Which cell phone companies are providing FCD and their relative market penetration.
- Whether the phones are switched on, as phones that are switched off cannot be tracked.
- Whether phones are being used for communication in cases where the system relies on continuous monitoring of the signal[28].

A study undertaken in Melbourne, Australia indicated that a cell phone suitable for use as a traffic probe was present for 61% of all vehicle-km travelled. A rate of this magnitude would most likely present a suitable sample size for the purposes of FCD[29]. Consequently, although there are some concerns regarding the biased nature of collected FCD, there is typically a large enough sample size available to facilitate its use.

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[25] VicRoads (2003). *Driving Around Melbourne*. Drummond Research Pty. Ltd. For Vic Roads Safety Department.

[26] Rose, Geoff (2006)

[27] Ibid

[28] Ibid

In the area of policy development, there is little that can realistically be done in order to address the issue of sampling size. One possible policy that would improve sampling would be the mandate that all cell phones present in a vehicle be turned on. However, this is not a prudent policy due to the obvious difficulty of enforcing it, and the fact that current sampling rates are acceptable.

2.3.3 ROADWAY SAFETY

Another issue regarding the use of FCD for traffic management is that of public safety. Many jurisdictions are implementing restrictions or outright bans on the use of cellular telephones while driving due to safety concerns. Even the use of hands-free devices does not eliminate the increase risk that is associated with cell-phone usage[30].

One example of such a policy is the 'Car-On, Phone-Off" program being implemented by BP Australia, which requires cellular phones to be powered off while driving. "Widespread adoption of that form of operating policy could have an impact on the number of vehicles available as traffic probes"[31].

The use of FCD may represent a contradiction for many roadway agencies, which stand to be the primary purchasers of FCD. It may become paradoxical for one arm of the government agency to promote cell-phone use while driving through the acquisition of FCD, while another actively tries to restrict or eliminate its use[32]. Therefore, roadway agencies would need to include consideration of the potential benefits of in-car use in any policies being developed in the area of banning cell-phones.

This is not to say that the goal of improving road safety should be subservient to the needs of FCD collection, rather that it should simply be included in the decision-making process.

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[29] Ibid
[30] Ibid
[31] Ibid

2.3.4 PRIVACY CONCERNS

Despite issues surrounding the accuracy of information and roadway safety, perhaps the most pressing concern raised regarding the use of Floating Cellular Data is that of privacy. As with most digitally recorded data, there are concerns regarding the use of FCD in areas such as who is collecting the data, what is being collected, how it is being stored, for how long and who has access[33]. As this is an emerging technology, effective policy development will be imperative in regards to alleviating any fears the public may have.

Even in cases where the agency collecting the data uses it for its intended purpose and with the best interest of the public in mind, this does not guarantee the safety of data. Data collected is susceptible to electronic theft, can be sold during bankruptcy proceedings or in some cases be obtained legally with a court order[34]. Further, there exists no statue of limitation regarding when companies must get rid of old data.

In the United States, there exists no national policy governing matters such as data privacy. Consequently, consumers are at [missing word?] the whim of each individual industry in order to set regulations and rules in regards to how digital data is handled[35]. In the case of automotive data, which is often considered to be GPS related, the current laws and regulations are somewhat lacking.

As a case example, American Car Rental, based out of Connecticut, recently installed GPS trackers in its rental vehicles. The devices were in constant contact with the head-office, relaying data pertaining to vehicle speed. Each time the driver exceeded a rate of 79 mph for more than two minutes; the system would take note and record the incident. When the vehicle was subsequently

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[32] Ibid.

[33] Larkin, Gary (2006)

[34] Ibid

[35] Ibid

returned to American Car Rental, they would charge the driver an additional $150 for each speeding instance. These fees were so controversial as to warrant a court case that was argued before the Supreme Court. The court ruled that although American Car Rental could not charge motorist the additional fee, it did not make a ruling prohibiting the use of GPS style devices in vehicles[36].

However, government intervention in this area is not always on behalf of the general public. The Department of Transportation in Oregon is pursuing a reform to gas taxes that would see motorist charged not by how many gallons of fuel purchased, but rather by the number of miles driving. This is being pursued in order to reflect changes in vehicle efficiency standards over the past few years[37]. "While Oregon has opted not to record locations, there is little to indicate that, like American Rental Car, it could not do so if it chose"[38].

Each of these cases is relevant to the use of FCD as it shows that if a system tracking each individual user of the roadway were to be implemented, there are collateral uses that may begin to emerge. It will be necessary for governments to implement effective digital data privacy policy before the public can be fully assured of the safety of collecting FCD.

To this end, there are a number of criteria that a policy governing the use of FCD should strive to achieve:

- National Agreement – In either the United States or Canada, the adoption of policy should be done on a nationwide basis. This will ensure consistent standards of practice regardless of

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[36] Ibid
[37] Ibid
[38] Ibid

the city being considered. In Canada, the Office of the Privacy Commissioner of Canada would most likely develop policy in this area[39].

- Stakeholder Involvement – FCD policy development would require the input of several different stakeholders such as the product vendors, cell-phone companies, privacy-advocacy groups, transportation agencies and government officials
- Types of Data to be collected – Information collected using FCD technology should be restricted to purely transportation related statistics, and at no time should it be linked to any record of the transponder or cell phone transmitting the data.
- Provide Statue of Limitations – Although the use of historical transportation data for planning purposes must be given due consideration, the collection of data pertaining to the specific locations of vehicles should not be allowed. Data retained for future reference should be limited to currently maintained statistics such as link traffic volumes during peak hours, turning counts at intersections and average speed data.
- Ensure Data Security – Considering the limits of available technologies, agencies responsible for the collection and organization of data should be required to take all reasonable steps to maintain electronic security over data.
- Full Information Disclosure – Full disclosure of which companies/agencies are responsible for collecting the data, as well as which agencies have access to it.

2.4 FCD Vendors

In order to evaluate the feasibility of pursuing a FCD based traffic management system, the author has reviewed the current capabilities of those companies that deal in FCD. In all cases, these companies are primarily concerned with the gathering of FCD, which is then relayed onto a traffic management system for analysis.

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[39] Government of Canada (2007). "Office of the Privacy Commissioner of Canada" Retrieved August 22nd, 2007 from http://www.privcom.gc.ca/index_e.asp

Table 2[40] provides a listing of these companies, as well as a brief description of their capabilities. Collectively, these vendors represent the ability to provide FCD in the majority of urban centres around the world.

Table 2 - FCD Vendor Overview

Company	*Capabilities*
AirSage	• Provides coverage on more than 100,000 centerline miles of roadway. • Large data pool (>51,000,000 cell signals). • Provides information to government agencies and private sector companies (e.g. state DOT, navigation companies, TV stations, radio stations, fleet companies).[41]
Andrew (Geometrix)	• Supports all phone technologies.[42] • Five sites that cover approximately 18 mi^2
Cellint (VirtualSensor)	• Immediate incident alert - similar to road sensors. • Highly accurate travel time.[43]
CouldBerry	• 100% coverage in America. • Designed for vehicle fleets.[44]
Decell (AutoTraffic)	• Uses existing mobile network infrastructure. • Random probing to protect privacy. • Error <10%.[45][46]
Delcan	• Uses cell phone and GPS data. • Tracking and travel time services.[47]
IntelliOne	• Reads position twice per second when call is made, every 2-5 minutes otherwise.[48]
IT2Me	• Extracts GPS information. • Exclusive access to the Nextel Wireless Network, no traffic information provided.[49]
LogicaCMG	• Provides journey travel times. • Covers entire networks of highways, regional and urban roads.[50]
RoDIN24	• Full roadway network coverage. • Based on existing GSM infrastructure.
Ulocate	• Two-minute updates. • Works only with Motorola.[51]
ZipDash	• Regional traffic information. • Provides average speed data.[52]

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[40] Wunnava, Subbarao et al. (2006). Travel Time Estimation Using Cell Phones (TTECP) for Highways and Roadways. Florida International University, Miami for Florida Department of Transportation.

[41] AirSage (2007). "Frequently Asked Questions". Retrieved August 10th, 2007 from http://www.airsage.com/pdf/faqs.pdf

[42] Wunnava, Subbarao et al. (2006).

[43] Cellient (2007). "Road Traffic Monitoring and Provides Accurate cellular network Information". Retrieved August 29th, 2007 from http://www.cellint.com/traffic_data/traffic_system.html

[44] Wunnava, Subbarao et al. (2006).

[45] Ibid

[46] Decell (2007). "Decell". Retrieved August 18th, 2007 from http://www.decell.com/solutions/floating%20car%20data.htm

[47] Wunnava, Subbarao et al. (2006).

[48] IntelliOne Technologies Corporation (2007) "Live Information – MSP". Retrieved August 18th, 2007 from http://www.intellione.com/Traffic%20%26%20Location%20Services/Live%20Information/liveinformation-.html

[49] Wunnava, Subbarao et al. (2006).

[50] Ibid

[51] Ibid

[52] Ibid

As can be seen in the above table, there are clearly a large number of vendors that are capable of providing FCD. Consequently, the availability of data will not be a prohibitive issue in regards to the establishment of FCD-based traffic management system.

2.5 FCD Summary

The use of FCD for the collection of real-time information is clearly an emerging field. There are several vendors who deal in the procurement of FCD and a number of jurisdictions who are either already using FCD or who are considering its use.

However, there are still substantial concerns regarding FCD. Issues arising from the level of data accuracy that can be achieved, sampling bias, road safety policy and invasion of privacy are serious matters for consideration. Due to these issues, it cannot be definitively stated that FCD represents a superior alternative to standard real-time information technologies at this time.

Despite these concerns, the potential for the future use of FCD should not be ignored. In order to move towards the predictive transportation system as outlined in Section 1.2.2, the use of FCD will be required. There are currently no other forms of real-time information that can realistically fulfill requirements such as:

- Arterial and collector roadway coverage
- Elimination of road-side equipment
- Provision of continuous traffic data

Consequently, although the application of FCD is currently feasible and appropriate for several applications, as evidenced by its widespread use, the outlined concerns currently prohibit its integration with dynamic modelling for the purpose of a predictive transportation system.

The development of policy surrounding the use of FCD is heavily dependant on the issue under consideration. The development of policy surrounding technical issues such as sampling size and the improvement of accuracy offer little potential benefits.

By contrast, issues of roadway safety and privacy offer areas where the development of proper policy would help tremendously. These recommendations are outlined in Sections 2.3.3 and 2.3.4, and are summarized here in Table 3.

Table 3 – FCD Policy Recommendations

Roadway Safety	***Privacy***
• No ‘Car-On Phone-Off’ policies	• Development of a National policy
• No outright banning of cell-phones in vehicles	• Ensure encompassing stakeholder involvement
• Give consideration to benefits of cell-phones in cars while drafting policy	• Restrict collection to common transportation statistics
• Avoid contradiction between various agencies	• Establish statue of limitations on data records
• Do not allow FCD requirements to supersede safety priorities	• Ensure data security
	• Provide full information disclosure

3. CURRENT STATE OF DYNAMIC MODELLING

3.1 Dynamic Modelling Overview

Dynamic transportation modelling involves the use of real-time transportation data in order to provide an estimate of the current condition of a roadway network. Dynamic modelling differs from other types of transportation models due to the fact that it is designed to ‘adapt’ to the current roadway conditions. This differs from Static models, which rely more on information such as historical traffic counts.

A dynamic transportation model is required in order to make full use of any benefits that may arise from the use of FCD. This is due to the fact that static models typically rely on data obtained from point sources, such as screen-lines or the aforementioned traffic counts. Conversely, dynamic models are capable of using and modelling data obtained from an entire stream of traffic data, such as that provided by FCD. As an additional benefit, the ability to provide predictive traffic information is something exclusive to dynamic modelling.

3.2 Currently Available Technologies

In order to examine the feasibility of using FCD with dynamic modelling for real-time incident management, it is necessary to evaluate the currently available models on the market. This model scan will give insight into the current state of the technology, its functions and potential applications.

For the purpose of this feasibility inquiry, dynamic models were defined to be any academic or commercially available transportation model that is able to fulfill three key criteria

- Allow the input of real-time traffic information
- Be capable of translating the inputted data into an easily digestible format such as a traffic congestion map, travel time information or similar disseminate format.

- Be able to provide some form of predicative estimation of future traffic conditions.

Using these criteria, eight suitable transportation models have been identified. Each of these models fulfills the three criteria outlined above. Of particular interest is the INRIX transportation model. This model is important in the context of FCD, as INRIX represents the only dynamic transportation model that has currently used data not directly gathered from roadway sensors. Any FCD-based system that would also employ dynamic modelling will require this approach.

Full descriptions of the models identified are provided as Appendix B.

3.3 Worldwide Use of Dynamic Modelling

In order to fully evaluate the feasibility of dynamic modelling in regards to its potential use with real-time data, a worldwide scan of current applications was completed. This scan provides insight into the current use of this technology worldwide, its benefits and any concerns that would prohibit its use with floating cellular data.

Cities were selected for investigation on the basis of several criteria. These criteria were developed by the Author in order to ensure that the best possible sampling of cities would occur. Among the criteria used were:

- Attempt to Capture a Worldwide Sample – Different geographical regions may have more experience than others. The review should capture all usage.
- Select Major Urban Centres - By nature, ITS development requires a large congestion problem to be present. Therefore, major urban centres are much more likely to be using dynamic modelling.

- Availability of Information – Selection of cities that had demonstrated some willingness to divulge information in this area.
- Include Cities With Known Applications – Include cities identified through literature and in discussion with industry contacts.

Based upon these criteria, twelve cities were identified for further investigation. These cities are listed in Table 4:

Table 4 - Dynamic Modelling Scan

North America	
Boston	Houston
Los Angeles	Washington/Maryland
New York	Seattle
Toronto	Ontario
Europe	***Asia***
Berlin	Beijing
London	Singapore

Using varying means, a scan was completed for each city. Information was obtained through methods such as internet research, direct contact with agencies operating transportation systems in the area and discussion with industry experts. Cities in which some information was found pertaining to dynamic modelling use are presented below.

3.3.1 HOUSTON

The city of Houston is a major city located in the southern United States. Houston is the largest city in the state of Texas, and the fourth largest city in the country. With over 575 miles of freeway road network in the metropolitan area, the City of Houston was identified as relevant for investigation based on the size of the city and complexity of the road network.

Houston utilizes the TransStar system in order to provide real-time traffic data on its website. The claimed refresh rate of 20 seconds and the provision of travel time information lead the author to believe that dynamic modelling may be present.

However, despite this real-time application, there is no use of dynamic modelling in Houston. Real-time data is obtained thorough the use of specialized probe vehicles in order to obtain Floating Vehicle Data (FVD). This data is then translated into the real-time traffic conditions that appear on the website[53].

3.3.2 LOS ANGELES

Los Angeles is home to the largest freeway system in the world, thus tackling significant traffic issues. A new traffic control centre has recently been completed, from which the region leads its traffic and incident management systems. According to information provided by the DynaMIT website, dynamic transportation modelling is to play a role in this new system[54].

The Los Angeles Department of Transportation (LADOT) has been pursuing an Advanced Incident Detection Algorithm (AIDA), which would automatically detect incidents occurring on surface streets by constantly analyzing detector data received from the traffic surveillance system. More than 10,000 loop detectors in the field will transmit traffic volume and road occupancy data every second to central computers through fibre-optic communications system. These real-time data will be combined with ArcView GIS database for display of incident detection.

The intent is to integrate DynaMIT with the LADOT's Adaptive Traffic Control System (ATCS). DynaMIT will interface with the AIDA program currently under development by LADOT.[55]

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[53] Houston Transtar System (2007). "Houston Transtar System". Retrieved August 3rd, 2007 from http://www.houstontranstar.org/

[54] MIT Intelligent Transportation Systems Program (2007). "Publications". Retrieved August 12th, 2007 from http://mit.edu/its/research.html

[55] SECTION MAY BE COPIED FROM DYNAMIT SITE – NEED TO CHECK AND REFERENCE PROPERLY

3.3.3 WASHINGTON/MARYLAND

The city of Washington is located in a special federal district of the United States called the District of Columbia. As the capital of the country, Washington is an epicentre of political and cultural activity. The DynaSMART website had indicated that it was being used to model transportation events in the Washington area as part of the Maryland Coordinated Highway Action Response Team (CHART) system. Maryland is located adjacent to the District of Columbia.

Discussion with officials in the CHART centre indicated that they currently do not utilize dynamic modelling for incident management. The implementation of DynaSmart did not fully occur due to the academic and theoretical nature of the currently available system[56].

In the future, CHART plans to pursue the implementation of a dynamic modelling application for the management of transportation events. Although this is a stated policy directive, there has been no formal work done to date[57].

3.3.4 BERLIN

The City of Berlin is a large urban centre located in Germany. As a major transportation centre, the City of Berlin has addressed its transportation incident management challenges through the use of a dynamic modelling system. The PTV Traffic Platform uses the VISUM Online program in order to dynamically estimate the impacts of transportation incidents. This system represents a state-of-the-art application of dynamic modelling[58].

This system was implemented at the Traffic Management Center in Berlin in order to address the anticipated transportation incidents arising from the FIFA World Cup in 2006. It was used to model

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[56] PHONE CALL REFERENCE

[57] IBID

[58] PTV America. “VISUM Online”. Retrieved August 12th, 2007 from http://www.ptvamerica.com/visum.html

incidents and a queue arising not only from the soccer matches themselves, but also regular incidents that occurred near the city-centre.[59]

The system provides predictive traffic states for 15 and 30-minute future conditions, which are updated every 10-15 minutes[60]. Data inputs include “real-time data from Traffic Eye Universal (TEU) detectors and loop detectors, construction/roadwork information, weather data and events”[61].

On parts of the road network that are not directly measured by detectors, the traffic conditions calculation is performed with the help of a route estimation procedure…”[62] This is accomplished through the integration of historical data and FVD. Approximately 300 of Berlin’s taxis and buses are equipped with FVD detectors, which record the position of the vehicle on the roadway. Data obtained form these FVD detectors and historical databases are fused with the real-time data in order to generate a Level-of-Service (LOS) Map for the whole area[63].

3.3.5 BEIJING

The city of Beijing is the capital of China, located in the northeastern part of the country. The highway structure of Beijing consists of four concentric ring roads, which are joined by nine expressways. Beijing represents an interesting case, as being the host of the 2008 Summer Olympic Games they are aggressively pursuing the latest in transportation technologies.

Delcan Engineering is currently working on adapting the DynaSmart system for implementation in Beijing. This application will result in some dynamic modelling and predicative capabilities[64], but information regarding the specific capabilities of this system was not available.

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[59] Ibid
[60] Ibid
[61] Ibid
[62] Ibid
[63] Ibid
[64] Delcan (2007). Newsletter – February 2007. Toronto, Ontario, Canada. Delcan: 2007

3.3.6 SINGAPORE

The use of dynamic traffic modelling in Singapore is a fairly recent development. The iTransport project is an on-going attempt to provide an integrated incident management system to Singapore. One of the modules of the iTransport package utilizes the AIMSUN traffic model in order to provide two main functions. First, it is used in an off-line case to provide evaluation of existing incident management plans for major planned events. Secondly, it is used for the prediction of traffic conditions using real-time data gathered from the field (inductive loops and other detectors).[65]

In the first case, Traffic Engineers are able to utilize the system to develop and test various incident management strategies. AIMSUN allows the Traffic Engineer to establish typical traffic volumes, introduce an incident and the associated response plans, simulate the outcome and see the resultant impact on the road network[66].

The second function of the Singapore system is to model and predict traffic conditions on a real-time basis. In order to accomplish this, the entire Singapore roadway network has been modeled into the system. The Origin-Destination (O-D) matrix and planed closures are updated onto the live model in real-time, along with current signal phasing and traffic volumes. The simulation model will continually gather these inputs in order to predict future traffic scenarios for approximately 30-minute intervals[67].

3.4 Dynamic Modelling Summary

There are currently eight models worldwide that can be considered to be dynamic to some degree. With the exception of the INRIX system, most models were very similar in their capabilities, with any of them representing a viable option for integration with FCD.

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[65] OneTrasnsport (2007). “Traffic Management in Singapore”. Retrieved July 15th, 2007 from http://www.onemotoring.com.sg/publish/onemotoring/en/on_the_roads/traffic_management.html

[66] Ibid

[67] Ibid

The INRIX system represents an important point in regards to the potential use of FCD. Each of the other seven models have typically been designed in order to take data from a single source, that being the agency responsible for the installation of a ITS. However, INRIX is capable of taking data from several sources and jurisdictions at once. This is evidenced by its reported usage in over 130 different areas[68].

This capability will be important moving forward, as the use of FCD will require the gathering and organization of input data from several sources. This will be required as cell-phone data will need to be obtained from several different service providers in order to fully incorporate all roadway users. This is in addition to the need to gather and incorporate data from any other standard floating traffic probes that may be on the roadway.

Further, as dynamic modelling has only been identified as being implemented in three cities worldwide, it can be said that this is still an emerging technology. Many cities investigated in regards to this technology either had not considered its use, or examined its use and found implementation to be daunting. Table 5 provides a summary of the worldwide scan for use of dynamic modelling,

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[68] INRIX (2006). "INRIX". Retrieved August 29th, 2007 from http://www.inrix.com/solutions.asp

Table 5 - Dynamic Modelling Summary

City	*Actual Use of Dynamic Modelling*	*Potential Future Use of Dynamic Modelling*
North America		
Boston	✗	✗
Houston	✗	✗
Los Angeles	✗	✓
Washington/Maryland	✗	✗
New York	✗	✗
Seattle	✗	✗
Toronto	✗	✗
MTO	✗	✗
Europe		
Berlin	✓	✓
London	✗	✓
Asia		
Beijing	✓	✓
Singapore	✓	✓

Overall, the capability to use real-time traffic information for the generation of predictive traffic information does exist. As FCD represents simply another form of real-time information, any of the presented models should be capable of utilizing it for the purpose of developing predictive traffic information, assuming it was organized and collected properly.

The unique challenge associated with FCD in terms of modelling is the fact that it would be necessary to gather and organize data from several sources. The case of the INRIX system shows that this capability is one that currently exists in the marketplace.

Therefore, while there exists no single model currently capable of using FCD for the subject purpose, the capability to fulfill each requirement (allow multiple data inputs, provide predicative traffic information) does exist within different models. Either the expansion of the INRIX system to provide accurate predictive information or the modification of one of the other seven models in order to accommodate multiple sources of data would be required in order to move forward.

4. EVALUATION OF FEASIBILITY

Overall, the use of FCD for real-time traffic management is a promising field. There are benefits to be had over the current state of practice, mainly in areas such a coverage, reduction of construction impact and cost.

However, there are still many outstanding issues that are currently prohibiting the widespread use of FCD. As outlined in Section 2.3, these issues are:

- Technology Issues
- Sampling Concerns
- Roadway Safety
- Privacy Concerns

Until these items are resolved, it will not be feasible for roadway agencies to fully adopt FCD. Until that time, the use of FCD will be limited to niche applications where the cost of installing more accurate technologies is too high and accuracy of data is not a overriding concern.

APPENDIX A

ACRONYMS AND ABREVIATIONS

CHART	Maryland Coordinated Highway Action Response Team
DOT	Department of Transportation
FCD	Floating Cellular Data
FVD	Floating Vehicle Data
GPS	Global Positioning System
GSM	Global System for Mobile Communications
HAR	Highway Advisory Radio
LADOT	Los Angeles Department of Transportation
LOS	Level-of-Service
O-D	Origin-Destination
VMS	Variable Message Signs
VSLS	Variable Speed Limit Sign

APPENDIX B

CURRENTLY AVAILIBLE DYNAMIC MODELS

AIMSUM

AIMSUN is a traffic simulation program capable of reproducing traffic conditions on any transportation network. It considers vehicle types and driver behaviour in order to provide a visual representation of traffic flows. Mainly used for testing new traffic control systems and management strategies, it can also be used for traffic state prediction. When used in this way, it can work in conjunction with real time applications.[69]

CONTRAM

CONTRAM is a Windows-based software package that is generally used by transport planners. "CONTRAM is fully dynamic, meaning it can model the build-up and decay of queues throughout the day and the impact of these queues on route choice behaviour".[70] Another feature is the ability to predict the impact of information on incident management, such as drivers becoming aware of an event and changing their route. Data is entered and results displayed via a graphical interface[71].

DynaMIT

DynaMIT is a real-time transportation model designed to support the operation of a transportation management system. "DynaMIT was the result of several years of intense research and development at the Intelligent Transportation Systems Program, Massachusetts Institute of Technology"[72].

Some features of the DynaMIT model include:

- Ability to distinguish between vehicle types and driver behaviour.
- Ability to distinguish between informed and uninformed drivers.

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[69] Traffic Design Group (2007). "Traffic Design Group – Software Programs". Retrieved August 28th, 2007 from http://www.tdg.co.nz/index.php?a=2&b=5&c=3

[70] Mott MacDonald and TRL (2007). "CONTRAM Dynamic Assignment Traffic Model". Retrieved August 28th, 2007 from http://www.contram.com/about/dynamicmodelling.shtml

[71] Ibid

- Individual simulation of each trip[73].

Paramics

Paramics is a commercial transportation-modeling tool that provides modeling capabilities for several applications. Among these are:

- Mixed urban and freeway networks
- Right-hand and left-hand drive capabilities
- Advanced signal control
- Roundabouts
- Public transportation
- Car Parking
- Incidents
- Truck-lanes

”By modeling individual vehicles [Paramics] provides the transportation professional with insight into and better understanding of many hundreds of network issues, resulting in a more efficient and effective approach to projects.”[74]

INRIX

The Inrix transportation service is unique in the realm of those models that utilize real-time data for dynamic modelling. Inrix is a private entity that provides real-time data to its clients for a fee. Unlike other models, which obtain data directly from the field equipment, Inrix uses publicly available data from various sources in order to provide traffic data independent of the jurisdiction in charge of the roadway[75].

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[72] MIT Intellegent Transportation Systems Program (2007). “How Does It Work?”. Retrieved August 28th, 2007 from http://mit.edu/its/dynamit.html

[73] Ibid

[74] Paramics Online (2007). “Paramics Modeller”. Retrieved August 29th, 2007 from http://www.paramics-online.com/products_modeller.php

[75] INRIX (2006). “INRIX”. Retrieved August 29th, 2007 from http://www.inrix.com/solutions.asp

INRIX acquires real-time and historical sensor data from hundreds of public and private sources including anonymous, real-time GPS probe data from more than 500,000 commercial fleet, delivery and taxi vehicles; toll tag data; and road occupancy (a proxy for vehicular density) and speed measurements from Department of Transportation sensor networks[76].

VISUM ONLINE

VISUM Online is dynamic model currently being used for numerous traffic management applications around the world. "VISUM Online is designed for freeways and arterial streets as well as for applications in the field of integrated traffic control. It is also the core component for sophisticated traveler information systems where information from VISUM Online can be provided either before or during a trip."[77]

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[76] Ibid

[77] PTV America (2007). "VISUM Online – the Intelligent Traffic Platform". Retrieved September 12th, 2007 from http://www.english.ptv.de/download/traffic/software/Visum-Online_Einleger_2005_e.pdf