Geo-visual Analytics of Canada-U.S. Transborder Traffic Data

Ali Nejaty Jahromi

A Thesis

in

Concordia Institute for

Information Systems Engineering

Presented in Partial Fulfillment of the Requirements

for the Degree of Master of Applied Science (Quality Systems Engineering) at

Concordia University

Montreal, Quebec, Canada

May 2014

Concordia Institute for Information Systems Engineering (CIISE)

CONCORDIA UNIVERSITY

School of Graduate Studies

This is to certify that the thesis prepared

By: **Ali Nejaty Jahromi**

Entitled**:** **Geo-visual Analytics of Canada-U.S. Transborder Traffic Data**

and submitted in partial fulfillment of the requirement for the degree of

Master of Applied Science (Quality Systems Engineering)

complied with the regulations of the University and meets with the accepted standards with respect to originality and quality.

Signed by the final examining committee:

Dr. Roch Glitho ________________ Chair

Dr. Ciprian Alecsandru ________________ Examiner

Dr. Chun Wang ________________ Examiner

Dr. Amin Hammad ________________ Supervisor

Approved by ________________________________

Chair of Department or Graduate Program Director

____

Dean of Faculty

ABSTRACT

Geo-visual Analytics of Canada-U.S. Transborder Traffic Data

Ali Nejaty Jahromi

This research aims to investigate new geo-visual analytics methods and techniques for visually analyzing the large amount of historical and near real time geospatial and temporal traffic data at the border crossings between Canada and the U.S. Historical traffic-related time-series data are available from different agencies in both countries for at least the last four decades for different modes of transportation and different purposes. Supplementary historical and near real-time data about delays, weather conditions, and different types of alerts and conditions at the ports of entry can be used to analyze the decision processes behind changes in traffic patterns. The data are gathered, processed, and linked to a web-based Geographic Information System (GIS) that can be accessed by authorized users over the Internet using an intuitive graphical user interface (GUI) to support different types of queries. The resulting database and information system can be beneficial for understanding the impact of the different factors affecting delays at the ports of entry and the impacts of these delays on the decision-making of travelers, planners, and supply chain operators.

ACKNOWLEDGEMENT

The writing of this thesis has been an amazing journey that I learned a lot from; but this could not be possible without all the help and support I received from so many people: from all the faculty and staff at Concordia university and our contacts at Canada Border Service Agency to my supportive friends in Montreal and my lovely family in Iran. The first person that deserves my gratitude is my steadfast supervisor Dr. Amin Hammad, who has always supported me and kept me in the right path with his encouraging attitude and patient guidance. I have always been inspired by his hard work and enthusiasm for research.

I am very thankful to my lab mates who helped me accomplish this project: Dhiren Bhatia, Danial Ghadiri and Farid Vahdati, who helped with data processing and Athena Moghaddam, who helped with some parts of the software development. I am also very grateful for the support I received from Dr. Paul Loo and Ms. Kathryn Mills (CBSA) with respect to defining the visual analytic requirements of the system. I would be remiss if I did not acknowledge the sacrifices my parents made to make graduate studies possible for me. They never stopped helping me succeed in a city 9800 km far from home.

Last but not least, I have no words to appreciate the love, support and patience of my beloved wife, Athena. Not only has she always encouraged me to fight for my dreams, but she also fights just next to me to make them become true. She has shared with me this entire journey. This dissertation is dedicated to her.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABREVIATIONS

2D	Two-Dimension
3D	Three-Dimension
ANN	Artificial Neural Network
API	Application Programming Interface
BIFA	Border Information Flow Architecture
BTS	Bureau of Transportation Statistics
CANSIM	Statistics Canada
CAP	Common Alerting Protocol
CAP-CP	Canadian Profile of the Common Alerting Protocol
CBP	Customs and Border Protection
CBSA	Canada Border Services Agency
CSCNSD	Canada Senate Committee on National Security and Defence
DOT	Department of Transportation
EDT	Eastern Daylight Time
EMPS	Emergency Management and Public Safety
FHWA	Federal Highway Administration

GeoRSS	Geographical Rich Site Summary
GIS	Geographic Information Science
GML	Geography Markup Language
GPS	Global Positioning System
GUI	Graphical User Interface
GVA	Geo-Visual Analytic
HTTP	Hypertext Transfer Protocol
HWY/B	Highway - Land Border Office
ID	Identifier
IMASH	Information Management System for Hurricane
IPAWS	Integrated Public Alert and Warning System
JIT	Just-In-Time
MASAS	Multi-Agency Situational Awareness System
MASAS-X	Multi-agency Situational Awareness Systems National Information Exchange
NAAD	National Alert Aggregation and Dissemination
NAFTA	North American Free Trade Agreement
O-D	Origin-Destination

OGC	Open Geospatial Consortium
PBOA	Public Border Operators
PoE	Port of Entry
R&D	Research and Development
RSS	Rich Site Summary
SA	Situational awareness
SCM	Supply Chain Management
SQL	Structured Query Language
TBS	Treasury Board of Canada Secretariat
TRB	Transport Research Board
TV	Television
U.S.	United States of America
URL	Uniform Resource Locator
USGS	United State Geological Survey
VA	Visual Analytics
W3C	World Wide Web Consortium
WGS84	World Geodetic System established in 1984

XML	Extensible Markup Language

CHAPTER 1 INTRODUCTION

1.1 BACKGROUND AND PROBLEM STATEMENT

Visual Analytics (VA) is a method that helps analyzing data based on visualization to find out the patterns, trends, cycles, etc. VA combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex datasets. VA is different from standard approaches of analysis. Interactive visual representations can amplify human natural capabilities for detecting patterns, establishing links, and making inferences (Fabrikant and Lobben, 2009).

Recently, research about Geovisual Analytics (GVA) has been getting momentum (Andrienko and Andrienko, 2006; Andrienko et al., 2010; Andrienko et al, 2013; Schumann and Tominski, 2011). GVA aims to provide a technology that combines the strengths of human and electronic data processing in a synergistic cooperation for analyzing spatiotemporal data and solving spatiotemporal problems. The main idea of using GVA is based on the simple fact that: everyone is a spatio-temporal analyst. Spatio-temporal analysis is not something that just experts and data analysts do. People use their spatio-temporal analysis skills when they are planning for an investment, seeking for a new job, searching a place to visit, etc.

The strategic plan of the visualization in Transportation Committee of the Transport Research Board (TRB) has identified VA as one of its main target areas and has indicated that transportation in general is significantly behind in using this technology in a comprehensive way (TRB-VTC, 2011). The plan has also identified that the main factor that impedes the wider usage of this technology is the cost of developing suitable VA tools and upgrading information technology infrastructure to manage and share data.

A study by Transport Canada (2004) on border wait time has found that congestion and excessive delays at Canada-U.S. border crossings in the wake of 911 were symptomatic of more fundamental problems, such as the unpredictability of crossing times, the potential vulnerability to further disruption, the lack of consistent and reliable empirical data on border wait times, and the absence of any systematic capacity to generate and transmit real-time data on wait time at Canada-U.S. border crossings.

1.2 RESEARCH OBJECTIVES

The research aims to propose a method to extend the GVA methods to transborder area by designing a transborder dedicated GVA system. Thus, the proposed method deals with three main goals and their implementations requirements (e.g., usability, accessibility and security). The proposed method covers three main objectives:

(1) Handling the large amount of transborder data in reasonable time via GVA by using human visual understanding capabilities; (2) Combining the historical and near real-time data for real time and more accurate decision making; and (3) Providing a user friendly environment to visualize the desired data based on the requests of the users with different levels of computer expertise.

1.3 THESIS ORGANIZATION

This thesis will be presented as follows:

Chapter 2 Literature Review: This chapter discusses about VA and GVA in general and briefly studies current available VA and GVA tools. Also, various data standards are reviewed in this chapter. Moreover, current Canada and U.S. efforts on GVA and specifically in the transborder area are reviewed in this chapter.

Chapter 3 Methodology: In this chapter, system requirements and advantages of large scale digital datasets are explained in detail. The proposed method and its elements like data collection, GVA toolbox, graphical user interface, dataset selection and the developed algorithms are fully explained.

Chapter 4 Implementation and Examples: In this chapter, the proposed system architecture and technology selection are explained. The proposed system is validated through several examples implemented using ArcGIS Viewer for Silverlight and ArcGIS Viewer for Flex. The developed tools, widgets and layers are described in detail.

Chapter 5 Conclusions and Future Work: This chapter summarizes the present research work, highlights its contributions, and suggests recommendations for future research.

CHAPTER 2 LITERATURE REVIEW

2.1 INTRODUCTION

This chapter covers the main objectives of VA and GVA as well as the established standards and policies related to them. Various standards lead to various VA and GVA tools and technologies in this area. Several governmental and nongovernmental organizations which are involved in Canada-U.S. transborder issues understand the importance and capabilities of GVA and aim to using this method to solve issues they are facing, such as big-data assessment and accurate real-time decision making.

The literature review comprises the definition of VA and GVA and the difference between visualization and the VA. Available VA tools and established data standards for storing, parsing and understanding geographic data are introduced. The importance of GVA in transportation is explained. Related data collecting and data sharing systems are surveyed. Eventually, potential supply chain applications of visual analytics are studied.

2.2 VISUAL AND GEOVISUAL ANALYTICS

2.2.1 VISUAL ANALYTICS

VA is a method that helps analyzing data based on visualization to find out the patterns, trends, cycles, etc. VA combines automated analysis techniques with interactive visualizations for an effective understanding, reasoning and decision making on the basis of very large and complex datasets. VA is different from standard data analysis approaches. Interactive visual representations can amplify human natural capabilities for detecting patterns, establishing links, and making inferences (Fabrikant and Lobben, 2009). VA is used to synthesize information and derive insight from massive, dynamic, ambiguous, and often conflicting data. The main idea of VA is using the strength of human processing of the graphical representation of data. The idea is inherited from information visualization, graphic information science, geovisualisation and data mining. The key features of VA are: (1) Focus on problem solving and decision making; (2) Apply computational and automated techniques and algorithms; (3) Involve human understanding through interactive visual interface; and (4) Support for derivation of analytical outcomes (Thomas and Cook, 2006; Keim et al., 2010; Kohlhammer et al., 2011).

2.2.2 VISUALIZATION VS. VISUAL ANALYTICS

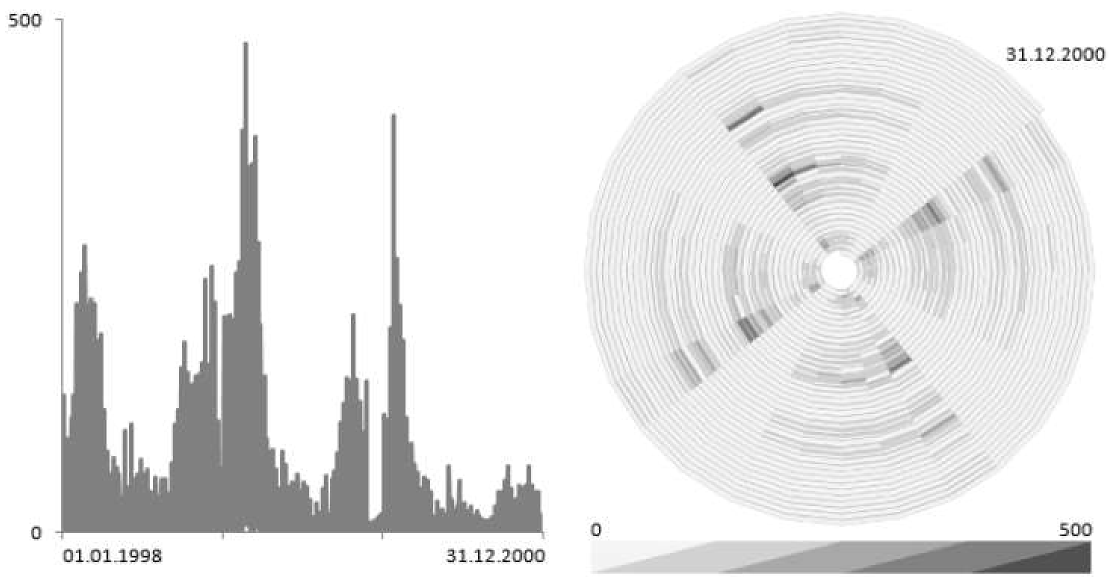
There is common misunderstanding about the differences between VA and visualization. Even though these two concepts are close but there is big difference between them. Visualization attempts to detect the expected events and discover the unexpected events in massive, dynamic, ambiguous, and often conflicting data. In fact visualization transforms data to information, and then information to knowledge; while VA is trying to go one step more and transforms knowledge to explanations. Actually VA is a way to detect the expected and discover the unexpected events in massive, dynamic, ambiguous, and often conflicting data, provide understandable assessments and communicate assessments effectively. Table 2-1 summarized the differences between Visualization and VA.

2.2.3 VISUAL METHODS FOR TEMPORAL DATA

Visual methods for temporal data can be categorized based on the time characteristics they were developed for: (1) linear time vs. cyclic time, (2) time points vs. time intervals, etc. Figure 2-1shows the same health-related data in linear and cyclic time manner. The line graph shows the trends and outliers and the cyclic graph illustrates the periodic behavior of data. The time point data show the exact current data, while the time interval approach shows the aggregation of data during a period of time.

Table 2-1 Difference of Visualization and Visual Analytics

Visualization	Visual Analytics
data → information → knowledge	data → information → knowledge → explanation
Reasoning and synthesis of information and knowledge are <u>implicit</u>	Information, knowledge, and reasoning must be made <u>explicit</u>



(a) Linear graph **(b) Cyclic Graph**

Figure 2-1 Different Type of Visualization on same Data (Tominski and Schumann 2008)

2.2.4 GEOVISUAL ANALYTICS

Recently, research about Geovisual Analytics (GVA) has been getting momentum (Andrienko and Andrienko, 2006; Andrienko et al., 2010; Andrienko et al. 2013; Schumann and Tominski, 2011). GVA has been conducted through research of European coordination action Vismaster (Vismaster, 2014) to define a roadmap for future visual analytics research area. GVA aims to provide a technology that combines the strengths of human and electronic data processing in a synergistic cooperation for analyzing spatiotemporal data and solving spatiotemporal problems. The main idea of using GVA is based on the simple fact which is: everyone is a spatio-temporal analyst. Spatio-temporal analysis is not something that just experts and data analysts do. People use their spatio-temporal analysis skills when they are planning for an investment, seeking for a new job, searching a place to visit, etc. They try to understand the current situation, how it might change, consider all options, choose the suitable strategy and make the best decision for the future. People want to use the collected data which are related to them for their decision making and planning. The challenge is to understand the users' need for creating GVA tools to meet their expectations.

The other challenge of GVA is the need to analyze and make sense of overwhelming amounts of complex, disparate, conflicting, and dynamic data and information, which requires human judgment and the collaboration of different specialists among whom the data should be shared. GVA combines visualization, human-computer interaction, Geographic Information Science (GIS), operations research, data mining and machine learning, decision science, database and data warehousing technologies.

2.2.5 AVAILABLE GVA TOOLS

Several tools are available that provide GVA functionalities, such as Tableau, OpenDX, GeoTime, Panopticon, Advanced Visual Systems, Visual Analytics, and Idvsolutions (Choosing Visualization for Transportation Knowledge Sharing, 2013). These tools vary in the set-up time and efforts, installation options, skills and training required, processing speed, data size limitations, visualization templates, querying ability, data integration ability, GIS support, and real-time data integration. However, none of these tools have the necessary functions to handle spatiotemporal traffic data and to link them to GIS layers including road networks where different types of network analysis can be performed. Therefore, ArcGIS software was selected for this project because of its superior functionalities and extensible Application Programming Interface (API). Appendix A has a list of available GVA solutions.

2.2.6 DATA CLUSTERING

Clustering means "the process of organizing objects into groups whose members are similar in some way" and cluster is a collected objects which are "similar" among them and are "dissimilar" to the objects belonging to other clusters.

In this case the similarity criterion is distance: two or more objects belong to the same cluster if they are "close" according to a given distance. This is called distance-based clustering.

<u>K-means algorithm</u>

K-means (McQueen, 1967) is one of the learning algorithms that solve the clustering problem. The procedure follows a simple and easy way to classify a given data set through a certain number of clusters (k clusters).

The main idea is to define k centroids, one for each cluster. Since the locations of these initial centroids points lead to different results, the best choice is to place them as much as possible far away from each other. The next step is to assign each point of data set to the nearest centroid. When all points are assigned, the initialization step is completed. The next step is to calculate k barycenter of the clusters resulting from the previous step and set them as the new centroids. After these k new centroids is set, a new assignment has to be done between the same data set and the nearest new centroid. A loop has been generated. As a result of the loop, the k centroids change their location step by step until no more changes are done.

2.2.7 DATA STANDARDS

The gathered data in this research will be transformed to conform to the following global standards:

2.2.7.1 GEOGRAPHY MARKUP LANGUAGE

The Geography Markup Language (GML): The OpenGIS GML Encoding Standard is an XML (Extensible Markup Language) grammar for expressing geographical features (GML, 2013). GML serves as a modeling language for geographic systems as well as an open interchange format for geographic transactions on the Internet. As with most XML based grammars, there are two parts to the grammar – the schema that describes the document and the instance document that contains the actual data. This allows users and developers to describe generic geographic data sets that contain points, lines and polygons. Using application schemas, that are specialized extensions of GML, users can refer to roads, highways, and bridges instead of points, lines and polygons.

2.2.7.2 COMMON ALERTING PROTOCOL

Common Alerting Protocol (CAP): CAP is a common electronic messaging format of public alerts. CAP is an international standard of the Organization for the Advancement of Structured Information Standards (CAP, 2013). CAP file contains tags to describe the event as much as possible in a structured format. Figure 2-2 shows the main elements of CAP standard and the tags name. More details about all attributes and their description is in Appendix B.

```
<alert …>
<identifier> … </identifier>
<sender> … </sender>
<sent>0000-00-00T00:00:00-00:00</sent>
<status> … </status>
<msgType> … </msgType>
<source> … </source>
<scope> … </scope>
<code>profile:CAP-CP:x.x</code>
<note> … </note>
<references> … </references>
…
<info>
<language>en-CA</language>
<category> … </category>
<expires>0000-00-00T00:00:00-00:00</expires>
<event> … </event>
<urgency>Expected</urgency>
<severity>Severe</severity>
<certainty>Likely</certainty>
…
<area>
<areaDesc> … </areaDesc>
<polygon> … </polygon>
<geocode> … </geocode>
</area>
</info>
</alert …>
```

Figure 2-2 CAP Standard Main Tags

2.2.7.3 GeoRSS

Geographical Rich Site Summary: GeoRSS (2013) is based on Rich Site Summary (RSS), which is the most known Web feed and syndication format. GeoRSS is an emerging standard for encoding location as part of a Web feed. Web feeds are used to describe feeds (i.e., channels) of content, which are rendered by programs such as aggregators and web browsers. In GeoRSS, location content consists of geographical points, lines, and polygons of interest and related feature descriptions. GeoRSS feeds are consumed by geographic software to generate a layer in the map viewer. By building these encodings on a common information model, GeoRSS promotes interoperability. At this point, the GeoRSS collaboration has completed work on two primary encodings that are called GeoRSS GML and GeoRSS Simple. GeoRSS Simple is a very lightweight format that supports basic geometries (point, line, box, and polygon) and covers the typical use cases when encoding locations. GeoRSS GML is a formal Open Geospatial Consortium (OGC) GML Application Profile, and supports a greater range of features than GeoRSS Simple, notably coordinate reference systems other than WGS84 latitude/longitude. There is also a W3C GeoRSS serialization, which is older and partly deprecated but still the most widely used.

2.3 CANADA-U.S. TRANSBORDER RESEARCH

2.3.1 RESEARCH ABOUT GVA IN TRANSPORTATION

The strategic plan of the Visualization in Transportation Committee of the Transport Research Board (TRB) has identified VA as one of its main target areas and has indicated that transportation in general is significantly behind in using this technology in a comprehensive way (TRB-VTC, 2011). The plan has also identified that the main factor that impedes the wider usage of this technology is the cost of developing suitable VA tools and upgrading information technology infrastructure to manage and share data. Fanga et. al (2012) have used a GPS tracking dataset of approximately 12,000 taxis in Wuhan, China over one week and presented a spatiotemporal analysis of origin-destination (O-D) patterns of trips that use three critical bridges over the Yangtze and the Han rivers. Hranac (2013) suggested using VA for investigating the reliability of traffic data collected by GPS or Bluetooth. Hughes (2010) has proposed using GVA methods for the visualization of freight data. However, none of the above-mentioned studies have applied GVA to analyze very large datasets such as Canada-U.S. transborder traffic data.

2.3.2 Research about Collecting and Analyzing Canada-U.S. Transborder Traffic Data

A study by Transport Canada (2004) on border wait time has found that congestion and excessive delays at Canada-U.S. border crossings in the wake of 911 were symptomatic of more fundamental problems, such as the unpredictability of crossing times, the potential vulnerability to further disruption, the lack of consistent and reliable empirical data on border wait times, and the absence of any systematic capacity to generate and transmit real-time data on wait time at Canada-U.S. border crossings. It was suggested in that study that GPS logs are a rich source of empirical data on the delays incurred throughout the entire origin-destination trips.

Khan (2010) has investigated methods for predicting private and commercial vehicle queues and delays and displaying information to motorists, border crossing authorities, and other decision makers on a real-time basis. His research included the use of a calibrated microsimulation model of the Windsor-Detroit Ambassador Bridge crossing, development of artificial neural network (ANN) models for predicting queues and delay, and imbedding these models in a traveler information system that uses sensor data as input and produces delay predictions for dissemination on dynamic message signs and other media on a real time basis.

Anderson and Coates (2010) have examined a GPS-based dataset of truck border crossing times at the Ambassador, Blue Water and Peace Bridges over the period from July 2008 through June 2009. The study has revealed some interesting trends in average crossing times and the implications of the variability in crossing times on buffer times in cross-border supply chains.

A Federal Highway Administration study (FHWA, 2010) has measured cross-border travel times for freight at Otay Mesa International Border Crossing. However, none of the above mentioned studies aimed to apply methods to study traffic data.

2.3.3 Related Data Sharing Initiatives in Canada

Situational awareness (SA) is essential to the planning and execution of emergency response efforts. SA tools enable access to, and sharing of, information in real time, and assist in making strategic decisions and developing proactive solutions. Several SA tools are used across Canada and the U.S. and the ability to connect these different tools for shared SA is a critical capability to improve interoperability and ensure a more efficient and effective response. This is realized by the harmonization of the Canadian Multi-Agency Situational Awareness System (MASAS, 2013) with the U.S. Integrated Public Alert and Warning System (IPAWS, 2013) to enable sharing of alert, warning, and incident information and to improve response coordination during bi-national disasters. However, the alerts published by these systems are not used for analyzing traffic patterns.

2.3.4 National Alert Aggregation and Dissemination

A private company called Pelmorex Communication Inc. developed National Alert Aggregation and Dissemination (NAAD) System that provides authorized government agencies across Canada with a simple, easily accessible means by which they can issue public safety messages (NAAD, 2013). The NAAD System validates and authenticates the messages it receives to ensure they are indeed from the participating government authority and are compliant with certain agreed upon standards and policies. After this, the NAAD System aggregates all the alert messages it receives from government authorities into a data stream which it distributes over the Internet and by satellite ensuring coverage across Canada. This allows "Last Mile Distributors" like radio and TV broadcasters, cable and satellite operators to broadcast the alert messages if they wish to. The NAAD System allows Authorized Government Agencies to issue a wide range of public safety messages. Typically however, an alert will be issued if there is imminent danger to persons or property. The scope is quite large and can cover things such as tornados, train derailments, industrial fires, water contamination, missing persons; the list is endless and is not limited to weather or environmental warnings. Each province or territory will decide the level of authority it wants to delegate within its jurisdiction. For example, one province may decide that only one organization such as the provincial Emergency Management Office, will have authority to issue an alert whereas another province may decide to allow local authorities, such as regional or municipal emergency management staff, police or fire departments, to issue certain types of alerts. Certain federal authorities such as Environment Canada also access the NAAD System to distribute their weather warnings. The amount and type of alerts issued will depend on the policies set by each province and the authority they delegate to other agencies and municipalities. However, the types of events that are severe enough to warrant alerts interrupting television or radio broadcasts are expected to be infrequent.

2.3.5 Canada's Multi-Agency Situational Awareness Systems (MASAS) National Information Exchange (MASAS-X)

Multi-Agency Situational Awareness Systems (MASAS) is a multi-stakeholder federally-led initiative that aims to develop and support capabilities that will enable the sharing of location-based situational awareness information and alerts between emergency management and response agencies using open standards and an open architecture (MASAS, 2013). The MASAS initiative is led by the Defence R&D Canada – Centre for Security Science, in partnership with Public Safety Canada and Natural Resources Canada, and represents an impressive collaborative effort involving federal, provincial, territorial and municipal governments, non-governmental organizations and industry.

In November 2011, the Defence R&D Canada – Centre for Security Science launched the Multi-Agency Situational Awareness Systems national information eXchanges (MASAS-X) Pilot Project in support of the broader MASAS Development Initiative (MASAS, 2013). MASAS-X is focused on operationalizing the pan-Canadian operational, exercise and training information situational awareness information exchanges that link many stakeholders. These core operational services are being managed through a centralized office to offer a stable, reliable, resilient, long-term shared situational awareness capability within the Canadian public safety (and critical infrastructure) community. MASAS-X is the first step in building an enduring national MASAS capability that aligns with Public Safety Canada's Communications Interoperability Strategy and Action Plan for Canada.

MASAS-X supports the distribution of authoritative alerts and situational awareness information, with a focus on non-sensitive content that can be openly shared within the greater Emergency Management and Public Safety (EMPS) community.

As per MASAS principles and technical architecture, the content in MASAS-X is published directly by the source, with some content coming from polling authoritative public domain sources, such as government websites and various sensor systems. Registered pilot participants can, without fee, post and consume situational information to and from other users through MASAS-X by using their own application(s) or by using the basic MASAS-X tools. Examples of MASAS content include road closures, including planned (due to road maintenance or security operations) or imposed by natural hazards such as floods and blizzards, community closures or temporary relocations in the north or remote regions, natural hazard alerts (i.e., earthquake, tsunami, space weather), hazardous materials or incidents involving chemical, biological, radiological-nuclear or explosives agents, water/stream level sensor alerts, points of interest information (i.e., rest stations, first aid, emergency shelter, etc.), perimeters of wildfires, quarantine zones, events, search and rescue activity, sandbagging operations, dike construction, pumping stations health alerts and pandemic zone demarcation. MASAS-X data sources are listed in Appendix C.

In addition to alerts and points of interest, MASAS-X supports the distribution of documents, pictures, audio, video files and other geospatially-referenced information products (e.g., situation reports pertaining to an incident or alert message). MASAS-X does not specify the maps to be used, only the formats for the individual content files so that they may be presented on any one of a number of standard and custom base maps.

MASAS-X is not an alerting system. But it does play a central role in alerting. MASAS-X supports a new paradigm in alerting whereby the alert issuer need only post an alert to a central aggregation system once, and need not identify and reach out to each stakeholder who may be interested in the alert. Stakeholders with a duty to know have the opportunity to alert themselves, wherever they may be, using the delivery methods of their choosing. As an example, some MASAS-X stakeholders have their incident management systems monitor MASAS-X for severe alerts in their area and send them to the duty officer's mobile device.

2.3.6 Border Information Flow Architecture

The Border Information Flow Architecture (BIFA) is a collaborative effort in involving stakeholders from both sides of the Canada-U.S. border from both the public and private sectors. BIFA has been leaded by Transport Canada and U.S. Department of Transportation (Canada-United States Transportation Border Working Group, 2005). The main role of BIFA is to provide policies, protocols and a system for communication between different organizations that respond during emergencies. However, BIFA does not aim to collect and analyze transborder traffic data.

2.4 Potential Supply Chain Applications of Visual Analytics

Supply Chain Management (SCM) is a set of approaches utilized to efficiently integrate suppliers, manufacturers, warehouses, and retailers. Goods must be produced and distributed in the right quantities, to the right locations, and at the right time, in order to minimize system-wide costs while satisfying service level requirements (Simchi-Levi and Kaminsky, 2008). SCM is sensitive to uncertainty factors, which can damage the industry that the supply chain is servicing. Hazards in supply chains can be categorized into internal and external hazards. Internal hazards are hazards related to and caused by the market environment. Shortages in raw materials, market demand fluctuation, competitors' strategies, large-scale network problems, work stoppages and the Bullwhip effect are major internal hazards of supply chain systems. In addition, uncertainty in supply chains arises from external factors not related to the market. Natural disasters, terrorist attacks, and political decision-making can be categorized as external hazards. Although external hazards are much rarer than internal hazards, associated financial losses can be much more severe. For example a disruption, defined as an event that interrupts the material flows in the supply chain, resulting in an abrupt cessation of the movement of goods (Wilson, 2007) can be associated with natural disasters. Despite the considerable amount of attention that many companies have paid to the design of hazard-resilient supply chains, the impact of external hazards has not been considered until recently (Sheffi, 2007).

Analyzing the spatial and temporal data of freight traffic between Canada and the U.S. is of great importance for understanding the patterns governing the flow of goods between the two countries. This analysis requires gathering and processing huge amounts of data not only about traffic flows, but also about the causes of delays and their impact on the decisions of cargo companies and operators of the supply chains linking the two countries. Industry groups have stated that, in the event that a crossing is compromised, production lines would begin to stop in various parts of Canada and the U.S. within hours, as demonstrated by the aftermath of 9/11 and the Japanese tsunami. The free flow of goods through international Ports of Entry (PoEs) also significantly affects exporters, importers and consumers because of the strong economic ties between Canada and the U.S. For example, commercial traffic between Ontario and Michigan/New York mainly serves the auto industry Just-in-Time (JIT) supply chain.

Emergency management of Canada-U.S. border crossings is extremely important in the case of natural or man-made disasters. In a report about Canada-U.S. relations prepared by Congressional Research Service (Ek, 2007), the issue of the ability of the transportation infrastructure to cope with increased safety and security measures has been raised. This report also emphasized the need for better emergency management for border crossings. Therefore, collaboration between emergency preparedness planners and responders on both sides of the border should be coordinated to insure minimal interruption of traffic and secure and safe operations of the crossings. While this would have different impacts for various crossings, in all cases, it would have an impact on lives, bordering economies, trade and social services, as well as the public's confidence in road infrastructure. The report by Canada Senate Committee on National Security and Defence (CSCNSD, 2005) mentioned that Canada Border Services Agency (CBSA) needs a streamlined system that links all unconnected border posts with real-time access to the customs mainframe. Therefore, communication and collaboration management among all these stakeholders is essential.

International bridges and tunnels have a giant role in the logistics of supply chains. These crossings have proven to be significantly important to the economic ties between Canada and the U.S. There are 33 international bridges and tunnels between Canada and the U.S. with various governance regimes (Crown corporations, federal/state/provincial agencies, joint authorities, private companies). These different regimes do not necessarily have obligations to report on operations and maintenance to the Government of Canada. For example, the Ambassador Bridge, the Blue Water Bridge and the Peace Bridge altogether carry approximately 50% of all the truck traffic (36,000 trucks) at Canada-U.S. land and bridge-tunnel border crossings. Over 30% of passenger and other vehicle traffic make use of the Ambassador Bridge, the Peace Bridge, the Detroit-Windsor Tunnel and the Blue Water Bridge. Traffic volumes at other international bridge and tunnel crossings are not as significant; however, the necessity of having an international link in some of the smaller or remote communities is of great importance for the local economy (Canada Gazette, 2008). Figure 2-3 shows traffic volumes during 2006 to 2008 for some international bridges between Canada and the U.S. The number of trucks crossing the border at these ports illustrates their importance, which implies giant negative impacts on supply chain systems in case of natural disasters or terrorist attacks.

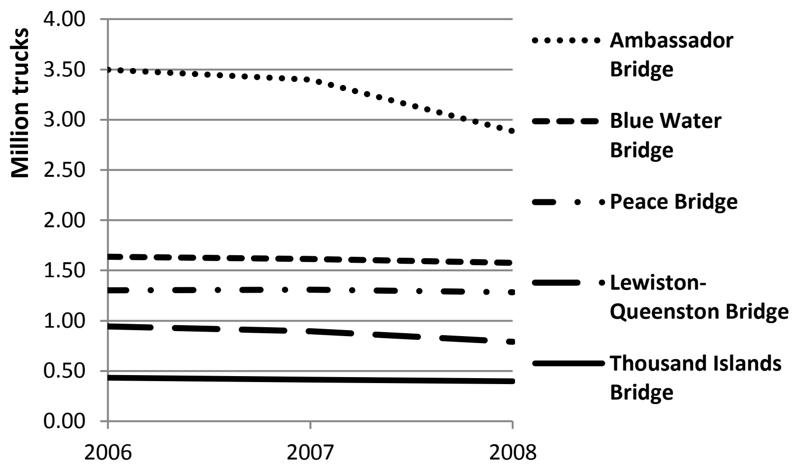


Figure 2-3 Annual Traffic Volumes (Trucks), Public Border Operators (PBOA, 2013)

Industry groups have stated that, in the event that a crossing is compromised, in a matter of several hours, production lines would begin to stop in various parts of Canada and the U.S. The free flow of goods through international bridges also significantly affects exporters, importers and consumers because of the strong economic ties between Canada and the U.S. For example, commercial traffic between Ontario and Michigan/New York is mainly serving the auto industry Just-in-Time (JIT) supply chain. Figure 2-4 shows one of the important areas near the border, which has many auto manufacturers near the crossings. Hence, if one port of entry (PoE) is barred due to a disaster, many auto manufacturers will face logistics problems in their SCM.

Figure 2-4 Auto Industrial Region near the Crossings between Ontario and Michigan/ New York States

2.5 SUMMARY

In this chapter several available tools and data standards were explored. Important applications of GVA in transportation were reviewed. Moreover, collecting and analyzing Canada-U.S. transborder data and data sharing efforts were assessed.

The literature review revealed the limitation of current VA tools to solve transborder issues. Indeed, the need of a dedicated GVA tool for transborder environment is clear. This chapter reviewed the initiatives of research and studies about GVA in transborder related issues and the data collecting and analyzing efforts by various organizations. These findings assist us to realize the missing parts and to move in the right direction to achieve our goal which is a step forward to design a dedicated GVA tool for transborder environment.

CHAPTER 3 METHODOLOGY

3.1 INTRODUCTION

Chapter 2 shows different factors that have effect on Canada-U.S. transborder and traffic that should be considered by GVA. According to our literature review we could not find any system that can gather, analyze and visualize different data about U.S-Canada transborder traffic. The need of traffic data GVA leads us to propose a method and develop a system to elicit hidden facts and information by combining different data and analyzing them based on human visual understanding. This cause-effect relationship can help planners and decision makers to have better understanding of the large amount of data and to solve traffic problems in incident and emergency situations.

Figure 3-1 shows the overall view of the proposed system. The system analyzes and visualizes the current gathered information for the user. Suppose the user has the authority to make a decision about trabsborder traffic. After observing and analyzing the current system's output, the user makes a decision which has an effect on traffic. Thus, for the next round of the loop shown in Figure 3-1, the traffic data should be updated. The data used in this section are limited to historical traffic data. However, other types of real-time data can be gathered and visualized helping the users to make better decisions. More details about data collection and different types of data are explained in Section 3.4.5.

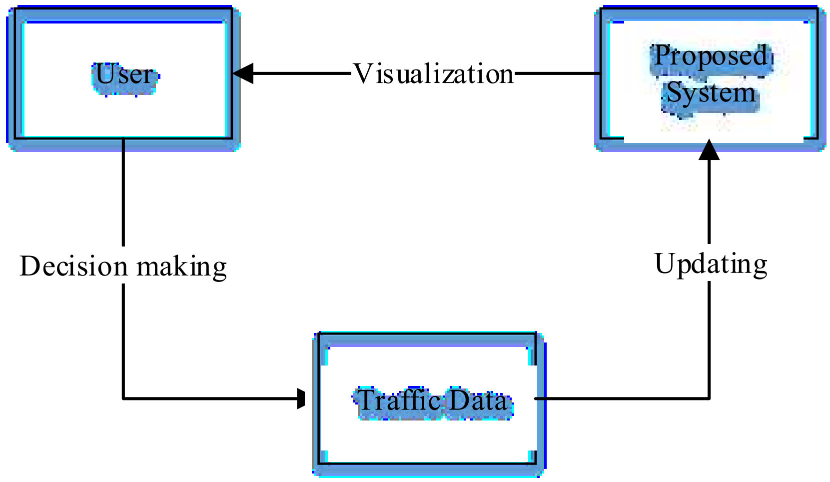


Figure 3-1 User and Proposed System Relationship

The proposed system has three main parts to collect, analyze and visualize data and a graphical user interface (GUI) to interact with the users. Different factors have influence on traffic, so different types of data should be collected from different sources. Since several VA tools are available for analysts, we should select which tools are applicable and useful for the proposed system. The VA toolbox is the other part of the proposed method which is explained in Section 3.4.2. The GUI is the last part of the system that is discussed about in Section 3.4.3.

The proposed method covers three main objectives: (1) Handling the huge amount of transborder data within reasonable time with the GVA tool using the human visual understanding capabilities; (2) Combining the historical and near real-time data for better decision making; and (3) Providing a user friendly environment to visualize the desired data based on users' requests for users with different levels of computer expertise.

3.2 SYSTEM REQUIREMENTS

For designing a multi-user and multi-purpose system, many requirements should be met. To define the system requirements, it is necessary to identify who are the system users and what are their expectations. One of acceptable ways to define the system requirements is to collect information through personal interviews. Any definition of system requirements should concentrate first on the needs and then examine how the user satisfaction can be maintained or increased (Mumford, 1985). In this section, the requirements which were defined by discussing with CBSA employees are fully explained.

(1) Multi-users and multi-purposes flexibility

Most systems have different users with different expectations. The proposed system in not an exception and has different types of users with different purposes. Therefore, it must be able to cover all types of users like managers and data analysts. For instance, a manager may want to observe a high-level view to make a decision while a data analyst may want to analyze historical and real-time data to find relationships among different factors.

(2) Usability

A computer system designer must always consider the users as the center of the system instead of as a mere peripheral (Shackle and Richardson, 1991). System user-friendliness will simplify users' understanding, operating and interacting with the designed system. Easy understanding is one of the most important requirements of every computer system which should be reflected in the GUI design. The GUI must be designed in a way that users with different computer knowledge can interact with the system easily.

(3) Accessibility

The system should be designed in a way that the users do not need any pre-installation to interact with the system. Users should be able to access to the system from anywhere and anytime. To meet this requirement, a web-based system is the best solution so that users can access the system using the Internet and a web browser. In addition, the system must give the users the ability of sharing information with others. Users should be able to publish their information by uploading and to access published data.

(4) Security

Security is a prerequisite of any system. Many cyber-attackers look for systems vulnerabilities to find a way to damage the systems by publishing viruses, worms, etc. In addition, systems with large amount of data are more vulnerable. So the system must be designed to be protected from cyber-attacks and should be resilient to any kind of networks attacks. In addition, the accessibility of the system should be restricted since the system is web-based, i.e. only authorized users should have access to the system by using username and password to login. Furthermore using a proxy can be useful to have different levels of accessibility for different users.

(5) Scalability

The proposed system is tested with smaller datasets in comparison with real datasets that the system is designed for. So the proposed system should be able to deal with large datasets with the scale of gigabytes. Loading, storing and making queries on huge datasets is required for any database. Thus, the system must be able to use external databases, send request to them and fetch the desired data for analysis and visualization. To avoid facing large scale data problems, the proposed system must be scalable in terms of data storage and making queries.

(6) Performance

Since the proposed system should load, make query and visualize large amounts of data, the performance is a critical issue. The performance of loading and rendering data for visualization is important and should be at least acceptable. The proposed system should perform with minimum lag time. Users' satisfaction depends on many factors and performance is one of main factors. Performance may have effect on other system requirements. For example, multiple users may not be able to use the system simultaneously due to performance issues.

(7) Reusing available data sources

Currently, some Canadian and U.S. agencies and organizations provide data related to our research area. Instead of collecting data from original resources, we can use reliable data sources as a shortcut. So the system should be able to fetch data from different sources of data such as using RSS or fetching the data by parsing forms from web pages and storing the data in geodatabases. To meet this requirement, the system may need some external applications that should be developed to collect and store the data from different non-standard sources.

(8) Using standard formats

As mentioned above, using available data sources is one of the system requirements. The data sources use different formats and standards for collecting and publishing their data. To be able to use different data sources, the system needs to be compatible with various data standards. Although it is not feasible to be compatible with all standards, the system should be able to fetch, parse, store and use common data formats which are used by data providers. For example, for using real-time data, many data sources use the RSS or GeoRSS standards for encoding information as part of Web feeds. Therefore, to collect data from these resources, the system must be compatible with RSS and GeoRSS standards.

(9) VA functionalities

VA is the main purpose of proposed system. Thus, the system should provide VA functions for users to apply them on different types of data. The system function list must be extensible to allow adding new functions in the future. VA functions, e.g., clustering and rerouting, are explained in Chapter 4.

(10) Open to add data

Proposed system has various functions which are applicable on different datasets. Although the users can apply the functions on preloaded data, it is possible that they have specific data with a standard format and they want to add them to the system. So the users should be able to customize the system by adding their own data. The system should provide a mechanism to allow users to easily add their own data, including historical data or real-time data sources. Geospatial and time series data are of special interest to this system.

Geospatial data is defined as data with reference to a location. Open GIS standard establishes the information infrastructure to support the use of geospatial information and to enable information sharing (TBS, 2014). The proposed system should support geospatial data and be able to parse and use the location information embedded in the data for geo-visualization.

Furthermore in order to analyze and visualize time series data, the system should provide time-aware functions to make understanding the data easier. For example, a time slider is a function which is designed to meet this requirement. The function must have different temporal resolution like hourly, daily, monthly or yearly. More information about the time slider development can be found in Section 4.4.3.2.

To satisfy these requirements we decided to use ArcGIS Viewer and ArcGIS. The ArcGIS Viewer is used to create web mapping applications. The viewer is fully extensible, so developers can implement new tools and create new layouts and integrate them into the viewer. In addition, ArcGIS Viewer can connect to ArcGIS server to fetch the published data. The viewer is web-based, extensible and able to integrate with geodatabases. More information about ArcGIS Viewer is explained in section 4.3.

3.3 ADVANTAGES OF THE LARGE SCALE DIGITAL DATASET

Large scale datasets related to the traffic flow between Canada and the U.S. have been systematically collected by both governments and the private sector (trucking companies) for decades. However, in order to efficiently analyze these datasets to answer questions related to congestions and delays at specific PoEs, and their impacts on other PoEs, it is necessary to collect data about the potential causes of congestion and delays (e.g. weather data, road maintenance activities), and to link these different datasets in a meaningful way. The ability to map all these time series datasets to a geographical reference and to interactively make queries and understand the results using GVA is expected to effectively change the cross-border research paradigm. This ability will provide the possibility of grasping the spatiotemporal correlation of causes and effects at a very large scale (the continental scale) while keeping the opportunity to focus on the local or regional effects by focusing down to the appropriate level of detail using, for example, clustering techniques.

The following issues have to be considered to make the best usage of the datasets addressed in this project: (1) Some of the datasets are highly structured (e.g. traffic data), but have heterogeneous data types because they are collected by different agencies in the two countries. However, some other datasets are less structured and more difficult to gather (e.g. information about events near the PoEs); (2) Sharing these datasets requires developing shared tools and storage, that can be used by different users in the U.S. and Canada; and (3) The data management and analysis are iterative and cyclical, rather than sequential, activities.

3.4 PROPOSED METHODOLOGY

As explained in Section 3.1, analyzing the datasets related to Canada-U.S. traffic is extremely labor-intensive unless proper methods and tools are developed. This research requires the development and continual refinements of GVA tools. The process used in these tools incorporates question formation, selection of one or more datasets for exploration and querying, changing the datasets and/or the queries as needed, making observations about the data, and drawing conclusions from the data. For example, time series datasets can be browsed using a time slider interface and visualized using customized pie charts on top of GIS maps. However, the different spatiotemporal resolutions for different datasets and the variety of attributes that can be used in the charts and the complex hidden relationships among them make this task difficult. Therefore, there is a need to develop a customized GVA toolbox that allows the user to pose a specific query and to selectively view the results using an intuitive GUI.

The proposed methodology as shown in Figure 3-2 will be realized according to the following tasks:

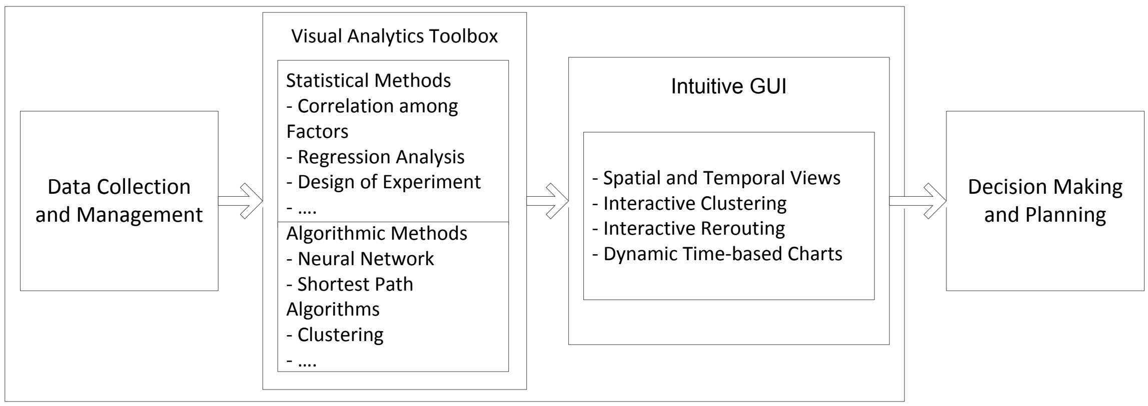


Figure 3-2 Proposed Methodology

3.4.1 DATA COLLECTION, TRANSFORMATION, INTEGRATION AND MANAGEMENT

This is a preliminary task in which the required data from different sources are gathered and integrated in a GIS relational database. The following two types of data have to be collected: (1) the mobility over the network: Origin-Destination, vehicle type, volume, commodity, value, etc.; and (2) the factors that can affect the mobility, such as weather and road conditions. For each of the datasets, there is a need to transform the data into a standard format compatible with the other datasets and GIS layers in the system.

3.4.2 INVESTIGATING THE REQUIREMENTS OF THE GVA TOOLBOX

GVA methods are used to explore cause-effect relationships among the collected data. These relationships cannot be recognized directly from the raw data stored in databases. GVA is used in this research due to its user-friendliness, quick response time and agility.

The main purpose of the toolbox is to use a set of common data analysis tools and to easily visualize the results of queries in a combined temporal and spatial manner. The proposed GVA tools can be categorized into statistical and algorithmic methods. The statistical methods, such as factor correlation, multi-variant analysis, and design of experiment aim to explain the impact of delays, weather conditions, etc., on the flow of goods. The algorithmic methods (e.g. dynamic clustering and neural networks) can be used to evaluate the effects of potential actions and the efficacy of investments. However the current research focus on the subset of these methods.

3.4.3 Investigating the Requirements of Visualization and the GUI

An intuitive GUI is required to display the results of the GVA tools. This GUI will allow, for example, the interaction with dynamic time-based charts, applying interactive clustering and rerouting. In order to realize this task, it is necessary to: (1) Identify the key data elements required for understanding the travel patterns (i.e., facility capacities, system operating characteristics, and the variables of which system efficiency is a function); (2) Identify the nature of the relationships between these data elements; (3) Identify the methods and models that are most appropriate for addressing different data-driven questions and issues regarding system-level travel operations; and (4) Develop an architecture of an integrated GVA model to permit the manipulation of critical data elements and their visual representation. The visualization methods should consider high dimensional data visualization, categorical data visualization and clustering/ranking, and issues relating to the resolution and large data set visualization. The visualization outputs can include 2D/3D charts, geographic charts, flow maps, real-time dashboard, and simulation results.

3.4.4 DEVELOPING, TESTING, AND REFINING THE PROPOSED GVA TOOLS AND THE GUI

In this task, we define and develop a set of essential functionalities and demonstrate through several examples the effective use of the GUI for model input, data manipulation, and model output. The development procedure details are explained in Chapter 4. Figure 4-1 shows the proposed system architecture, which has three main parts: the client, the GIS server and the GUI. The client is a web browser to connect to the server. Authorized users can connect to the system using a web browser without the need to install any applications due to the server-side implementation. The data are secured and their accessibility is limited to authorized users. The main part of the implementation is on the server side to query the database using the GUI and to visualize the results on the client side. The client can be a mobile device with a wireless connection to the Internet or a desktop computer equipped with different interaction devices, such as a multi-touch display. This flexibility of accessing and analyzing the data from any compatible client is required for sharing the data in the widest possible way among users and researchers.

3.4.5 DATASETS THAT CAN BE USED IN THIS SYSTEM

In addition to freely available base maps, several datasets are collected from different public agencies, and organized and published on a dedicated web server at Concordia so that other researchers can access remotely. The datasets that can be used in this research can be categorized into the following groups:

3.4.5.1 HISTORICAL DATA

(1) <u>PoEs' basic data:</u> Information on land PoEs between Canada and the U.S. includes detailed data about each PoE, such as the name, location, hours of operation, and

services available. Using the data provided publicly on the official website of the CBSA, several Excel sheets are created manually containing land PoEs and ports and airports data, for locations where there are CBSA offices. The details of data collection and data organization are in Appendix D.

(2) Land traffic time series: are available disaggregated by the PoE and the month. Statistics Canada (CANSIM, 2012) provides datasets since 1972 about the vehicles entering Canada based on the mode of transportation (i.e., automobiles, trucks, others) and the length of stay (i.e., same day, one night, two or more nights). On the U.S. side, the Research and Innovative Technology Administration (RITA, 2012) provides similar data about the vehicles entering the U.S. based on the mode of transportation. For CANSIM land traffic data, we used Table 427-002 (CANSIM-427-0002, 2014). The details of data processing are in Appendix E.

(3) Freight data: *Statistics Canada's Canadian International Merchandise Trade Program* provides information on transborder truck shipments (Statistics Canada, 2006). The program monitors freight movements into and out of Canada and is used extensively by importers, exporters, manufacturers, shipping companies and the Canadian government. The data consist of geographical PoE, origin and destination, and shipment characteristics. Since January 1966, data have been compiled on a monthly basis. Canada Customs does not offer details on weight, and no clear distinction is made between for-hire carriers, owner-operators, and private carriers. U.S. Bureau of Transportation Statistics (BTS) compiles cross-border freight flows on a monthly basis and by PoE. The data is classified by commodity type and surface transport mode (U.S. Department of Transportation, 2003). The Customs entry data include details such as

Harmonized Tariff Classification, weight, state of destination, etc. *The Transborder Surface Freight* dataset has been compiled since April 1993 to monitor North American trade flows after implementation in 1994 of the North American Free Trade Agreement (NAFTA). As an example Figure 3-3 shows the flow of all commodity exports between Ontario and Michigan for January 2003.

Figure 3-3 Shows the Flow of all Commodity Exports between Ontario and Michigan for January 2003

3.4.5.2 NEAR REAL-TIME DATA

(1) Global Positioning System (GPS) data: GPS used by trucking companies for commercial, in-vehicle, fleet management systems is a source of truck travel data that is just starting to be utilized for a variety of applications including modeling (Bassok et al., 2010; Liao, 2009).

(2) Border wait times: CBSA website lists wait times for selected PoEs (CBSA, 2013). The U.S. Customs and Border Protection (CBP, 2013) website provides the projected wait time for pedestrians, commercial and passenger vehicles updated throughout the day. It also provides the number of the lanes (gates) at each PoE.

(3) Near real-time alerts: The Canadian Multi-Agency Situational Awareness System (MASAS, 2013) and the U.S. Integrated Public Alert and Warning System (IPAWS,

2013) provide alerts, warnings, and incident information to improve response coordination during bi-national disasters. Examples of MASAS and IPAWS contents include: (a) Road closures, including planned (due to road maintenance or security operations) or imposed by natural hazards such as floods and blizzards; (b) Natural hazard alerts (e.g., earthquake, tsunami); (c) Hazardous material incidents involving chemical, biological, radiological-nuclear or explosives agents; and (d) Water/stream level sensor alerts.

The challenge in collecting and organizing near real-time data is in accumulating these data in a GIS system using a standardized format for the various reporting structures.

3.4.6 Developed Algorithms for GVA Toolbox

3.4.6.1 Weather Data Collection

Figure 3-4 shows the flowchart of gathering information from the web service and updating the SQL table. The steps of the algorithm are: (1) create an SQL data with ID, PoE name, longitude, latitude and weather conditions; (2) Use ArcMap to assign proper symbols to different weather values. As shown in Figure 3-5, by using ArcMap, different symbols can be assigned to different weather conditions. There is a column labeled as condition in the weather table which indicates if the weather is sunny, rainy, cloudy, etc. More details about applying symbology using ArcMap is available in Developer Manual on CBSA Project report (Moghaddam, 2013); (3) The database is published on ArcGIS sever; (4) The system reads the longitude and latitude of every PoEs; (5) Based on the longitude and latitude, the application sends a request to the weather web service; (6) If the request is accepted, the application parses the output XML file to fetch the weather attributes and updates the SQL table. After updating all PoEs' weather information, the data are available on the server and whenever the user loads the weather layer, the latest data will be shown. Sending the request to the weather web service is iteratively repeated every hour.

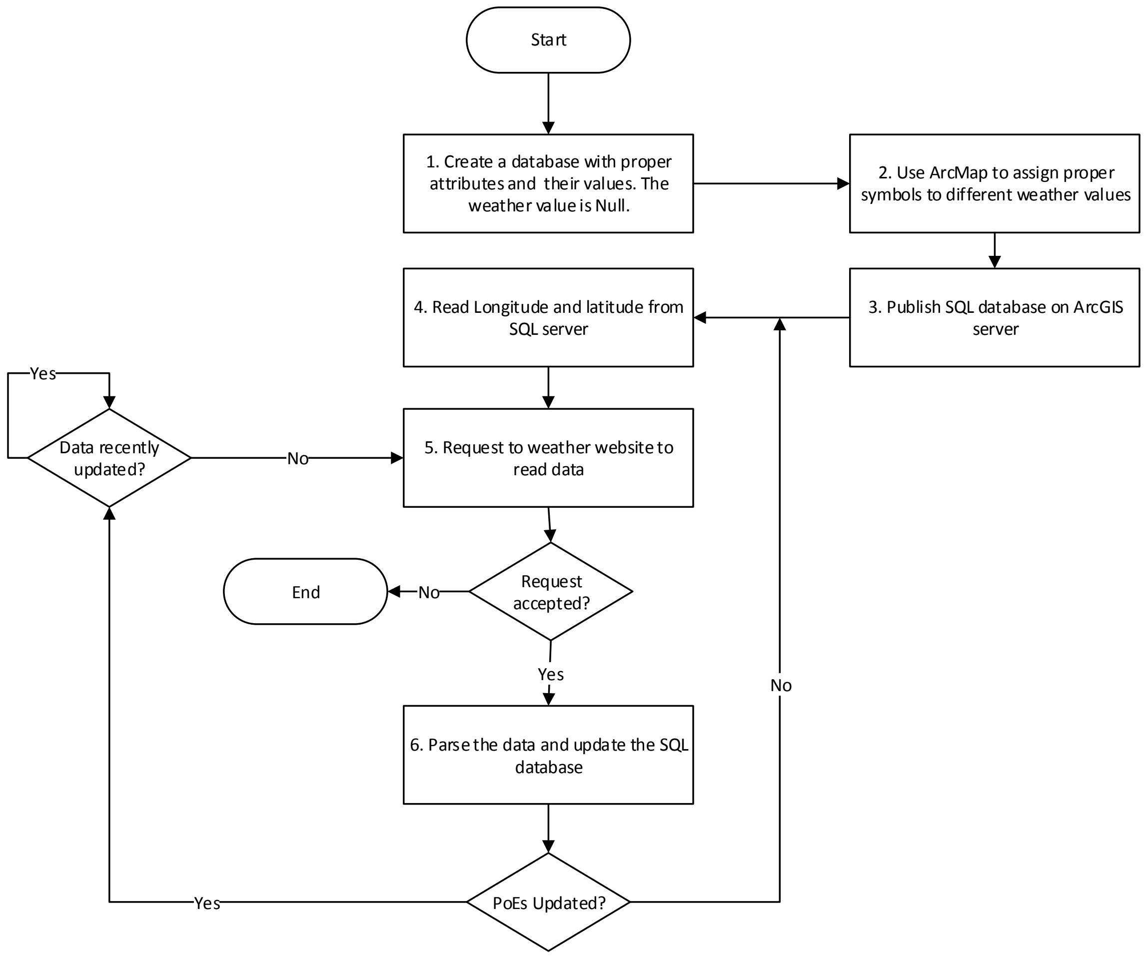


Figure 3-4 Weather Information Collection and Visualization Flowchart

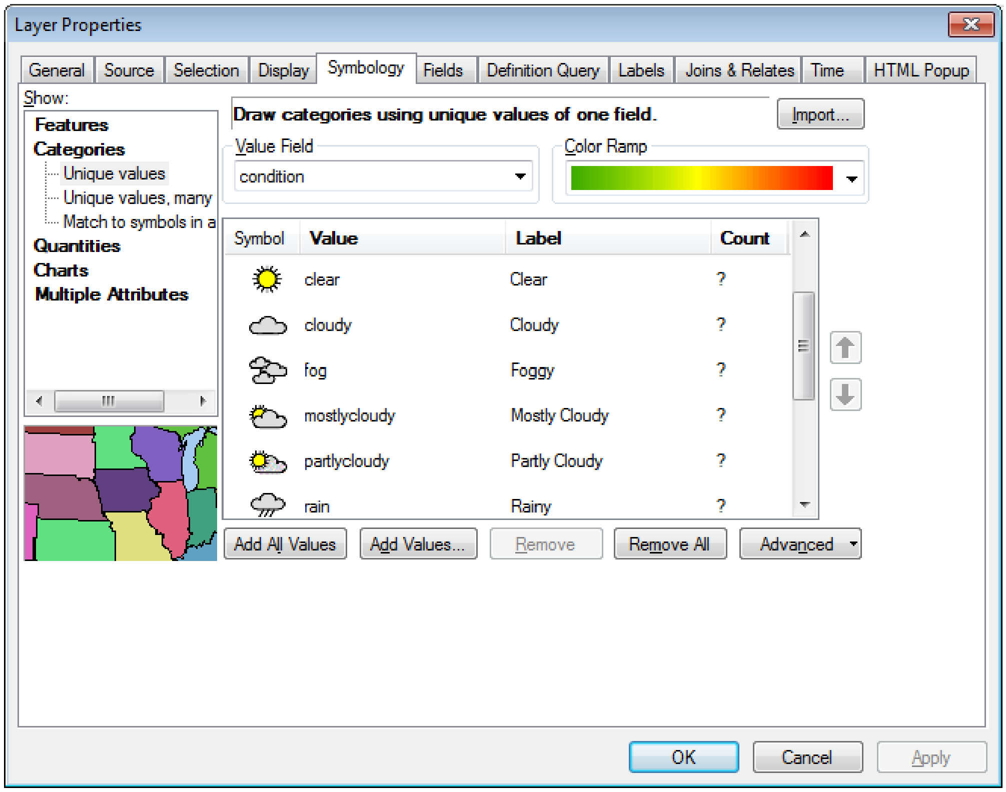


Figure 3-5 Dynamic Symbols for Weather Conditions

3.4.6.2 Waiting Time Data Collection

Figure 3-6 shows the flowchart of waiting time data updating and visualization. The steps are: (1) create an HTML list that contains the main basic information of PoEs; (2) In addition, it is necessary to create an empty SQL table with required attributes; (3) Proper symbols should be assigned to different possible values. The difference between weather symbology and delay symbology is that the possible values for weather are discrete and limited but they are continous for delays. Two different methods are available in ArcMap to assign symbols. The details can be found in Developer Manual on CBSA Project report (Moghaddam, 2013). Figure 3-7 show the symbology assigned to delays; (4) Publishing the SQL table on ArcGIS; (5) After preparing all prerequisites, the developed code send a request to CBSA web site to read the data; (6) If the request is accepted, a new list is created based on the PoE name as a primary key; (7) Assign delay information to the corresponding PoEs in the new created list in step 6. According to the PoEs name, the list will be updated by longitude and latitude; (8) Next, in the checking phase for all elements in the table, if the information is in SQL table, it should be updated with new delay information, and if it is not in SQL table (9) the element must be added to SQL table. This condition makes the algorithm more flexible in case of new PoE added to the list of CBSA website. The whole procedure should be iteratively repeated.

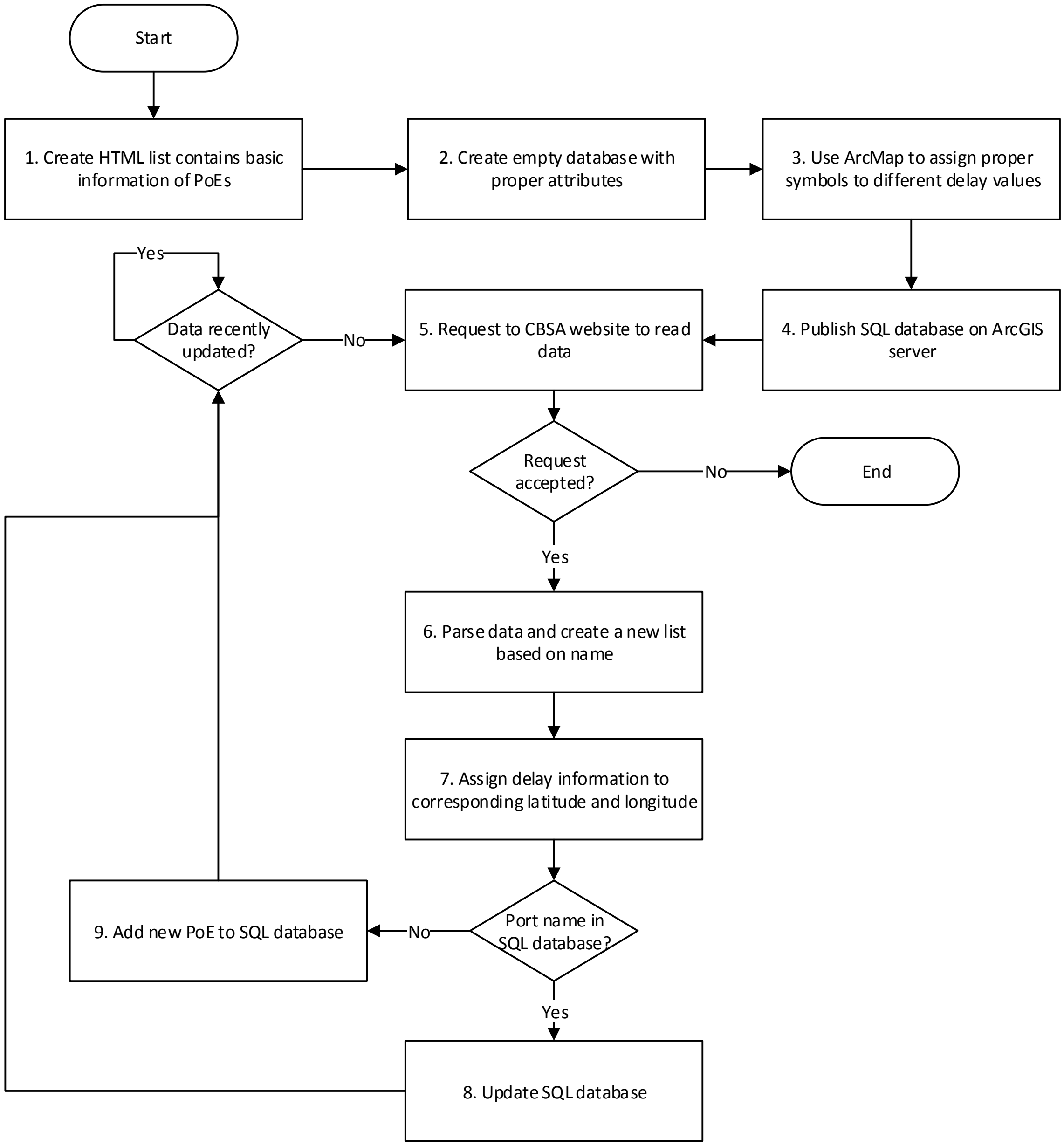


Figure 3-6 Delay Information, Collection and Visualization Flowchart

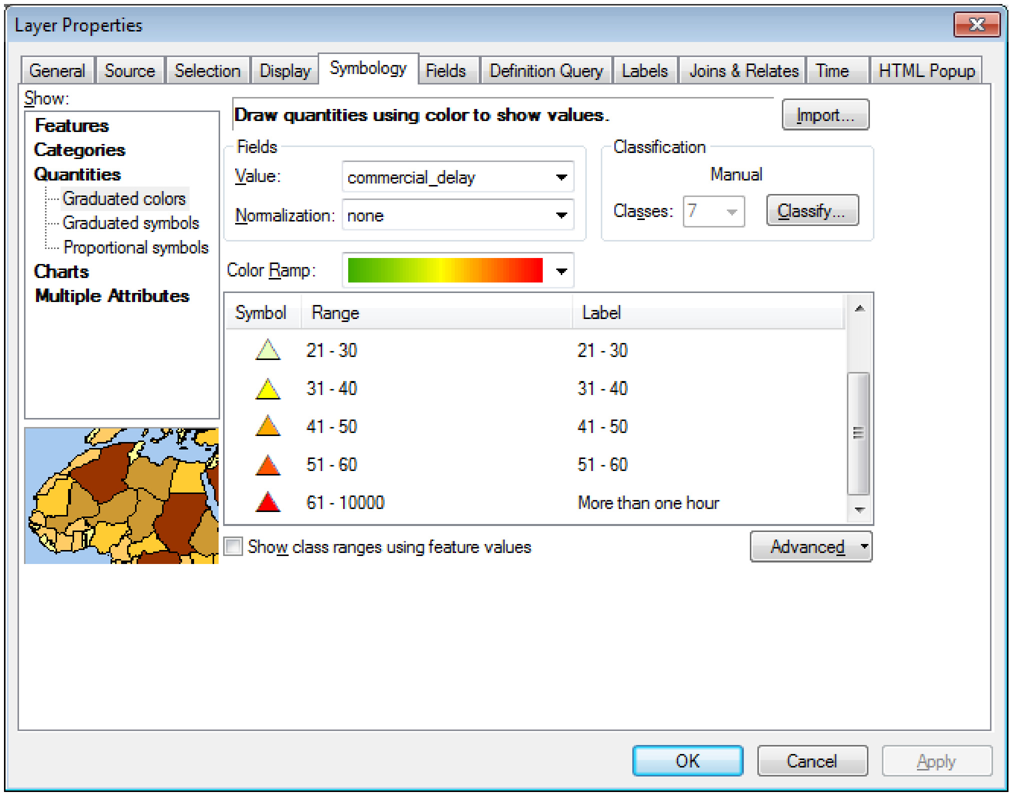


Figure 3-7 Dynamic Symbols for Delays

3.4.6.3 ALERT DATA COLLECTION

Pelromex is a private company that provides the alert data for Canada (NAAD, 2013). For every day there is a directory which contains several XML files. Each XML file is related to an alert. So to access the alerts of a specific day it is necessary to parse the related XML files and store the data in an SQL database for publishing. As mentioned in Section 2.2.6.2 the XML files use the CAP standard to describe an alert. To be able to parse the XML files and fetch the required information, it is necessary to understand all the CAP attributes and their hierarchy which are shown in Appendices B and F. In addition, Appendix G shows an example of CAP amber alert on April 14th, 2013.

Figure 3-8 shows the flowchart of data processing, updating and visualization of the alerts. The algorithm steps are:

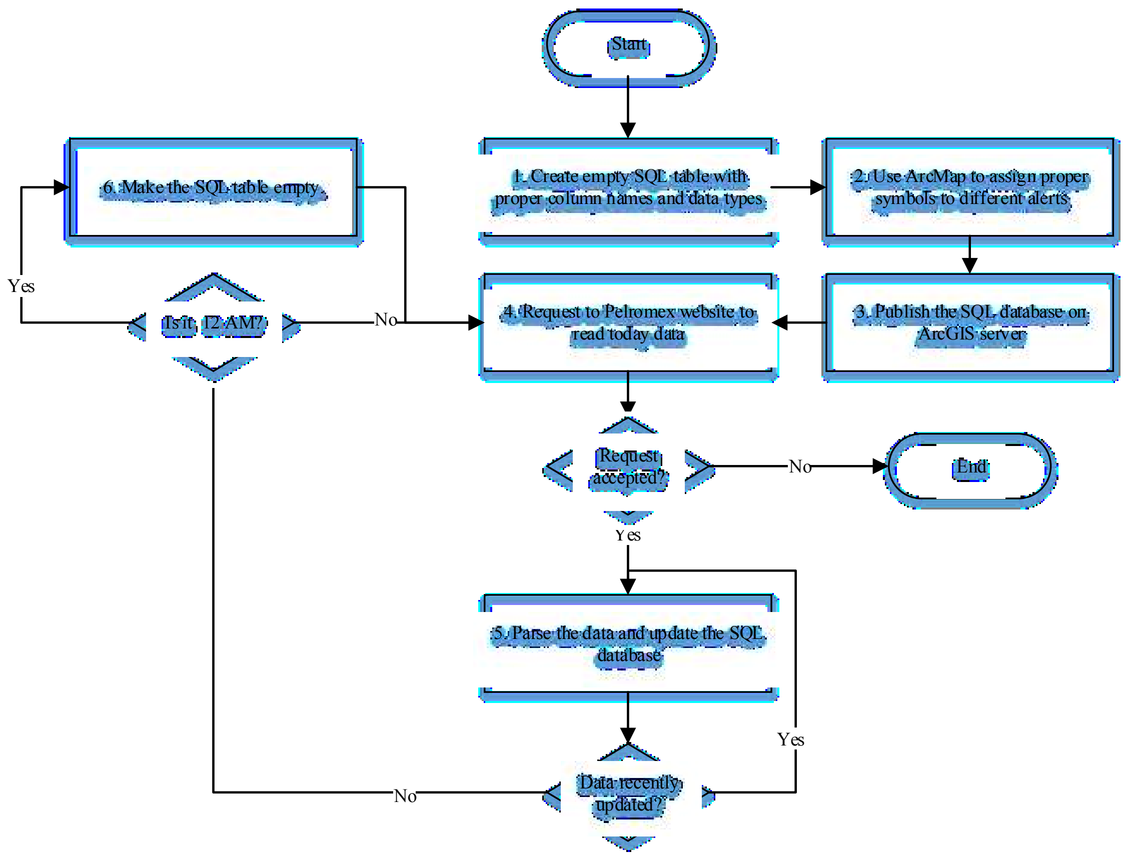


Figure 3-8 Alert Information, Collection and Visualization Flowchart

(1) Create an empty SQL table with the proper column names and data types. The table schema contains the attributes which are interesting for the user; (2) Use ArcMap to assign proper symbols to different alerts. Figure 3-9 shows an example of different symbols that are assigned to different alerts. The symbols are standard and chosen from Emergency Mapping Symbology (Emergency Mapping Symbology, 2010) which is shown in Appendix H; (3) After symbol assignment, the empty SQL database is published on the ArcGIS server; (4) Send a request to Pelromex website to access the XML files; (5) If the request is accepted; the application will parse the XML files and add them to the SQL database. After that the application will check the latest SQL table update time, if it is recently updated it will wait; else it goes to the next phase. Furthermore, the application

checks the current time; (6) Since the alert layer will show the current day alerts, if the next day has started the SQL table should be made empty and jump to step 4.

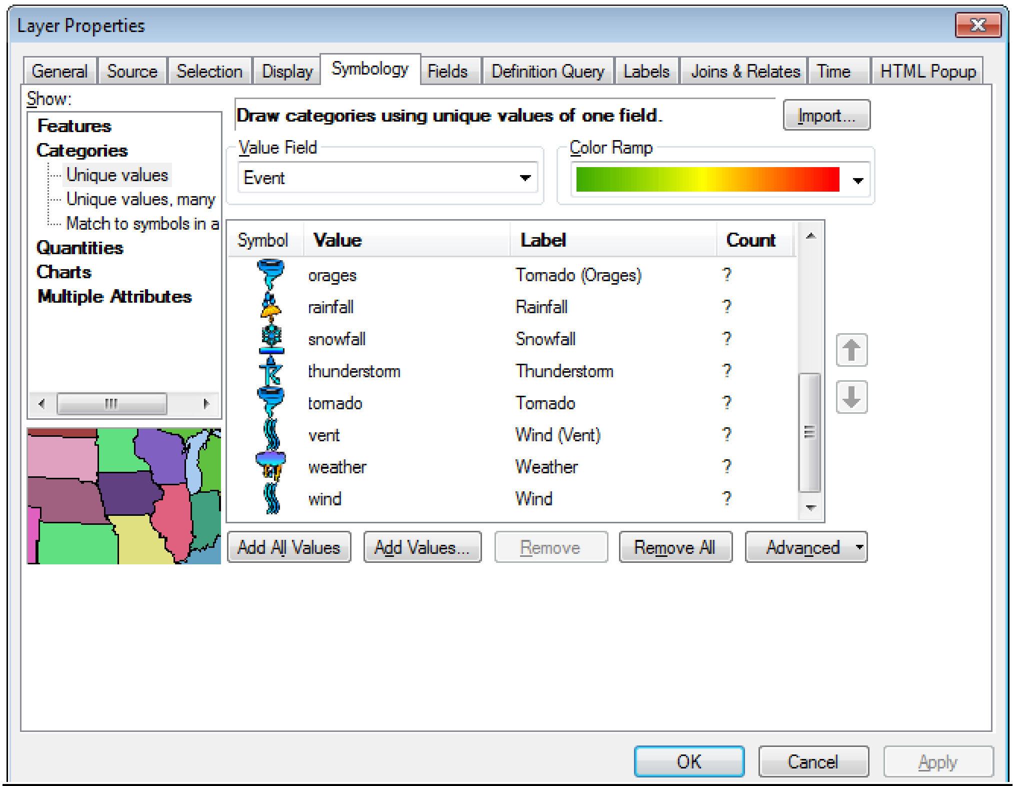


Figure 3-9 Dynamic Symbols for Assigned Alerts

3.4.6.4 DATA CLUSTERING

The algorithm used in clustering is shown in Figure 3-10. Some fixed values used in this algorithm are retrieved by try and error for visualization effect.

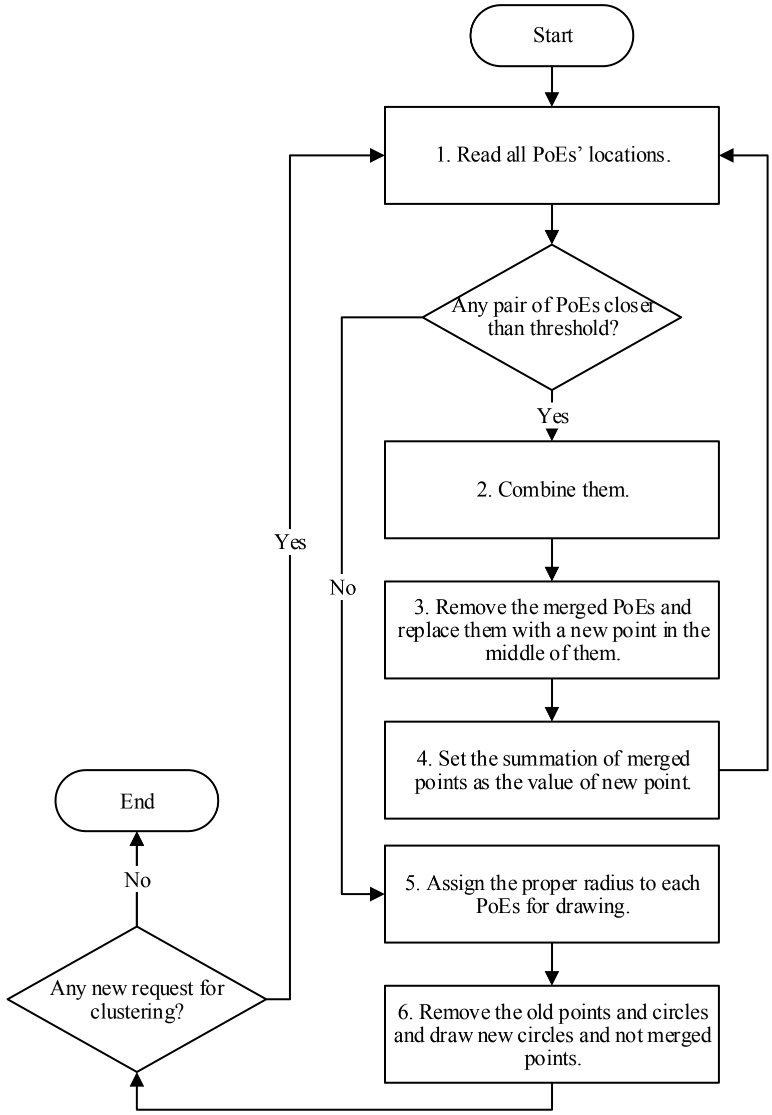


Figure 3-10 Flowchart of the Algorithm for Clustering

We defined a threshold in a way that if the distance between two points is less than the threshold, the points must be clustered. (1) The first step is to read the location of points. Then the distance between points is checked; (2) If a pair of points are close enough (threshold > distance) they will be merged a new point is added to the list.

(3,4) These steps will be done in a loop untill the distances of all remaining points are more than the threshold; (5) According to the new points and values, the radius will be assigned to every points; (6) In the next step, all previous clustering visualization will be cleared and new circles with new values will be visualized. If the zooming level is changed, the algorithm will start from the first step.

3.5 SUMMARY AND CONCLUSIONS

This research proposed a system to collect, analyze, visualize, and share informing in near real time. To achieve these purposes the system should cover three main parts: (1) Data collection, transformation and management which is essential due to huge amount of data added continuously from different sources of data using different data standards; (2) Investigating and designing the GVA algorithms for analyzing and visualizing the gathered data; and (3) Providing a proper user-friendly GUI for people who are not specialist in using advanced computer systems.

Using historical and near real time data needs an implementation to combine these two different types of data that does not affect the performance of the system due to continuous updating.

CHAPTER 4 IMPELEMENTATION AND EXAMPLES

4.1 INTRODUCTION

This chapter explains the steps of the proposed system implementation in detail. The system architecture is designed in a way to be as easy as possible for users. After comparing different technologies the decision was to use ArcGIS Viewer and the implementation is done on top of that. ArcGIS Viewer provides three different platforms for different programming languages (Silverlight, Flex and JavaScript). Although the main focus of the implementation was on ArcGIS Viewer for Silverlight, some implementations in ArcGIS for Flex were developed to compare GVA tools for better understanding. The developed tools are explained in detail with examples.

4.2 SYSTEM ARCHITECTURE

Figure 4-1 shows the proposed system architecture, which has three main parts: the client, the GIS server and the graphical user interface (GUI). The client is a web browser to connect to the server. The proposed system should be accessible without any extra application installation. Therefore, due to the server-side implementation, users can connect to the system with any browser after authorization. The data are secured and theirs accessibility is limited to authorized users. The main part of the implementation is on the server side to query the database using the GUI and to visualize the results on the client. Based on the user request, the system connects to the server, applies the database query, and visualizes the results.

Four types of data are used for visualization: (1) GIS data represent freely available base maps for the visualization and spatial processing. (2) Historical data provided by governmental organizations are processed and linked to the GIS data on the server; (3) Various web services provide different types of real-time or semi-real-time data (e.g. weather alerts) that are useful for managers; and (4) At every PoE, some cameras are installed to observe current traffic conditions. The users can connect to those cameras through the GUI and observe the PoE in real time.

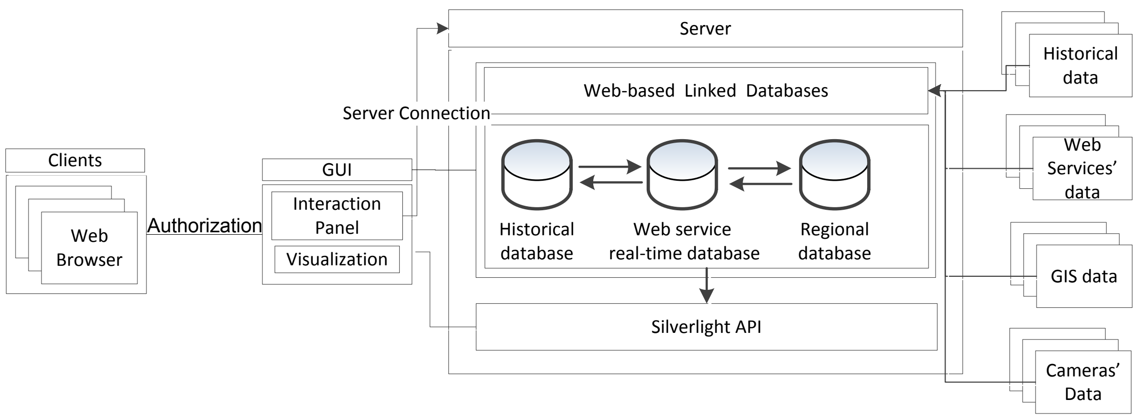


Figure 4-1 System Architecture

For the software implementation, ArcGIS server (ESRI, 2013) offers three web Application Development Interfaces (APIs) with similar functionalities: JavaScript, Flex and Silverlight. We chose Silverlight as the main development API because of its better compatibility with the widely available Windows operating system. The steps of the implementation are shown in the Figure 4-2.

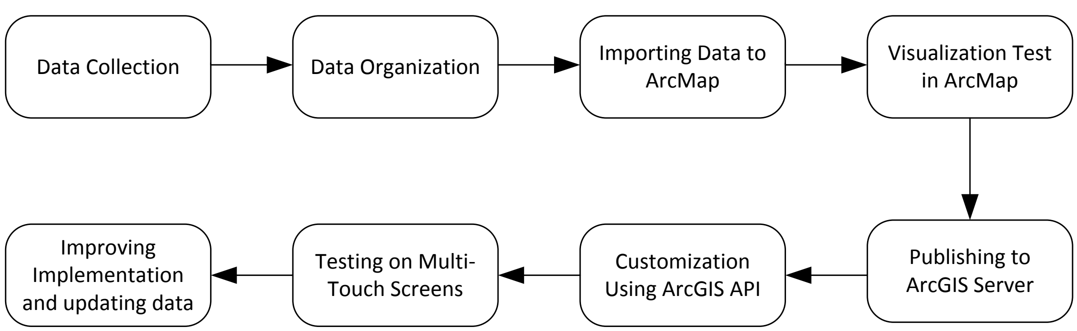


Figure 4-2 Steps of the Implementation

From the system architecture point of view, the system has two main parts (tools, layers) which are available in GIS. All the tools and layers are explained in Section 4.3. The hardware and software requirements for the implementation are listed in Appendix I.

4.3 TECHNOLOGY SELECTION

ArcGIS Viewer

ArcGIS Viewer is a solution developed by ESRI to create, store and share maps and geospatial data. The viewer has several functionalities such as setting up and modifying an application background, operational layers, tools, colors, title, logo, layout, links, etc., without writing any code or editing any configuration files. These functionalities make the application more user friendly. However, the main reason that we chose this viewer is because it is fully extensible; so designers and developers can implement new tools, create new layouts and easily integrate them into the viewer. By using the viewer, developers do not have to develop basic functions like connecting to the geodatabase, zooming, panning, publishing the application on the Internet, etc. Advanced functions need writing codes and editing configurations. Most of the functions that are related to visualization and analysis are developed and added to the viewer.

Figure 4-3 shows the different types of viewer and their programming languages. The different types have similar usability but the programming details are different. For the proposed system, two applications are developed with ArcGIS Viewer for Silverlight and ArcGIS Viewer for Flex. ArcGIS API prerequisites installation links are provided in Appendix J.

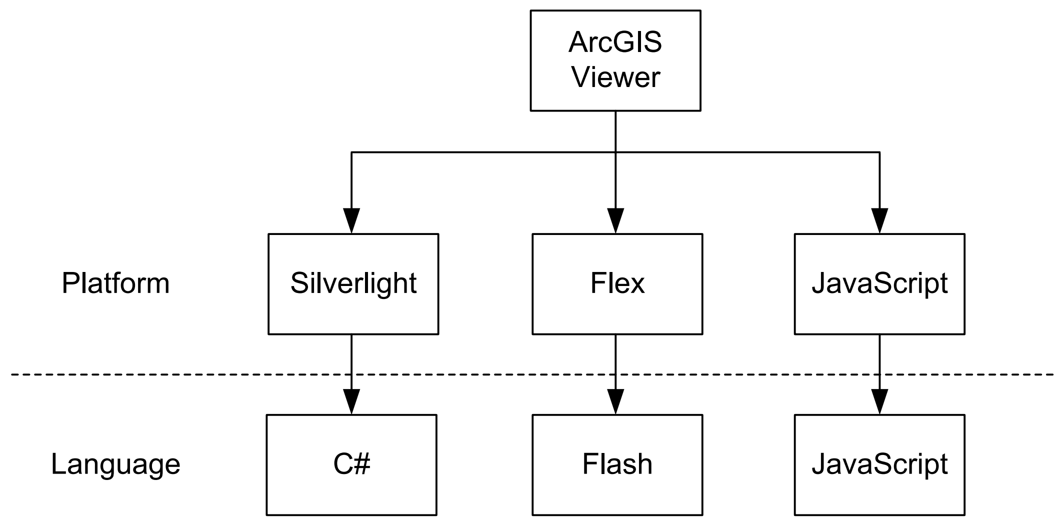


Figure 4-3 ArcGIS Viewers for Different Platforms and Languages

4.3.1 ArcGIS Viewer for Silverlight 3.0

This section provides an overview of ArcGIS Viewer for Silverlight including creating an application, adding layers and tools, and deploying the application.

Creating new application

After installing the ArcGIS Viewer for Silverlight and running it, the user should click *Create New Application*. To create the application, the user starts by selecting the basemap. It is possible to use the default map or use web maps which are available at ArcGIS Online website (ArcGIS, 2013). To create a new viewer application, the user should click the *Open link* next to the default map in the *New Map* section. Figure 4-4 shows the initial new application in ArcGIS Viewer for Silverlight.

Figure 4-4 Manager View of ArcGIS Viewer for Silverlight

<u>Adding layer</u>

To add new layers to the new application, the user can use *Brows* and connect to ArcGIS server and add to the Viewer. Figure 4-5 shows the *Brows* to add a layer. Figure 4-6 shows adding layer from ArcGIS server.

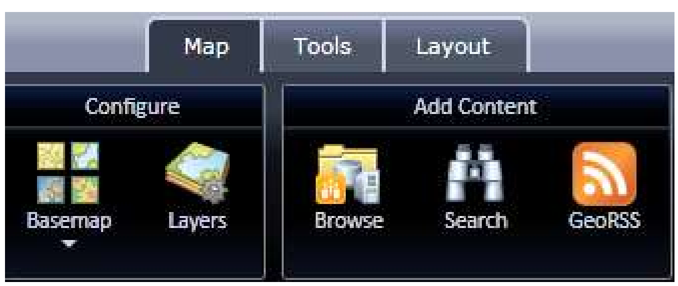


Figure 4-5 Brows Button to Add New Layer

Figure 4-6 Connect to the ArcGIS Server to Add a Layer

Adding Tools

As shown in Figure 4-5, the *Tool* tab is next to *Map* tab. By clicking on that tab and selecting the *Add Tool* button, the list of available tools are shown and the user can add the desired tools. Figure 4-7 shows the list of available tools including the default ones and the ones developed by the research team. More details about the tools are explained in Section 4.4.3.

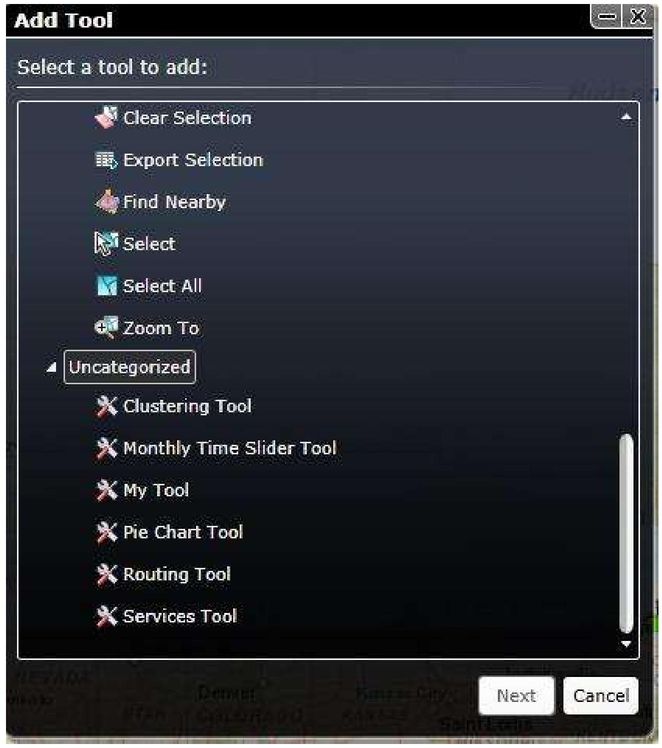


Figure 4-7 List of Available Tools Included in ArcGIS Viewer for Silverlight

4.3.2 ArcGIS Flex Viewer 3.3

Flex Viewer is another viewer developed by ESRI for building a customized viewer for ArcGIS. This section provides an overview of ArcGIS Viewer for Flex including creating an application, adding layers and widgets, and deploying the application.

Creating new application

After installing the ArcGIS Viewer for Flex and opening it, the user should select *Create New Application*. Next he should choose a name for the new application (the default name is *MyFirstApplication*) and he can see a URL indicating the web address that the application can be accessed from as shown in Figure 4-8. It is possible to use the default basemap. To change that, the user should click on the *Edit* icon next to the name of the application in ArcGIS Viewer and from the *Maps* tab he should select *Basemaps and*

Operational Layers. Then the user should select one of the maps from *ArcGIS online* tab or browse for other maps on *ArcGIS servers* and click *Include* as shown in Figure 4-9. The final step is to select *Done* and the application can be accessed from the URL which is provided in the first step.

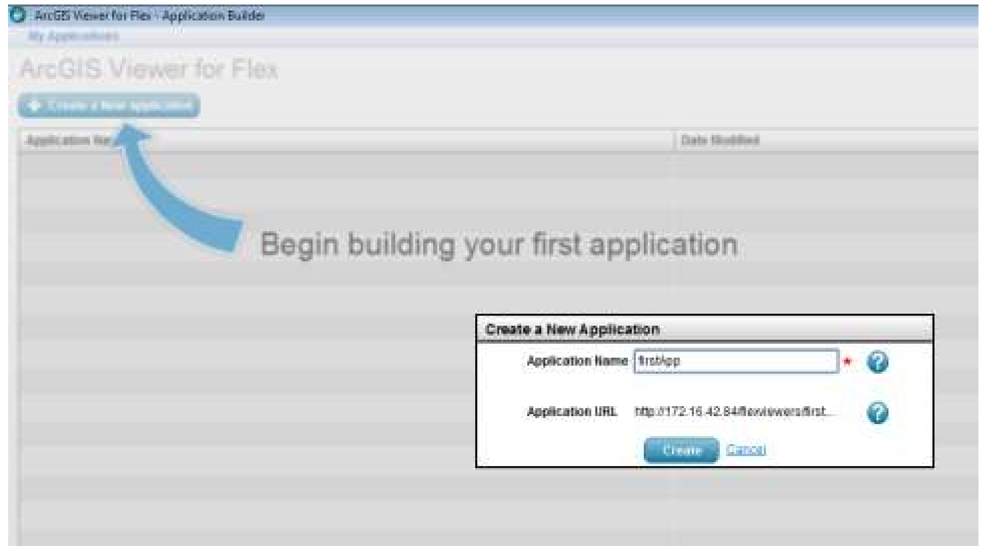


Figure 4-8 Creating a New ArcGIS Viewer for Flex Application

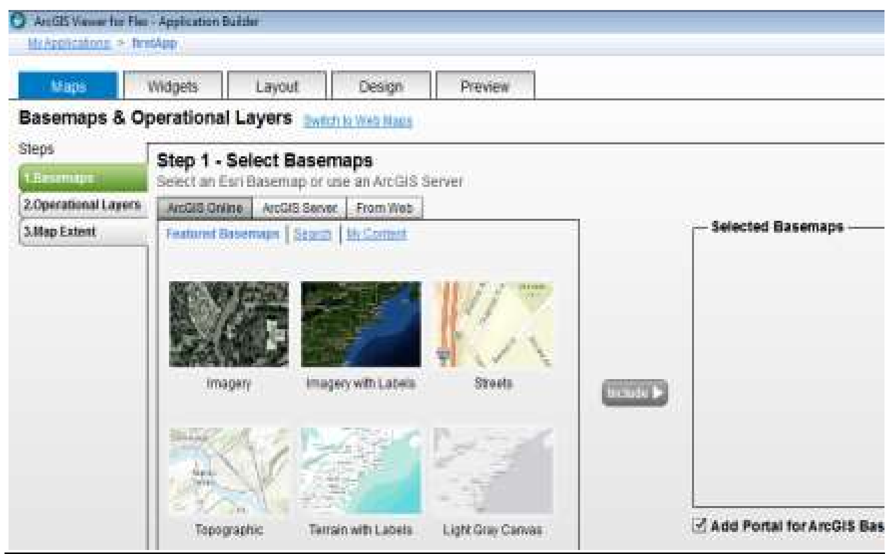


Figure 4-9 Choosing a Basemap for Created Flex Application

Adding layer

To add new layers to the new application user can use the *Maps* tab, and then select *Operational Layers*. Next *Browse* for a layer and select *Include.* The final step is *Save* and *Preview* to see the operation layer in the application window as shown in Figure 4-10.

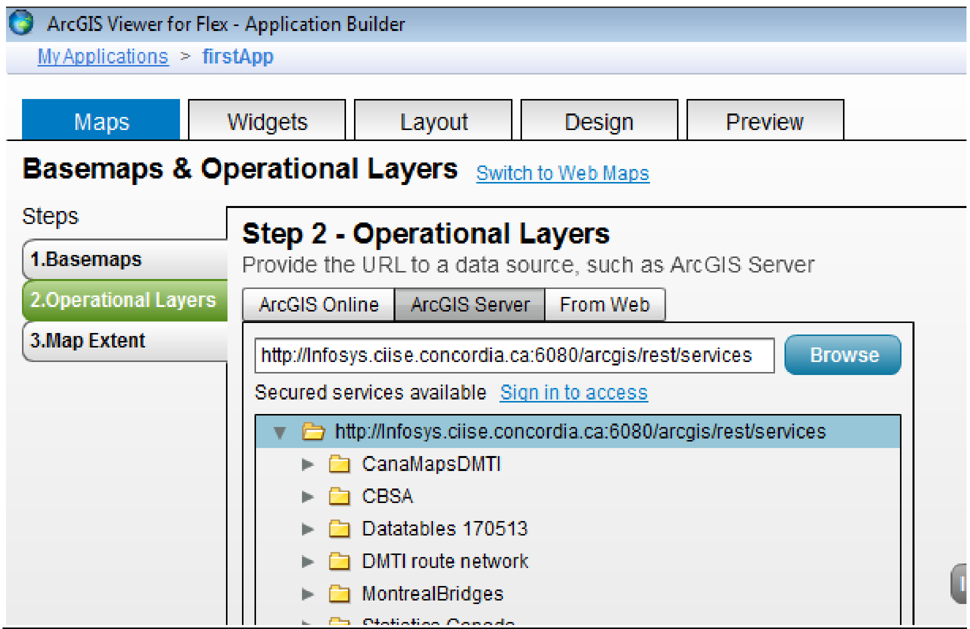


Figure 4-10 Adding a Layer to the ArcGIS Viewer for Flex Application

Adding Widgets

Widgets in Flex Viewer are some pre-compiled codes which add some functionality to the viewer. There are a few widgets included in Flex Viewer by default. There also some other widgets available on ArcGIS website made by third-party users. A developer can also develop his own widget using Flex and add it to the viewer. From *Widge*t tab in *ArcGIS Viewer for Flex*, the user can select one of the available widgets in the catalog, for example *GeoRSS* widget. The following list indicates the available widgets for Flex viewer: *Bookmark*, *Chart*, *Data Extract*, *Draw*, *Edit*, *GeoRss*, *Legend*, *Layer List*, *Locator*, *Print*, *Query*, *Search and Time.* By selecting to include the widget, the widget configuration window opens. By filling out the configuration window and hitting *OK* the widget will be available through the viewer application. Figure 4-11 shows the configuration windows of a widget.

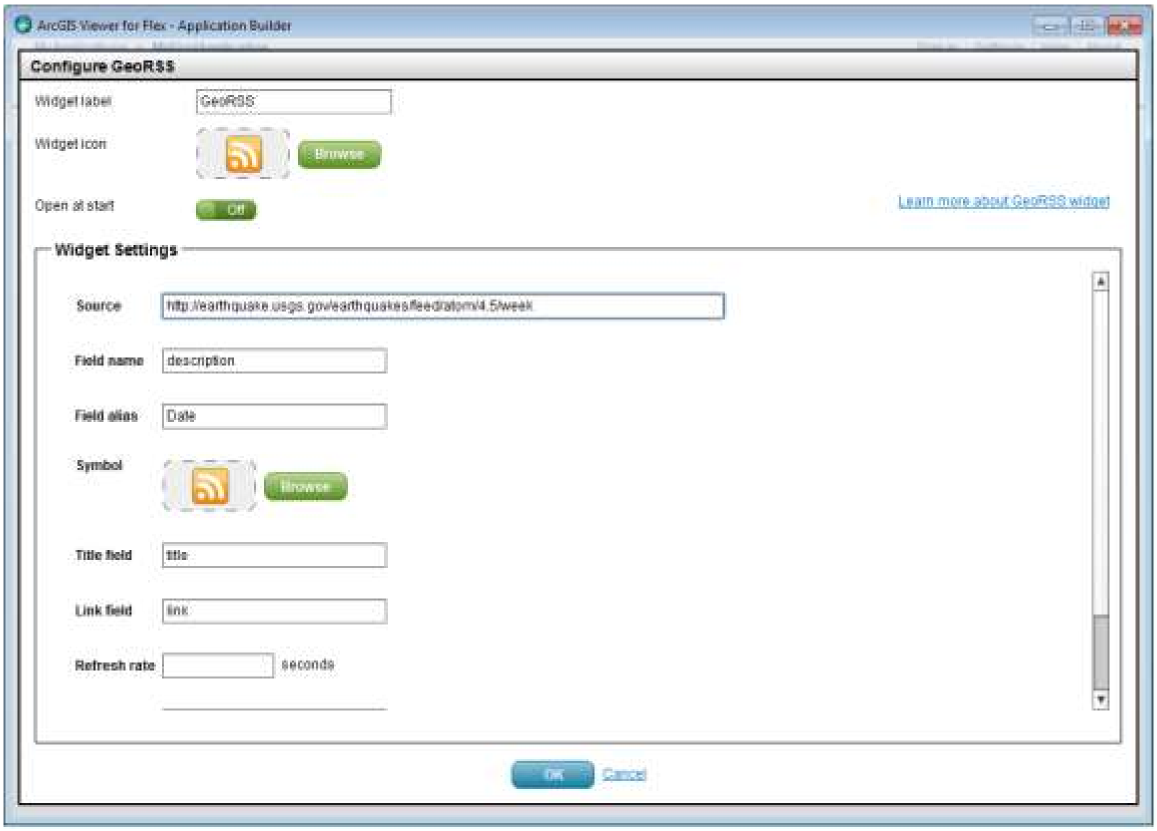


Figure 4-11 Configuration Window for a Widget in ArcGIS Viewer for Flex

4.4 Developed Layers, Tools and Widgets

4.4.1 Layers

Layers are the mechanism used to display geographic datasets which define how a GIS dataset is symbolized and labeled. A layer represents geographic data, such as a particular theme of data. Examples of map layers include streams and lakes, terrains, roads, political boundaries, parcels, building footprints, utility lines, and orthophoto imagery. Each map layer is used to display and work with a specific GIS dataset. A layer references the data stored in geodatabases.

Two types of layers are developed in the proposed system: (1) Layer which are not dependent on any tools and are updated automatically and periodically. Weather and delay layers are two instances of this type; and (2) Layers which are used by tools or widgets that are described in Section 4.4.2. The traffic layer added to the system is an example of dependent layers.

4.4.1.1 WEATHER DATA

Data source

Access to weather data in a real time has much added value for decision making and agile scheduling. Weather conditions can influence delay time at PoEs or possibly cause their closure. Thus, the system's users are interested in knowing the current weather information. Most of the weather forecast websites, such as *The Weather Network*, report weather information using RSS feeds. *Yahoo! Weather* is one example which reports the weather data as GeoRSS feeds. Therefore, in order to get current weather and weather forecast data for a city, like Sunnyvale, CA, we have to submit a request which looks like this:

`http://weather.yahooapis.com/forecastrss?w=2502265`

Although the output file has the needed data, it is necessary to parse their file and collect the desired information. Although the response is in GeoRSS format and includes the proper tags, ArcGIS Viewer cannot load this data on ArcGIS map because the time and date format that *Yahoo! Weather* used in the response are not the same as the time and date format that ArcGIS Viewer can parse –*Yahoo!* uses HH:MM while CBSA viewer can only parse HH:MM:SS.

The solution used is to read the port's latitude and longitude data from a predefined table and to use a weather forecast service which takes latitude and longitude as input. An example of this service is *Weather Underground* (weather forecast service used by *Facebook Inc*.). In order to fetch data from this API, an *HTTP Request* must be sent to the following URL (e.g. for Summerstown, Ontario):

`http://api.wunderground.com/auto/wui/geo/WXCurrentObXML/index.xml?query=44.99104,-74.739288`

Weather Underground updates the weather data every hour; so fetching and updating data should be done every hour.

Example

Figure 4-12(a) shows the weather information at PoEs on May 10, 2013 at 4 pm (EDT). The overall weather information of PoEs is reflected by the assigned symbols, but for more details the user can click on the PoE to get the detailed weather information such as temperature, humidity, wind, pressure and time of update. Figure 4-12(b) shows the details about Pigeon River PoE on June 19, 2013 4 pm (EDT).

As mentioned above, the SQL database updates every hour. The old information is stored in another SQL database to create a time series dataset. This dataset is accumulated and can be shown in GIS as historical data. By using a time slider, the historical weather data can be visualized for a specific duration.

(a) **(b)**

Figure 4-12 Weather Information (a) At PoEs on May 10, 2013 at 4 pm (EDT) (b) Popup Window with Details

4.4.1.2 WAITING TIME DATA

Data source

CBSA website has a table showing the delay time in main PoEs between Canada and the U.S., which is updated hourly. The table is text based and has no standard format like RSS. The solution to extract data from CBSA website is developing an HTML parser. In order to fetch HTML and extract waiting time from a table that can be seen by accessing the CBSA website (Border Wait Times, 2013), a request should be submitted. The call back function is called when the request is finished and the response is received. After receiving the HTTP response, we have the entire html page as a stream in *localHTMLFileBuilder* variable. This stream must be parsed to recognizable variables. In order to do so, we used *HTMLAgilityPack* library for parsing HTML documents (HTMLAgilityPack, 2013). Figure 4-13 shows the estimated wait times for reaching some primary inspection booths at main PoEs when crossing the Canada-U.S. border.

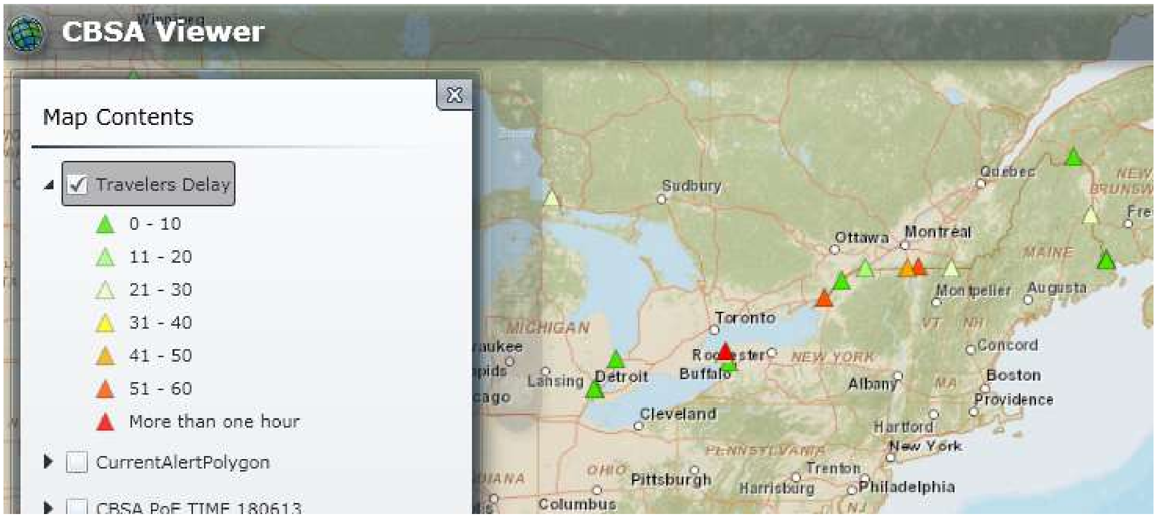


Figure 4-13 Estimated Wait Times for Reaching Some Primary Inspection Booths at Main PoEs when Crossing the Canada/U.S. Border on August 2, 2013 at 13 pm (EDT)

4.4.1.3 Alerts Data

Several emergency and incident alerts are collected and ready to publish based on CAP-CP which is explained in Section 2.2.6. The CAP-CP attributes are listed in Appendix B.

Example

Figure 4-14 shows the incident and emergency alerts that are provided by Pelromex (NAAD, 2013) July 24, 213 at 5 pm (EDT). The symbols are developed under the auspices of GeoConnections, with participation from emergency management organizations across Canada. Appendix H contains the table of symbols.

Figure 4-14 Alerts of Canada in July 24, 2013

4.4.2 TOOLS AND WIDGETS DEFINITION

Silverlight tools and Flex widgets provide a simple way to surface logic in the GIS that should be initiated by the user. If it makes sense to have the functionality initiated by clicking on a button in the toolbar, then this functionality should be encapsulated in a tool or widget. According to ESRI standard naming, if the developed function is in Silverlight, it is a called tool and if it is in Flex it is called a widget. More details about ArcGIS Viewers are explained in Section 4.3. Three types of tool/widget are developed: (1) The first type are independent from layers and just use the basemaps. As an instance, the rerouting tool/widget is independent from layers; (2) The second type, which are related to a specific layer which is embedded in the code and fixed. This type of tools/widgets always uses the same layer to visualize the data. For showing historical data this type of tools/widgets is mostly used, such as the pie chart tool and the services tool; (3) The last type is tools/widgets which are applicable to selected layers. For example the user can starts by selecting a layer. If the tool/widget is applicable to the selected layer, it is enabled and user can select the tool/widget to visualize the selected layer's data. The time slider tool/widget is categorized in this type.

4.4.3 SILVERLIGHT TOOLS

Figure 4-15 is the overview of the developed ArcGIS Silverlight Viewer. The details about layers and tools are explained in the following sections.

Figure 4-15 Developed Silverlight Viewer Overview

4.4.3.1 VISUALIZATION OF STATIC DATA

As explained in Section 3.4.5.1, static information about PoEs is stored in geodatabases. 21 types of services are available in each PoEs. To visualize the availability of different services in PoEs, we developed a tool called *Services*. By using the *Services* tool, the user can select any of the listed services in the menu and hit the *select* button. The tool uses color coding to show the availability of the selected service in all PoEs. If the service is available, a green circle at the PoE's location will appear. If the service is not available, a red circle will show the unavailability of the selected service in the PoEs. Figure 4-16 shows the PoEs with Immigration Services as an example of basic static data. By using the *Services* tool, the users can understand the distribution of the selected service over the crossing border in a visual manner.

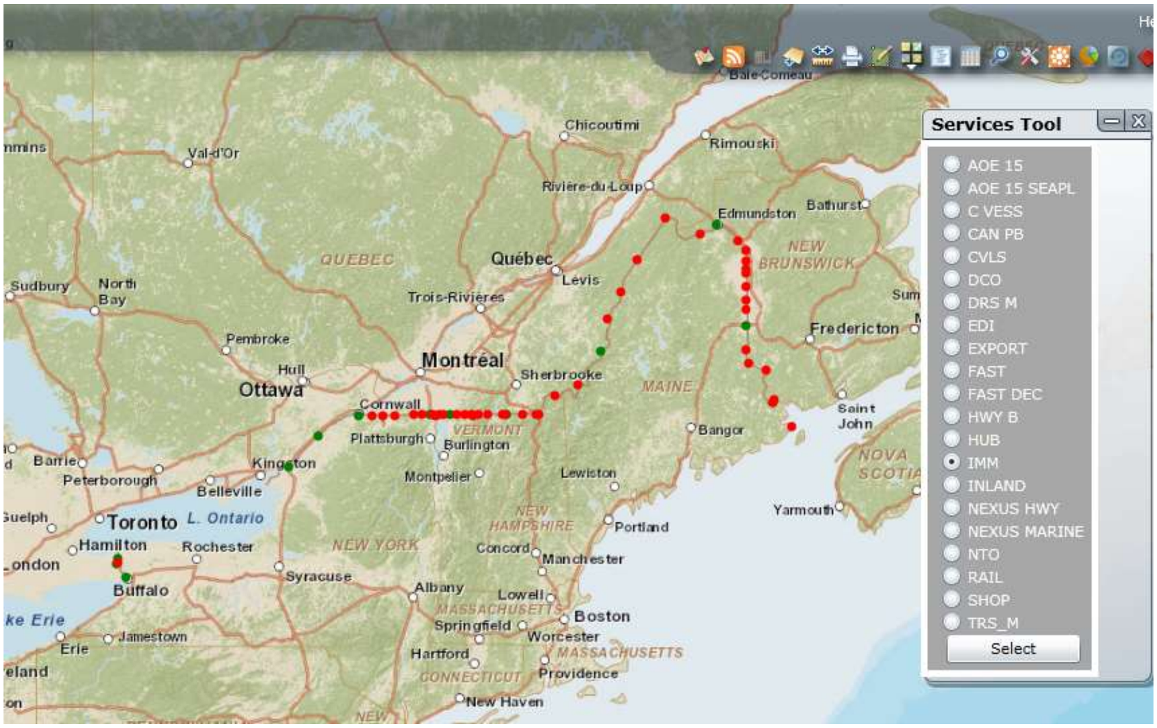


Figure 4-16 PoEs with Immigration Services (shown with green dots)

4.4.3.2 VISUALIZATION OF TRAFFIC HISTORICAL DATA

In Section 3.4.5.1, the traffic data format and sources are explained. These data are gathered over more than 20 years. To visualize large amount of data, two visualization methods are combined in a tool that is called *Monthly Time Slider*, first the pie charts and second the time slider. Pie charts show the values of pre-selected attributes of every PoE. In addition, their sizes reflect the magnitude of the pre-selected attributes in comparison with other PoEs' pie charts. So the bigger pie charts show the PoEs with more traffic. The embedded Time slider in this tool lets users select the start date and end date of slider duration by selecting the month and the year. This option helps users to narrow the duration to focus on specific period of time. For example, Figure 4-17 shows the number of Canadian and U.S. trucks traveling from Canada to the U.S. using historical time series data. A time slider at the bottom of the Figure 4-17 indicates the year and the month and allows the user to select the range of years to be visualized. In addition, by using the pie chart tool, the user can specify a month and a year and select a number of the available attributes to visualize for all the PoEs. Figure 4-18 shows the result of a specific combination of selected attributes for August 2000 on Pigeon River PoE.

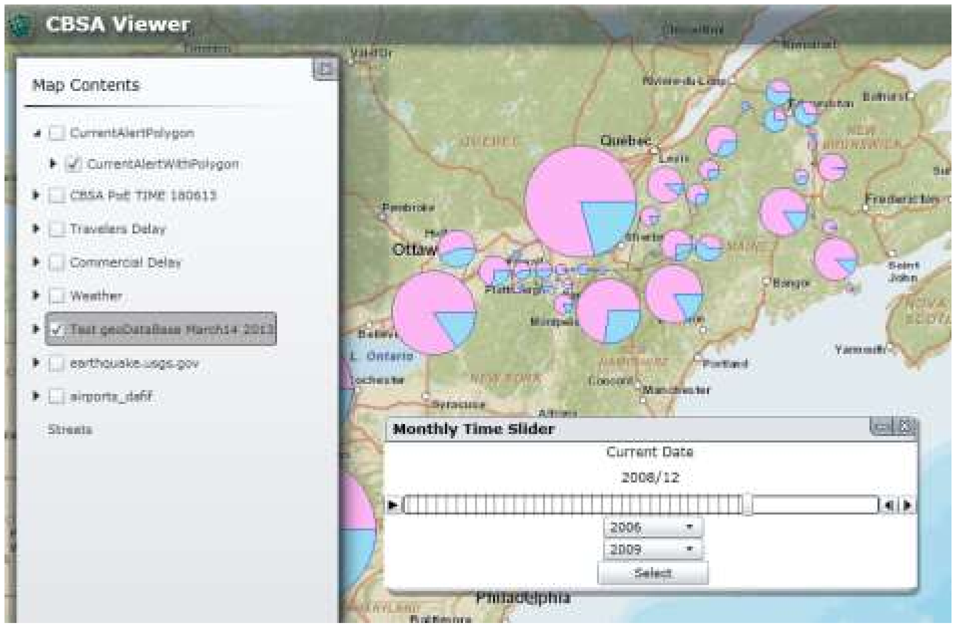


Figure 4-17 Number of Canadian and U.S. Trucks Travelling to Canada in December 2008

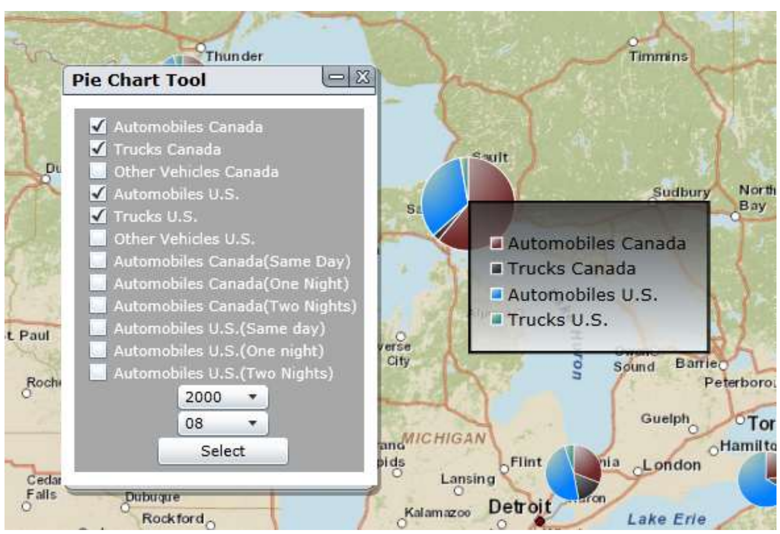


Figure 4-18 Pigeon River PoE Traffic Disaggregated based on Selected Attributes on August 2000

4.4.3.3 Clustering Based on Map Scale

Clustering is a common technique for statistical data analysis to compare different regions according to their values. To visualize clustered data, the *Clustering* tool is developed. Based on a selected attribute and specified date by the user, the tool visualizes the clustered circles which are dependent on the map scale.

As an example, Figure 4-19 shows the number of trucks that cross the border in British Columbia and Alberta. Figure 4-19(a) shows the number of trucks that cross the border with small scale clustering. Figure 4-19(b) shows the same region after zooming out. The number of trucks is clustered based on the new scale.

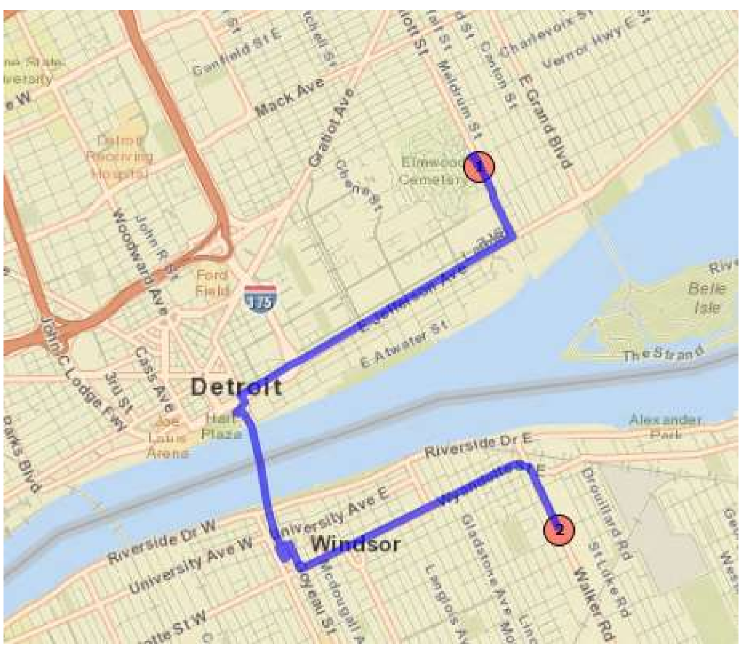
(a) **(b)**

Figure 4-19 Clustering (a) before Zooming out (b) After Zooming out

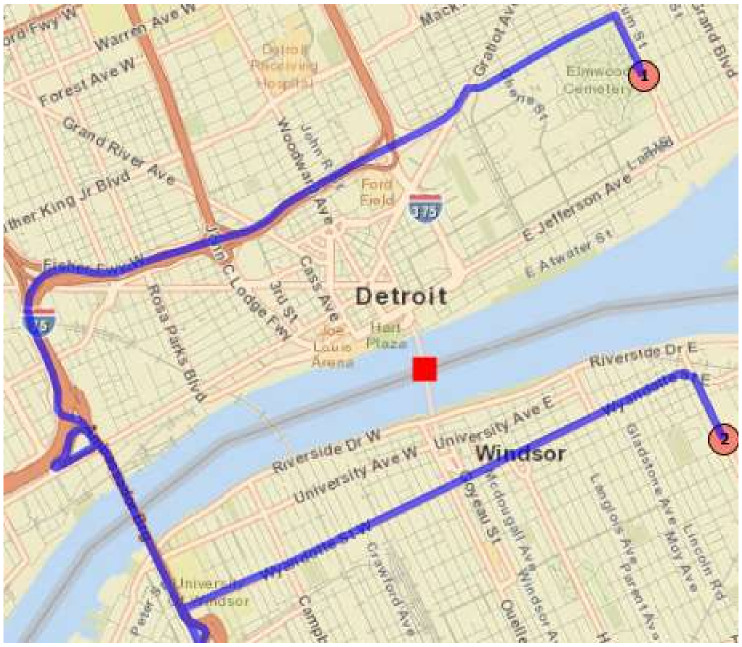
4.4.3.4 Interactive Rerouting

Transportation networks should have redundancy in case a link is cut. For example, the new structures proposed by CSCNSD (CSCNSD, 2005) have to be built to assure adequate separate and secure infrastructure redundancy in case of a disaster on the Ambassador Bridge at the Windsor-Detroit crossing. The Canadian and U.S. governments initiated a process to examine possible alternative crossings either north of Lake St. Clair along the Ontario-Michigan border or along the Ontario-New York border. Figure 4-20 shows an example of rerouting after closing the Windsor-Detroit Tunnel and the Ambassador Bridge.

Although using the Windsor-Detroit tunnel is not allowed for trucks and heavy vehicles, the example still can be applied for other vehicles. Suppose in normal condition, a vehicle wants to travel from point 1 to point to 2. As shown in Figure 4-20(a) the vehicle will use Windsor-Detroit tunnel. Suppose there is a road closure in the tunnel. The designed GUI let the user close any road using the barriers option. So by closing the tunnel, this situation can be simulated. Figure 4-20(b) shows the closure condition. The alternative path is using the Ambassador Bridge. Suppose there is an emergency in that area which causes the closure of the tunnel and the bridge. The user can close the tunnel and the bridge using the barriers option of the system. The suggested detour is longer and more time consuming as illustrated in Figure 4-20(c). The times and distances of the three paths are shown in Table 4-1.



(a)



(b)

(c)

Figure 4-20 Rerouting from Point (1) to (2) in Three Cases: Normal Situation (a), Tunnel Closure (b) and Tunnel and Bridge Closure

Table 4-1 Comparison among Different Routes

Route	Distance (miles)	Travel time (min)
(a)	9	20
(b)	12	24
(c)	132	186

4.4.3.5 ALERT IMPACT AREA DRAWING TOOL

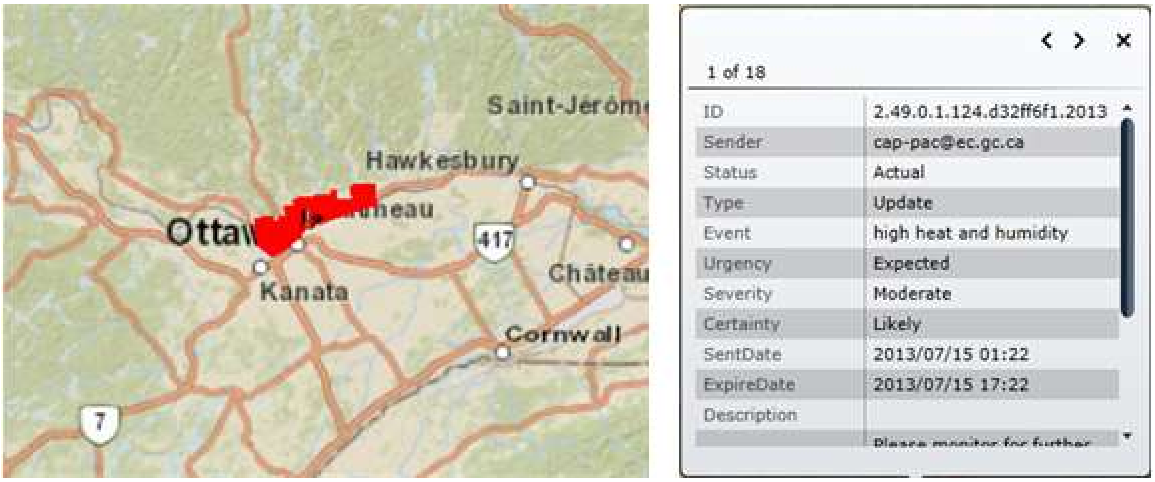
As mentioned in Section 4.4.1.3, we provide a layer that shows the alerts of the current day. In addition to that a tool is developed to show the current alerts impact areas. By showing the alerts polygons, the impact area of alerts can be found easily.

The developed tool has two main parts: (1) drawing the polygon; and (2) Finding the center of the polygon to show the alerts symbols.

As explained in Section 4.4.3.1, the alerts data are fetched form Pelromex website (NAAD, 2013) so the provided data has CAP standard (CAP-CP, 2013). To draw the polygons after fetching the XML file for each alert, we should: (1) Parse the XML file and find the polygon tag. The polygon tag contains ordered pairs as longitude and latitude of every vertice. To show the polygon area completely the tag starts and ends with the same vertex. For instance: `<polygon> x1,y1 x2,y2 x3,y3 x1,y1 </polygon>`; (2) Parse the polygon and add the longitudes and latitudes to an array as points; and (3) Connect the points by drawing the lines in a single file and adding the lines as a graphical layer.

<u>Example</u>

Figure 4-21(a) shows the high heat and humidity in Ottawa on the 15th of July 15, 2013 at 4 pm (EDT).



(a) **(b)**

Figure 4-21 (a) High Heat and Humidity in Ottawa, 15th of July 15, 2013 at 4 pm (b) Popup Window to Display Alert Details

The alert data are collected from National Alert Aggregation & Dissemination System (NAAD). Figure 4-21(b) shows more details about the alert in a table. On the top left of the alert details in Figure 4-21(b) is written a number which shows the number of updates for the same alert. It means that the current alert has been updated 18 times and its details can be changing. However the alerts IDs for all 18 updates are the same. The full list of attributes of the alert table is shown in Appendix B. In addition, another function is developed for showing archived alerts as explained in Section 4.4.4.6.

4.4.3.6 GEORSS TOOL

As explained in Section 2.2.6.3, GeoRSS is a method for showing real-time data in GIS. By using the RSS tool, which is one of basic tools in ArcGIS Viewer, a GeoRSS feed is fetched. When data is received, it will be parsed and used to create graphics for visualizing the data, which are then added to GIS.

Figure 4-22 shows the window to add URL for a GeoRSS feed. After adding a GeoRSS URL, ArcGIS Viewer will fetch the data, parse them and show them on the map. Figure 4-23 shows the earthquakes that occurred during the previous period of seven days with a magnitude more than 2.5 in Richter scale, which are accessible via a web service that is updated every 10 minutes at the Geological Survey's (USGS) website.

Figure 4-22 Adding URL for a new GeoRSS Feed

Figure 4-23 Earthquakes for a Previous Period of Seven Days (USGS)

For more information, Silverlight-based system brief user guide in Appendix K can be helpful to understand the tools and layers.

4.4.4 FLEX WIDGETS

Figure 4-24 is an overview of the developed ArcGIS Flex Viewer. The details about layers and widgets are explained in the following sections.

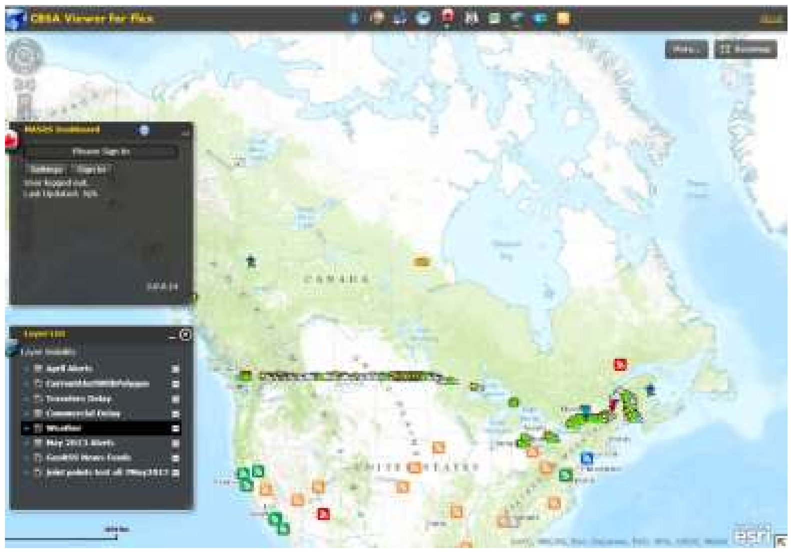


Figure 4-24 Developed Flex Viewer Overview

4.4.4.1 CHARTING BASED ON AGGREGATION

To summarize the gathered data and find out the trends and patterns, different types of charting are available in Flex Viewer. These visualization methods are using aggregation based on one of PoEs' attributes. For example Figure 4-25 is showing the GUI designed for charting based on aggregation. The users can select one or more PoEs by using the draw function. After selecting a draw function, the user can visually select some PoEs and the chart will show the result as shown in Figure 4-25. The main advantage of this widget is that the user can select any number of PoEs to draw the chart. This may help the users to compare different sets of PoEs. The other advantage of this widget is that the selection function is graphical and the user can select PoEs by drawing a rectangle, circle, oval or any arbitrary polygon.

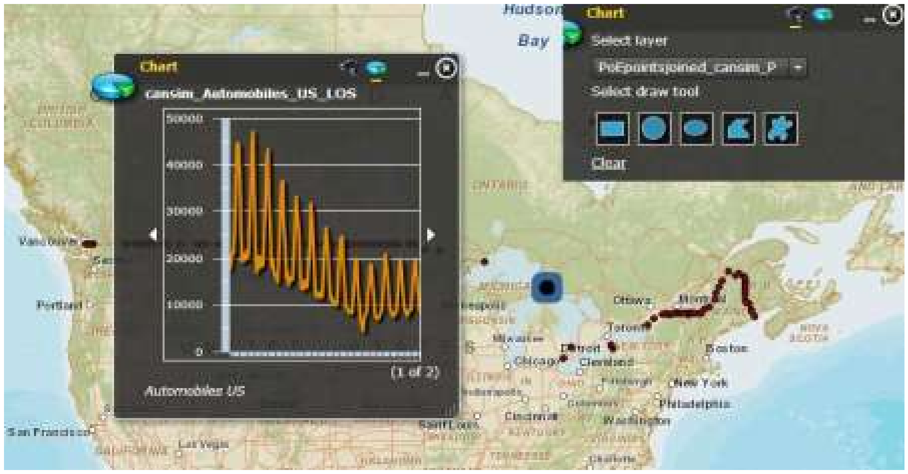


Figure 4-25 Different Modes of Draw Tool for Selection and the Result as an Aggregated Chart based on U.S. Automobiles that Entered Canada during 2000 to 2012 for Selected PoEs.

4.4.4.2 DIFFERENT ATTRIBUTE CHARTING

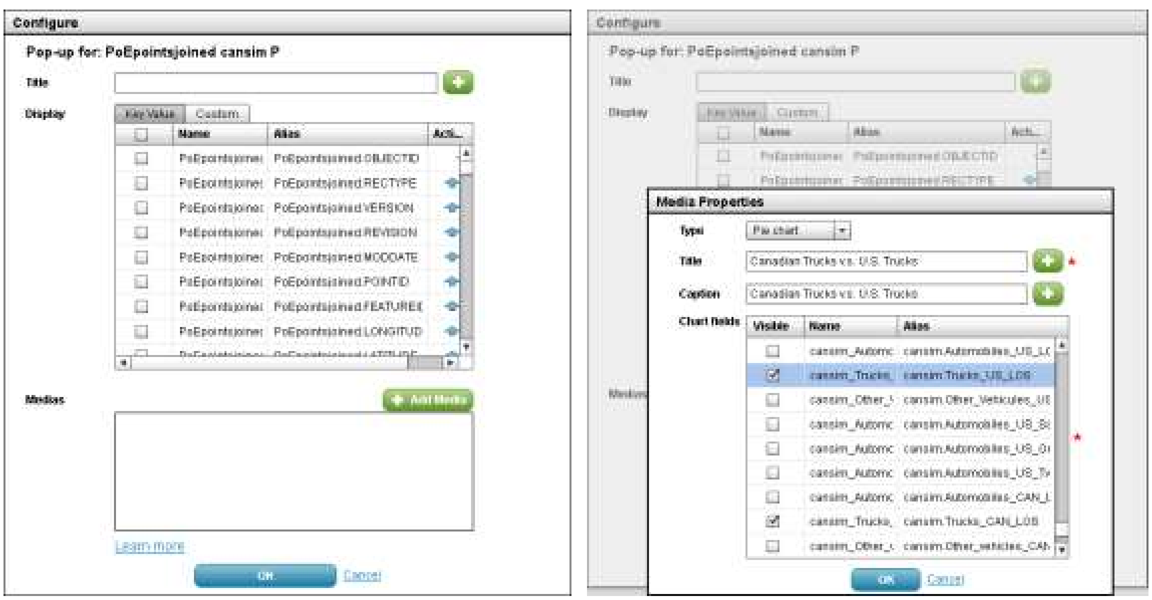


Figure 4-26 Selecting the Attributes to Display

One of the Flex Viewer behaviors is to add a charting ability to an added layer. After selecting a layer, it is possible to configure the layer. By going to the Configure menu, the user can select which attribute of the layer is going to be shown by clicking on the layers points. Figure 4-26(a) shows the configure menu for attribute selection. By using the add media button in the configure menu, a new window will open. This window lets the user select the type of charting and the attributes which are going to be compared.

By selecting the bar chart, the result will be as shown in Figure 4-27(a) and by selecting the pie chart option, the result will be as shown in Figure 4-27(b). On the top right of Figures 4-27(a) and 4-27(b) is written 1 of 155. For every PoE, the collected data are for 13 years disaggregated by month. So the user can see the charts for every PoE from January 2000 to December 2012. Note that December 2012 is not included in this data. The historical traffic data on the ArcGIS server should be updated monthly.

(a) **(b)**

(a) **(b)**

Figure 4-27 Drawing a Chart based on Attribute Aggregation: (a) Bar-Chart (b) Pie-Chart

4.4.4.3 ADDING LINKS TO SURVEYANCE CAMERAS

By installing cameras at different PoEs, it is possible to access them to observe traffic and weather conditions. The camera access is limited and authorization is needed due to security issues. To add a link for a camera, the attributes in the PoEs table should contain the URL address attribute. Figure 4-28 shows the custom tab in the Configuration menu of any layer where user can add a hyperlink to the table. After adding the camera’s link as a hyperlink to the layer, the result will be as shown in Figure 4-29.

Currently, for testing purpose, all PoEs are assigned to one Sony web-based camera (SNC-ER580) in Concordia University E.V.8.415 office as a dummy camera. Figure 4-30 shows the view of the dummy camera. Accessing to this camera has been limited by authorization step which needs valid username and password.

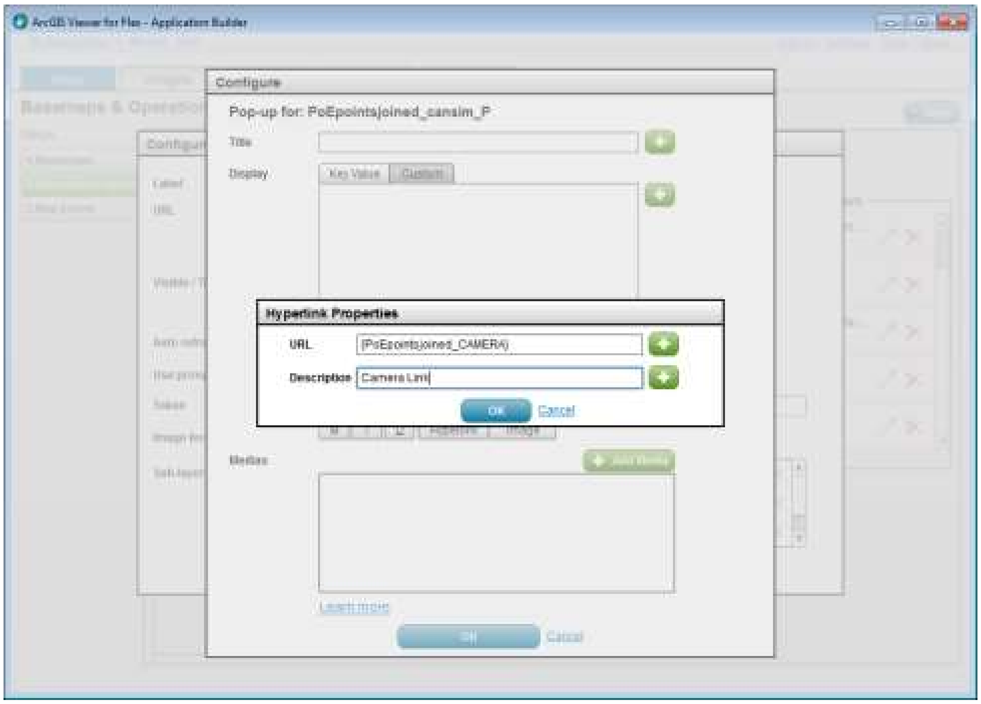


Figure 4-28 Adding Camera's Link to the PoEs

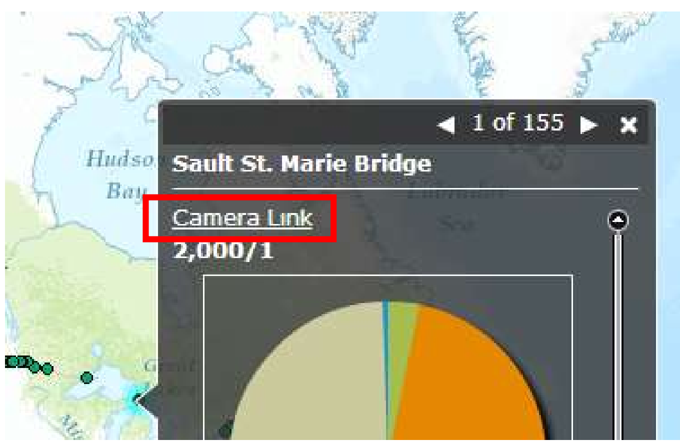


Figure 4-29 Camera Link Assigned it every PoEs

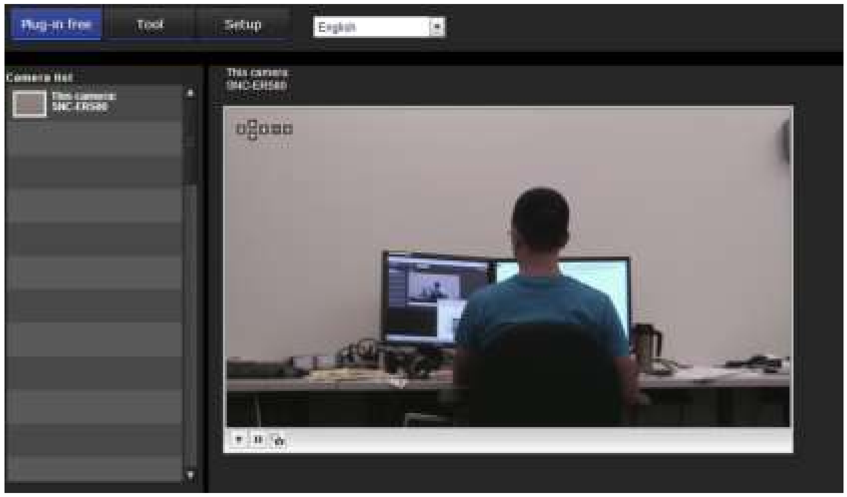


Figure 4-30 Dummy Camera's View

4.4.4.4 EXCEL WIDGET

Adding a layer to ArcGIS Viewer is not as easy as it looks. The layer should follow standard formats. Although it is highly recommended to upload layers as geodatabase or as shapefiles (standard formats), the users can also upload files with .xls extension. A widget called Excel widget is available for users to be able to add an Excel file which contains geographical information to the GIS without any conversion. The limitation of this widget is that Excel files with new format (.xlxs) cannot be published on the Viewer. So, to upload files with .xlsx extension it is necessary to convert them to the old Excel files format and then upload them.

4.4.4.5 MASAS WIDGET

MASAS widget is developed to use the current updated alerts which are published by MASAS-X project without using their system. By using the MASAS widget, the user can connect to MASAS-X server and fetch the data. Since MASAS-X data are not public, the user needs to sign in with an access code before using the widget. After logging in, the last updated alert data will be shown on the map. By clicking on an alert, more details and information about alerts will be shown in a popup window.

4.4.4.6 ALERT TIME SLIDER

The time slider widget is a function to visualize the historical alert data on the basemap. For using this widget, the user should select one of the available archived months for visualization. By hitting the *play* button, the alerts will be shown on the map in a daily manner. The time slider widget lets the users follow the alerts and their updates based on the time. Figure 4-31 shows the GUI designed for time slider widget. The *Select Layer* menu let the user choose the desired month.

Figure 4-31 Time Slider Widget GUI Developed for Archived Alerts

4.4.4.7 ROUTING WIDGET

This widget allows the user to visualize a blockage in traffic for an origin and destination, as well as to avoid barriers along the way. This widget has options to calculate the shortest time or distance and to use the best sequence and return to first stop. By clicking on the buttons on the top row the user has options such as viewing directions and printing. Other options of this widget is to add stops by an exact address as a text or interactively select the points on the map by mouse clicks. Figure 4-32 shows the GUI of the route widget.

Figure 4-32 The Route Widget Allows for Additions of Stops and Barriers

4.4.4.8 DRAWING WIDGET

The drawing widget allows drawing on the map with the addition of features which will provide measurements of the drawing. These measurements include distances and areas based on the lines or polygons drawn. This can be a very useful tool in terms of getting quick measurements from the map. Text and different predefined shapes are provided by this widget. Figure 4-33 shows different options of the drawing widget.

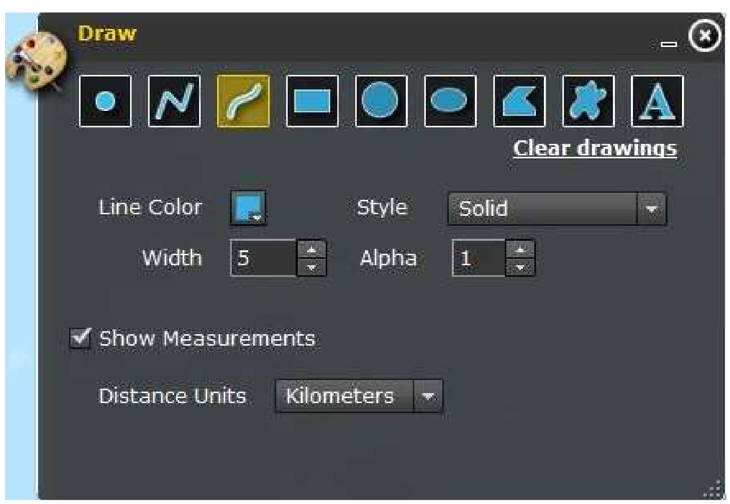


Figure 4-33 Drawing Widget and Its Different Options

4.4.4.9 GEORSS WIDGET

The primary function of the GeoRSS is to provide real time event and alert information that are attached to a geographic location. This can come in the form of earthquake reports, amber alerts, weather information, road construction, news stories, etc. In the Layer List there are default GeoRSS based layers already attached pertaining to the above listed services, these can also be activated/deactivated. The equivalent tool is available in ArcGIS Silverlight Viewer which is explained in Section 4.4.3.6. Figure 4-34 shows the earthquake information which is added to GeoRSS widget.

Figure 4-34 Screenshot of GeoRSS Widget Showing Earthquake Information

4.4.5 INTERACTION WITH THE SYSTEM WITH MULTI-TOUCH SCREENS

A multi-touch user interface is proposed to interact with the designed system. We tested the system on four multi-touch screens that are synchronized for displaying information as shown in Figure 4-35. Using the multi-touch screens makes the system more user friendly and helps non-professional users to interact more easily.

Figure 4-35 Using Multi-Touch Screens to Interact with the Developed System

4.5 Summary and Conclusions

The implementation illustrated the potential power of GVA, using ArcGIS Viewers. The examples have been implemented using historical data and near real-time data. Historical traffic data between Canada and the U.S. are gathered and the near real-time data are mostly gathered from public websites. This gathered data and several implemented tools using ArcGIS API for Silverlight are used to show the capabilities of GVA in transborder research area. In addition to Silverlight Viewer tools, some GVA tools were provided using ArcGIS Viewer for Flex to show other potentials of GVA. Since user friendliness is one of system's requirements, the system is designed in a way to be compatible with big multi-touch screens. Furthermore, the system is capable to be extended. Adding tools to the GVA toolbox helps the system to meet new expectations of users and to customize the system for specific purposes.

CHAPTER 5 SUMMARY, CONCLUSIONS AND FUTURE WORK

5.1 SUMMARY OF RESEARCH

Visual and geovisual analytics are tools that can be used in many research areas, such as health care, security, military, etc. This research proposed a system to extend the GVA research into the trabsborder area. Using GVA can be helpful to solve many current transborder issues. The research provides a framework to gather and store historical and real-time data and to make different queries. Thus the proposed system covers three main parts which are: (1) Handling the large amount of transborder data in reasonable time via GVA tools by using human visual understanding capabilities; (2) Combining the historical and near real-time data for more accurate decision making; and (3) Providing a user-friendly environment to visualize the desired data based on users' requests for users with different levels of computer expertise. There are many system requirements that should be considered in designing the system which are explained in Section 3.2.

5.2 CONCLUSIONS OF RESEARCH

The conclusions of this research are as follows: (1) A transborder dedicated GVA system has been proposed to gather, store and analyze real-time and historical data and to visualize and share them for decision making; (2) The proposed system provides a framework for GVA which can be applied to many problems by extending the data and tools; (3) Designing the user-friendly GUI helps users with different skills and knowledge to interact with the system; (4) Changing the format of data from different sources to standard formats and storing them in geodatabases help data integration and query making; (5) Visualizing the data from different sources helps the users in finding out the potential problems based on cause and effect relationships.

5.3 LIMITATIONS AND FUTURE WORK

The limitations of this research are as follows: (1) Data collection requires the access to some classified data which were not accessible for our research group; (2) The implemented Silverlight Viewer is compatible with Windows OS and is not compatible with Linux and Mac OS; (3) Although the system has alert impact drawing tool, it does not work for different alerts simultaneously. Improving this tool makes it possible to show a hazard map, which is colored polygons related to the risks of a region. So overlapped polygons show the high risk regions.

In addition to addressing these issues in our future work and improving the performance of the system in general, the proposed system can be extended to target supply chain flow data between Canada and the U.S. Applying GVA system on SCM can be helpful to solve many SCM issues. Updating the system to be compatible with new versions on ArcGIS API and ArcGIS Viewer and also with Linux and Mac OS is necessary. Furthermore the various functions of the system should be tested using rigorous testing methods.

REFERENCES

Anderson, W., Coates, A. (2010). Delays and Uncertainty in Freight Movement at U.S.-Canada Border Crossings, CTRF 45th Annual Conference, Transportation and Logistics Trends and Policies: Successes and Failures.

Andrienko, G., Andrienko, N., Bak, P., Keim, D., Wrobel, S. (2013). Visual Analytics of Movement, Springer.

Andrienko, G., Andrienko, N., Demšar, U., Dransch, D., Dykes, J., Fabrikant, S., Jern, M., Kraak, M., Schumann, H., Tominski, C. (2010). Space, Time, and Visual Analytics, Int. J. of Geographical Information Science, V. 24, N. 10, pp. 1577-1600.

Andrienko, N., Andrienko, G. (2006). Exploratory Analysis of Spatial and Temporal Data - A Systematic Approach, Springer.

ArcGIS (2013). ArcGIS, < http://www.arcgis.com/>

Bassok, A., McCormack, E., and Outwater, M. (2010).Use of Truck GPS Data for Freight Forecasting. The Third International Conference on Innovations in Travel Modeling (ITM) of the Transportation Research Board (TRB), Tempe, Arizona.

Border Wait Times (2013). Canada Border Service Agency, <http://www.cbsa-asfc.gc.ca/bwt-taf/menu-eng.html >

Bourke, P. (1988). Calculating the Area and Centroid of a Polygon, <http://www.seas.upenn.edu/~sys502/extra_materials/Polygon%20Area%20and%20Centroid.pdf >

Canada-United States Transportation Border Working Group (TBWG) (2013). Border Information Flow Architecture (Final Report), <www.thetbwg.org/meetings-archive-200511_e.htm/>

CANSIM (2012). Canadian Socioeconomic Database from Statistics Canada, <http://www5.statcan.gc.ca/cansim/>

CANSIM-427-0002 (2014). Number of vehicles travelling between Canada and the United States,

<http://www5.statcan.gc.ca/cansim/a26?lang=eng&retrLang=eng&id=4270002&tabMode=dataTable&srchLan=-1&p1=-1&p2=9/>

CAP-CP (2013). Common Alerting Protocol, <cap-cp.ca>

CAP-CP Specification Documents (2013). Communications Interoperability Working Group, <http://www.cap-cp.ca/index.php/en/#CAP-CP Specifications>

CBSA (2013). Border Wait Times, <http://www.cbsa-asfc.gc.ca/bwt-taf/menu-eng.html/>

Choosing Visualization for Transportation Knowledge Sharing (2013). <http://choosingviz.org/>

CSCNSD (2005). Canada Senate Committee on National Security and Defense. Borderline Insecure.

Directory of CBSA Offices (2014). <http://www.cbsa-asfc.gc.ca/do-rb/menu-eng.html/>

Drabek, T., McEntire, D. (2003). Emergent Phenomena and the Sociology of Disaster: Lessons, Trends and Opportunities from the Research Literature. Disaster Prevention and Management, V. 12, pp. 97-112.

Emergency Mapping Symbology (2010). Emergency Mapping Symbology, version 1.0, <http://emsymbology.org/EMS/docs/EMS_Symbology_v1.0.pdf/>

ESRI (2013). ArcGIS Server, www.esri.com/software/arcgis/arcgisserver/

Fabrikant, S. I., Lobben, A. (2009). Cognitive Issues in Geographic Information Visualization. Special Issue on Cognitive Issues in Geovisualization. Cartographica, V. 44, N. 03, pp. 139-143.

Fanga, Z., Shawa, S.L., Tua, W., Lia, Q., Lia, Y. (2012). Spatiotemporal Analysis of Critical Transportation Links Based on Time Geographic Concepts: A Case Study of Critical Bridges in Wuhan, China. Journal of Transport Geography, Special Issue on Time Geography, V. 23, pp. 44-59.

FHWA (2010). Measuring Cross-Border Travel Times for Freight: Otay Mesa International Border Crossing, Final Report, September 2010, U.S. Department of Transportation, FHWA.

Fischer, H. (2000). Mitigation and Response Planning in a Bio-Terrorist Attack. International Journal of Disaster Prevention and Management, V. 9, pp. 9-15.

GeoRSS (2013). GeoRSS, <georss.org/>

GML (2013). Geography Markup Language, <www.opengeospatial.org/>

Hranac, R. (2013). Visual Analytics for Reliability, Transportation Research Board, Session 627.

HTMLAgilityPack (2013) HtmlAgilityPack 1.4.6, <nuget.org/packages/htmlagilitypack/>

Hughes, R.G. (2010). Freight Data Visualization: A Pivotal Point in the Development of Visualization Applications in Transportation. The 2011 Transportation Research Forum, Long Beach, CA.

Iakovou, E., Douligeris, C. (2001), An Information Management System for the Emergency Management of Hurricane Disasters. International Journal of Risk Assessment and Management, V. 2, pp. 243-262.

IPAWS (2013). U.S. Integrated Public Alert and Warning System, <www.fema.gov/integrated-public-alert-warning-system/>

Keim, D.A., Kohlhammer, J., Ellis, G., Mannsmann F. (2010). Mastering the Information Age. Solving Problems with Visual Analytics, Eurographics Association, Goslar (2010).

Khan, A.M. (2010). Prediction and Display of Delay at Road Border Crossings, Open Transportation Journal, V. 4, pp. 9-22.

Kohlhammer, J., Keim, D., Pohl, M., Santucci, G., Andrienko, G. (2011). Solving Problems with Visual Analytics, Procedia Computer Science, V. 7, pp. 117-120.

Kunreuther, H. (1996), Mitigating Disaster Losses through Insurance, Journal of Risk and Uncertainty, V. 12, pp. 171-187

Liao, C.F. (2009). Using Archived Truck GPS Data for Freight Performance Analysis on I-94/I-90 from the Twin Cities to Chicago, Minnesota Department of Transportation, CTS pp. 09-27.

Mapcruzin. (2014) Free GIS Mapping, ArcGIS Shapefiles, Tools, News, Geography Maps and Resources, < http://www.mapcruzin.com/>

MASAS (2013). Canada’s Multi-Agency Situational Awareness System, <http://www.masas-x.ca/>

McHugh, C. (1995). Preparing Public Safety Organizations for Disaster Response: a Study of Disaster Prevention and Management, V. 4, pp. 25-36.

J. B. McQueen (1967). Some Methods for classification and Analysis of Multivariate Observations, Proceedings of 5-th Berkeley Symposium on Mathematical Statistics and Probability, Berkeley, University of California Press, V. 1, pp. 281-297

Moghaddam, A. K. (2013). Developer Manual on CBSA Project report.

Mumford, E. (1985). Defining System Requirements to Meet Business Needs: a Case Study Example, The Computer Journal, V. 28, pp. 97-104.

NAAD (2013). National Alert Aggregation and Dissemination (Pelmorex Alerting System), <http://alerts.pelmorex.com/en/>

Perry, R.W., Lindell, M.K. (2003). Preparedness for Emergency Response: Guidelines for the Emergency Planning Process. Disasters V. 27, N. 4, pp. 336-350.

Public Safety Canada (2013). Communications Interoperability Action Plan for Canada, Public Safety Canada, < https://www.publicsafety.gc.ca/index-eng.aspx/>

RITA (2012). Bureau of Transportation Statistic, Border Crossing/Entry Data: Query Detailed Statistics, RITA, <www.bts.gov/programs/international/transborder/TBDR_BC/TBDR_BCQ.html/>

Schumann, H., Tominski, C. (2011). Analytical, Visual and Interactive Concepts for Geo-visual Analytics, Journal of Visual Languages & Computing, V. 22, N. 4, pp. 257-267.

Shackel, B., Richardson. S. J. (1991). Usability – Context, framework, definition, design and evaluation. Human Factors for Informatics Usability, New York, Cambridge University Press, pp. 21–37.

Sheffi, Y. (2007). The Resilient Enterprise: Overcoming Vulnerability for Competitive Advantage, The MIT Press.

Simchi-Levi, D., Kaminsky, P. (2008). Designing and Managing the Supply Chain. McGraw-Hill.

Statistics Canada (2006). Canadian International Merchandise Trade. Survey 2202, <www5.statcan.gc.ca/bsolc/olc-cel/olc-cel?catno=65f0013x&lang=eng/>

TBS (2014). Treasury Board of Canada Secretariat. < https://www.tbs-sct.gc.ca/pol/doc-eng.aspx?id=25597&section=XML/>

Thomas, J., Cook, K. (2006). A Visual Analytics Agenda. Computer Graphics and Applications, V. 26, N.1, pp. 10-13.

Tominski, C. and Schumann, H. (2008). Enhanced Interactive Spiral Display, The Annual SIGRAD Conference Special Theme: Interaction, Stockholm, Sweden.

Transport Canada (2004). Border Wait-Time Project; Phase 2 (Proof of Concept) Executive Summary, Coordination & Policy Advice, Transport Canada, Ontario.

TRB-VTC (2011). Strategic Plan of the Visualization in Transportation Committee of the Transport Research Board, <www.trbvis.org/storage/TSP-ABJ952012.pdf/>

CBP (2013). Border Wait Time, U.S. Customs and Border Protection, <http://apps.cbp.gov/bwt/>

U.S. Department of Transportation (2003), Bureau of Transportation Statistics. U.S. International Trade and Freight Transportation Trends, BTS03-02. Washington, DC.

Vismaster (2014). Visual Analytics Mastering the Information Age, <http://www.vismaster.eu>

Warwick, M. (1995). Painful Lessons in Crisis Mismanagement. Communications International, V. 22, pp. 4-5.

Wilson, M. C. (2007). The Impact of Transportation Disruptions on Supply Chain Performance. Science Direct, V. 43, N. 4, pp. 295-320.

Witt, J. L. (1997). Creating the Disaster-Resistant Community. American City & County, V. 112, pp. 23-31.

APPENDIX A – OTHER VISUAL ANALYTICS SOLUTIONS

Software	Availability	Aggregation	Clustering	TimeSeries	Mapping	Routing	Spatial Analytics
MAPPOINT	Trial - 14days	N	N	N	A	A	N
TABLEAU	Trial - 14days	A	A	A	A	N	N
PANOPTICON	Trial - 17days	N	N	N	N	N	N
OPENDX							
GEOTIME		N	N	N	A	N	A
Advanced Visual Systems							
Visual Analytics							
IdvSolutions							

A: Available N: Not Available

- **TABLEAU**

Provides users a very interactive and user-friendly interface to view data. Once the data values are entered into the software and categorized, it is very easy to manipulate and view the data in different ways. It has the ability to view the time-enabled data, and also allows for data aggregation and mapping. It is a good program to analyze data within, as it allows for very quick generation of different types of data.

Tableau may have limitations in terms of its mapping options, as spatial analysis options are limited and so are routing options. This software would be primarily useful for visualizing, analyzing and interpreting data.

- **MS Mappoint**

Mapping tool with limited functionality with data or spatial analysis. It does feature routing tools, but most other tools seem rudimentary. Mappoint extracts geographic data from within the data – it searches for information such as zip codes, city and state names, etc. This feature did not seem to recognize Canadian Zip Codes.

- **Panopticon**

This software has a simple interface, but the features seems to mostly reflect the business and data analytics aspects and may be very useful for these options. In terms of our project the software may have limitations as it does not have any spatial analysis or mapping options at all.

APPENDIX B – CAP ATTRIBUTES

(CAP-CP Specification Documents, 2013)
For more information please refer to:
http://www.cap-cp.ca/index.php/en/#CAP-CP Specifications

Attribute	C# Lib Variable	Necessity	Values	Type	Example or Discr.
identifier	messageID		Any string	String	559BED43-4D87-D8CE-D509-873C6F1CA0B0
sender	senderID	Mandatory	Any string	String	AmberAlertCoordinator@OntarioProvincialPolice
sent	sentDateTime		Date and Time	String	2013-04-14T17:32:05-04:00
status	messageStatus		Actual, Exercise, System,Test, Draft	String	
msgType	messageType		Alert, Update, Cancel, Ack, Error	String	
source	source		Any string	String	Environment Canada - Environnement Canada - Toronto (CWTO)
scope	scope		Public, Restricted, Private	String	
restriction	restriction		Any string	String	
addresses	addresses		Any string	String	
references	referenceIDs	Mandatory for Update and Cancel Messages	Any string	String	List of other message IDs which are related to this message, separated by comma
incidents	incidentIDs		Any string	String	
info	info	Mandatory	List of Attributes	List of Attributes	<info> <language>en-CA</language> <category>Met</category> </info>
Info.language	language	Mandatory	Any string	String	en-CA
Info.category	category		Geo, Met, Safety, Security, Rescue, Fire, Health, Env, Transport, Infra, CBRNE, Other	String	
Info.event	eventType	Mandatory	Any string	String	blowing snow
Info.responseType	responseType	Strongly Recommended	Shelter, Evacuate, Prepare, Execute, Avoid, Monitor, Assess, AllClear, None	String	
Info.urgency	urgency		Immediate, Past, Expected, Future, Unknown	String	
Info.severity	severity		Extreme, Severe, Moderate, Minor, Unknown	String	

Info.certainty	certainty		Observed, Likely, Possible, Unlikely, Unknown	String	
Info.audience	audience		Any string	String	General Public
Info.eventCode	eventCode	Mandatory	Must be one of event codes in the Appendix A	String	<eventCode> <valueName>profile:CAP-CP:Event:0.4</valueName> <value>blowingSnow</value> </eventCode>
Info.effective	effective		Date and Time	String	2013-04-14T22:53:00-00:00
Info.expires	expires	Strongly Recommended	Date and Time	String	2013-04-15T14:53:00-00:00
Info.senderName	senderName	Strongly Recommended	Any string	String	Environment Canada
Info.headline	headline		Any string	String	blowing snow warning in effect
Info.description	description		Any string	String	
Info.instruction	instruction		Any string	String	If you have information call 911
Info.web	web		Any Uri	String	http://www.weatheroffice.gc.ca/warnings/warnings_e.html
Info.contact	contact		Any string	String	
Info.parameter	parameter		Any string	String	<parameter> <valueName>layer:EC-MSC-SMC:1.0:Alert_Type</valueName> <value>warning</value> </parameter>
Info.resource	resource		List of Attributes	List of Attributes	<resource> <resourceDesc>larabie.jpg </resourceDesc> <mimeType>image/jpeg</mimeType> </resource>
Info.resource.size	Size		Integer	Integer	Size of the attachment in bytes
Info.resource.resourceDesc	attachmentName		Any string	String	larabie.jpg
Info.resource.mimeType	mimeType		Any string	String	image/jpeg
Info.resource.uri	resourceUri		Any Uri	String	larabie.jpg
Info.resource.derefUri	derefUri		Byte[]	Byte[]	Binary representation of attachment converted to ASCII code
Info.resource.digest	Digest		Any string	String	126707ca7e43c9dbcc91095ea7f88966e6b4e9b1

Info.area	area	Mandatory	List of Attributes	List of Attributes	<area> <areaDesc>ontario</areaDesc> <polygon> … </polygon> </area>
Info.area.areadesc	areaDesc		Any string	Any string	<areaDesc>ontario</areaDesc>
Info.area.geocode	geocode	Mandatory	Must be one of events from the Appendix A	Any string	<geocode> <valueName>profile:CAP-CP:Location:0.3</valueName> <value>6001045</value> </geocode>
Info.area.polygon	polygon		Any string	Any string	<polygon> 67.2901,-136.1155 67.3063,-136.0829 … </polygon>
Info.area.circle	Circle		Any string	Any string	

APPENDIX C – MASAS-X MAIN ALERT SOURCES

(MASAS, 2013)

Alert Type	**Publisher**	**Link**
Canadian Weather	Environment Canada	http://weather.gc.ca/canada_e.html
Canadian Earthquakes	Earthquakes Canada	http://www.earthquakescanada.nrcan.gc.ca/index-eng.php
NAADS	NAADS	http://alerts.pelmorex.com/en/
US Weather	US NWS	http://weather.noaa.gov/
BC Highways	DriveBC	http://www.drivebc.ca/
BC Hydro	BC Hydro	http://www.bchydro.com/index.html
Vancouver Roads	City of Vancouver	https://app.vancouver.ca/roadahead_net/
Ontario Fires	Ontario Ministry of Natural Resources	http://www.ontario.ca/law-and-safety/forest-fires
Ontario Highways	Ontario Ministry of Transportation	http://www.ontariohighways.org/
Ottawa Roads	City of Ottawa	http://traffic.ottawa.ca/map/index
Manitoba Highways	Manitoba Infrastructure and Transportation	http://www.gov.mb.ca/mit/roadinfo/

APPENDIX D – DATA ACQUISITION

1. Land PoE Data Acquisition

The extracted Excel sheets include all the data that were available on the CBSA website (Directory of CBSA Offices, 2014).

These data were extracted and entered into Excel sheets in order for the data to be used in various databases for analysis. It is possible to label headers with underscores, for example use 'Point_of_Entry' instead of Point of Entry. This will allow for smoother integration into ArcGIS. For the Services Available portion of the CBSA website, all the possible services were added and in order to show the availability. These services are shown in Excel and given a simple designation of 1 for available and 0 for not available. It is necessary to convert the Excel file into format compatible with ArcGIS. To achieve this, we have written a Visual Basic script to make the conversion simpler and faster. To use the script for every Excel sheet the parameters of Excel sheet should be assigned before running. The following is the body of the code and brief explanation about the script.

2. Data processing script

Once the data is gathered it must be formatted in a particular way so that ArcGIS can use the data to geodatabases. To process data, Microsoft Excel is used since the row data is stored in Excel sheets and the Excel has developing and data processing ability.

First it is needed to add the Developer tab in MS Excel. This can done by using the customize ribbon feature and checking Developer.

In the developer tab, click on the VB tab and right-click in the project explorer. Select Insert userform and drag a user button into the window, and by clicking on the button there is another window open for the actual function of the button. Inside there needs to be a script to transform the arrangement of the data into something comprehensible by ArcGIS. The script is the following:

```
Private Sub CommandButton1_Click()
Dim i As Integer
Dim b As Integer
Dim l As String
Dim s As Integer
Dim n As Integer
Dim p As Integer
Dim c As Integer
n = 0
s = 163
i = 1
l = Range("R4").Select
For i = 0 To 4000
n = 0
For b = 0 To 14
n = n + 1
For p = 0 To 275
Range("A" & (s + p)).Value = ActiveCell.Offset(0, 1).Value
Range("B" & (s + p)).Value = Range("B" & (8 + p)).Value
Range(Chr(66 + n) & (s + p)).Value = ActiveCell.Offset(4 + p, b).Value
ActiveCell.Offset(4 + p, b).Clear
Next p
Next b
ActiveCell.Offset(0, 15).Select
'For c = 1 To 24
'Range(Chr(64) & (c + s)).Value = Range(Chr(65) & (15 + c)).Value
'Next c
s = s + p
Next i
End Sub
```

It should be noted that the numbers at the beginning of each line are only for line reference and should not be included the actual script. The script may need to be manipulated for different data types and to understand this, further description of the code and its functions are needed:

Line 5 - It may be necessary to change the 's as integer' to 's as Double' in order to accommodate larger values.

Line 10 – This value is variable and is the field value of the last row for the first PoE

Line 11- Is the iteration loop value and dictates the amount of times the script must loop

Line 12 – The Value R4 is variable and should be set to where the first PoE data ends and the values before the field stay in their location.

Line 15 – b is the number of columns for each PoE. Note this value starts at 0.

Line 17 – This is the range of the number of rows per PoE. All the PoEs should have the same time range and therefore the same number of rows. Note this range starts at 0

Line 24- This is the range of the columns for the data for each PoE, and in this case the first column starts at the Total Vehicles Entering – Length of Stay Total and the last column is Total Canadian Vehicles Returning - Two or more nights

The primary focus was on Highway/Land Border offices. In total there have been 117 offices gathered into the Land PoE Excel sheet, which include all the 117 offices from the HWY/B services link, which can be identified by their respective office numbers.

The border crossing shapefile for ArcGIS has been found from a public source online (Mapcruzin, 2014). This data has been used as it is fairly accurate, but it does have some issues. There are some border offices from the CBSA data that are not included in the shapefile and also there are some points that are not very accurate at smaller scales. There have also been points added for the missing data and the inaccurate points have been correctly identified.

3. PoE points

To obtain the corresponding latitude/longitude for each new point, we have to convert from the ArcGIS data frame value which is in Degrees Decimal Minutes to Degrees Decimal Hour. This is done by taking the value Decimal Minutes portion and dividing by 60 to obtain the Decimal Hours in 6 digit form and add it to the Degrees.

Take point 502 for example: The Latitude / Longitude in the current ArcGIS (Degrees Decimal Minutes) are -97 14.264 and 49 0.031 respectively, to convert these we take the Decimal Minutes, 14.264 and divide by 60 to get Decimal Hours of -97237.733. To insert into the format of the existing database, we need to multiply the returned number by 1000. This will yield a value of -97237733, which corresponds with the data format in the existing ArcGIS dataset.

4. Joining tables

In order to join the databases with the user created Excel database, we must ensure that the table schema in the Excel file has no symbols or spaces in the headers. An underscore will work and is recommended for labeling. It is also very critical that the two corresponding databases have identical and matching Field entries values as primary key. In this situation we used the values of the Office Number designated by the CBSA which is unique. To create a join we must first add the Excel sheet to ArcMap as a layer and then *right click* the shapefile with points you wish to connect, scroll to *Joins and Relates*, and select *Join*. We then chose the field in the layer, then the corresponding table and then the field in the user-created table to connect with. Joins create a 1:1 connection and anything that has duplicate IDs is ignored, except the first one. For example, if there are two PoEs with the same ID, then only the first one will connect with the shapefile layer. We can choose to use the Relate function which allows for a 1-to-Many connections and may be useful in some situations. Once the table and the layer are connected, we need to export the data in order to save the connection, as it will be lost upon the next time we open the .mxd file. This exportation should be done as a geodatabase file.

APPENDIX E – DATA PROCESSING

The data can be downloaded from CANSIM website as a .csv file, which will then be imported into Excel. To download the data and maintain consistency click on the download tab and select the following:

Step 1: Only select the individual ports without the Provinces

Step 2: Select all

Step 3: Select Length of Stay and also Same Day, One day and Two plus days

Step 4: Select all

Step 5: Select all

Step 6: Select Time as Rows

The time range used was Jan 1980 to Dec 2012.

Naming Fields

It is important at this stage to know our naming rules. First, it is important to know that we cannot have names with spaces or special characters in Excel, as it would prevent importation into ArcGIS. The method used for naming here is that the spaces are shown with an '_' (underscore), as this is accepted by ArcGIS. The names must also be short and comprehensible.

In the data acquired from CANSIM, we had to ensure that the field names were done properly and met the criteria shown above. Below is a list of all the fields' names which were changed as well as, their meaning:

-TOTALDATE: This field is shown as YYYYMMDD, the DD value is always written as 01.

-Total_VEHICLES_ENTERING: The total number of all vehicles entering through a Canadian Port of Entry, including all lengths of stay.

-Total_US_AUTOMOBILE_Entering_TOT: The total number of automobiles originating in the US, entering Canada, including all lengths of stay.

- Total_US_TRUCKS_Entering_TOT: The total number of trucks originating in the U.S., entering Canada, including all lengths of stay.

- Total_US_OTHERVEHICLES_Entering_TOT: The total number of vehicles, excluding automobiles and trucks originating in the U.S., entering Canada, including all lengths of stay.

- Total_US_AUTOMOBILE_Entering_SameDay: The total number of automobiles originating in the U.S., entering Canada, and returning to origin on the same day.

- Total_US_AUTOMOBILE_Entering_OneNight: The total number of automobiles originating in the U.S., entering Canada, and returning to origin after one night.

- Total_US_AUTOMOBILE_Returning_TwoorMoreNights: The total number of automobiles originating in the U.S., entering Canada, and returning to origin after two or more nights.

This same naming methodology is repeated for Canadian vehicles departing and returning back to Canada.

APPENDIX F – CAP ALERTS CATEGORY CODING

CAP-CP Specification Documents, 2013)

For more information please refer to:

http://www.cap-cp.ca/index.php/en/#CAP-CP Specifications

Tier 1 events	**Tier 2 Events (More specific)**	**Event Code**	**Category**
Administration		admin	Other
air quality		airQuality	Env, Health, Geo, Met, Transport
animal health		animalHealth	Health
	animal disease	animalDiseas	Health
	animal feed	animalFeed	Health
aviation		aviation	Transport
	notice to airmen	notam	Transport
	airspace closure	airspaceClos	Transport
	airport closure	airportClose	Transport
Aviation	aircraft crash	aircraftCras	Transport
Civil		civil	Security
	civil emergency	civilEmerg	Security
	public event	civilEvent	Security
	volunteer request	volunteer	Other
criminal activity		crime	Security
	dangerous person	dangerPerson	Security
	home crime	homeCrime	Security
	industrial crime	industCrime	Security
	retail crime	retailCrime	Security
	terrorism	terrorism	Security
	vehicle crime	vehicleCrime	Security
dangerous animal		animalDang	Security
fire		fire	Fire
	wildfire	wildFire	Fire
	industrial fire	industryFire	Fire
	urban fire	urbanFire	Fire
	forest fire	forestFire	Fire
flood		flood	Met
	storm surge	stormSurge	Met
	high water level	highWater	Met
	overland flow flood	overflood	Met
	flash flood	flashFlood	Geo, Safety
	dam overflow	damOverflow	Infra, Safety
Geophysical		geophysical	Geo
	avalanche	avalanche	Geo
	earthquake	earthquake	Geo
	landslide	landslide	Geo
	magnetic storm	magnetStorm	Geo
	tsunami	tsunami	Geo

Geophysical	meteorite	meteor	Geo
	lahar	lahar	Geo
	lava flow	lavaFlow	Geo
	pyroclastic flow	pyroclasFlow	Geo
	pyroclastic surge	pyroclaSurge	Geo
	volcano	volcano	Geo
	volcanic ash cloud	volcanicAsh	Geo, Transport
hazardous materials		hazmat	CBRNE
	chemical hazard	chemical	CBRNE
	biological hazard	biological	CBRNE
	radiological hazard	radiological	CBRNE
	explosive hazard	explosive	CBRNE
	falling object	fallObject	Safety
health		health	Health
	ambulance	ambulance	Health
	blood supply	bloodSupply	Health
	drinking water	drinkingWate	Health
	food and drug supply	foodSupply	Health
	hospital	hospital	Health
	infectious disease	infectious	Health
ice		ice	Met
	ice pressure	icePressure	Met
	rapid closing of coastal leads	rpdCloseLead	Met
	special ice	spclIce	Met
marine		marine	Met, Transport
	freezing spray	freezngSpray	Met
	gale wind	galeWind	Met
	hurricane force wind	hurricFrcWnd	Met
	iceberg	iceberg	Met, Transport
	marine security	marineSecure	Transport
	nautical incident	nautical	Transport
	special marine	spclMarine	Met
	squall	squall	Met
	storm force wind	stormFrcWnd	Met
	strong wind	strongWind	Met
	waterspout	waterspout	Met
missing person		missingPer	Rescue
	AMBER	amber	Rescue
	missing vulnerable person	missingVPer	Rescue
	silver	silver	Rescue
Other		other	Other
plant health		plant	Other
	plant infectious disease	plantInfect	Other
Preparedness reminders		reminder	Safety
product safety		product	Safety
public services		publicServic	Infra
	emergency support facilities	emergFacil	Infra, Safety
	emergency support services	emergSupport	Infra, Safety
public services	school bus	schoolBus	Infra
	school closure	schoolClose	Infra

	school lockdown	schoolLock	Infra
	service or facility	facility	Infra
	Transit	transit	Infra
railway		railway	Transport
	train accident	train	Transport
Rescue		rescue	Rescue
roadway		road	Transport
	bridge closure	bridgeClose	Transport
	roadway closure	roadClose	Transport
	roadway delay	roadDelay	Transport
	hazardous road conditions	rdCondition	Transport
	traffic report	traffic	Transport
	roadway usage condition	roadUsage	Transport
	motor vehicle accident	accident	Transport
Storm		storm	Met
	Blizzard	blizzard	Met
	blowing snow	blowingSnow	Met
	dust storm	dustStorm	Met
	freezing drizzle	freezeDrzl	Met
	freezing rain	freezeRain	Met
	Hurricane	hurricane	Met
	Rainfall	rainfall	Met
	Thunderstorm	thunderstorm	Met
	Snowfall	snowfall	Met
	snow squall	snowSquall	Met
	Tornado	tornado	Met
	tropical storm	tropStorm	Met
	winter storm	winterStorm	Met
	Weather	weather	Met
temperature		temperature	Met
	arctic outflow	arcticOut	Met
	cold wave	coldWave	Met
	flash freeze	flashFreeze	Met
	Frost	frost	Met
	heat wave	heatWave	Met, Health
	high heat and humidity	heatHumidity	Met, Health
	wind chill	windchill	Met
test message		testMessage	Other
utility		utility	Infra
	cable service	cable	Infra
	diesel supply	diesel	Infra
	electricity supply	electric	Infra
	gasoline supply	gasoline	Infra
	heating oil supply	heatingOil	Infra
	internet service	internet	Infra
	natural gas supply	naturalGas	Infra
Utility	satellite service	satellite	Infra
	sewer system	sewer	Infra
	telephone service	telephone	Infra
	911 service	911Service	Infra

	waste management	waste	Infra
	water supply	water	Infra
Wind		wind	Met

Appendix G – XML File that is Generated with the CAP Format in April 14th, 2013 related to Amber Alert

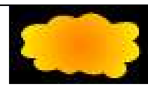
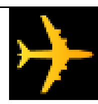
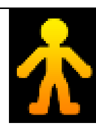
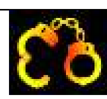
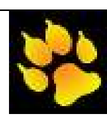
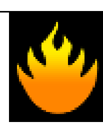
(NAAD, 2013)
For more information please refer to:
http://alerts.pelmorex.com/en

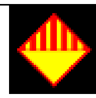
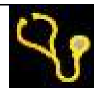
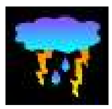
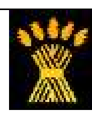
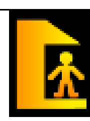
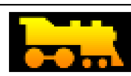

```xml
<alert xmlns="urn:oasis:names:tc:emergency:cap:1.2">
<identifier>559BED43-4D87-D8CE-D509-873C6F1CA0B0</identifier>
<sender>AmberAlertCoordinator@OntarioProvincialPolice</sender>
<sent>2013-04-14T17:32:05-04:00</sent>
<status>Actual</status>
<msgType>Alert</msgType>
<scope>Public</scope>
<code>profile:CAP-CP:0.4</code>
<info>
  <language>en-CA</language>
  <category>Other</category>
  <event>AMBER Alert</event>
  <urgency>Immediate</urgency>
  <severity>Extreme</severity>
  <certainty>Observed</certainty>
  <eventCode>
      <valueName>profile:CAP-CP:Event:0.4</valueName>
      <value>amber</value>
  </eventCode>
  <expires>2013-04-14T21:30:00-04:00</expires>
  <senderName>Ontario Provincial Police</senderName>
  <headline>Ontario AMBER Alert activation</headline>
  <description>
      THE Peterborough County OPP HAS REQUESTED AN “AMBER ALERT”
      FOR AN ABDUCTED CHILD IN Douro/Dummer Township. Victim’s
      name: Victoria LARABIE Date of Birth: 29 JAN 2000 Physical
      Description: Female, Piercing in eye, lips, ears, belly
      button Height- 5’ 8” Weight- 135lbs Hair color- Black
      Clothing: black tights, purple shoes, black sweater with
      pink/white/grey circles Believed to be in the company of:
      Unknown person or persons Details of Incident: On April 14th
      2013, 13 year old Victoria Larabie was reported missing to
      the Peterborough County OPP. Investigation reveals that at
      approximately 11:20 AM on April 14th 2013 Victoria was picked
      up by an unknown person driving a black SUV. Investigation
      thus far reveals that Victoria may be held against her will.
      The last known information provided to the police was that
      Larabie was in the Norwood area heading towards Highway 115
      possibly the Oshawa area.
  </description>
  <instruction>If you have information call 911</instruction>
  <parameter>
      <valueName>layer:SOREM:1.0:Broadcast_Immediately</valueName
      >
```

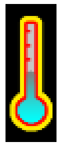
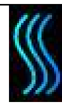
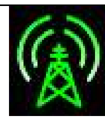
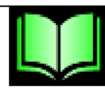
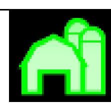
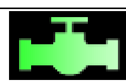
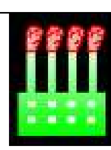
29	<value>Yes</value> </parameter> <resource> <resourceDesc>larabie.jpg</resourceDesc> <mimeType>image/jpeg</mimeType> <size>79455</size> <uri>larabie.jpg</uri>
30	<derefUri>...</derefUri> <digest>126707ca7e43c9dbcc91095ea7f88966e6b4e9b1</digest>
31	</resource> <area> <areaDesc>ontario</areaDesc> <polygon> 48.250074,-88.836514 48.304678,-88.367093 47.999999,-87.5 48.25,-87.5 48.25,-87 47.777681,-87 47.749999,-86.5 47.578248,-86.5 46.890006,-84.859604 46.460896,-84.556591 46.53051,-84.129578 ... 48.250074,-88.836514 </polygon>
32	<geocode>...</geocode>
33	</area> </info> <Signature xmlns="http://www.w3.org/2000/09/xmldsig#" Id="NAADS Signature">...</Signature> </alert>

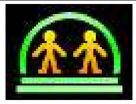
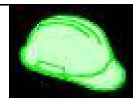
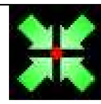
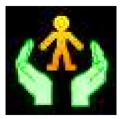
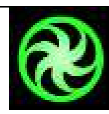
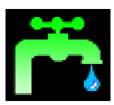
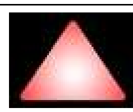
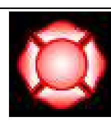
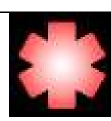
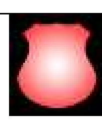
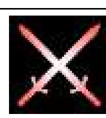
APPENDIX H – EMERGENCY MAPPING SYMBOLOGY, TIER 1, VERSION 1.0

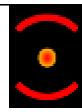
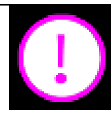
(Emergency Mapping Symbology, 2010)

Tier 1 (event or category)	Symbol	Definition
		Events/Incidents
Air Quality		An elevated particulate count in the atmosphere which adversely affects visibility or health.
Animal Health		An incident affecting the health of wild or domesticated animal populations.
Aviation		An incident involving aircraft resulting in damage, bodily injury, death, or the disruption of transportation service.
Civil		Human activities resulting in the disrupting of services or requiring varying levels of support, law enforcement or attention.
Crime		An unlawful pursuit or action in which an individual participates.
Dangerous Animal		A dangerous or threatening animal, wild or domesticated.
Fire		The destructive act of something burning; caused either by electrical or technological malfunction, lightning, arson, human error or human negligence.
Flood		A relatively high stream flow that overtops the stream banks in any part of its course, covering land that is not normally under water or when water overflows the natural or artificial confines of a stream or other body of water, or accumulates by drainage over low-lying areas.
Geophysical		An event or incident resulting from a geophysical process.

Hazardous Material		An incident involving a hazardous material (chemical, biological, radiological, explosive, poisonous gas or other.
Health		An incident affecting human health.
Ice		An event involving surficial or marine ice.
Marine		An incident involving a boat, ship or navigable waterway.
Meteorological		Any disturbed state of an astronomical body's atmosphere, especially affecting its surface, and strongly implying severe weather. It may be marked by strong wind, thunder and lightning (a thunderstorm), heavy precipitation, such as ice (ice storm), or wind transporting some substance through the atmosphere (as in a dust storm, snowstorm, hailstorm, etc).
Missing Person		A missing or un-located person.
Plant Health		An incident affecting wild or cultivated vegetation.
Public Service		An incident or event involving public services or facilities.
Railway		An incident involving train resulting in damage, bodily injury, death, or the disruption of transportation service.
Rescue		An incident that requires an organized rescue effort.
Roadway		An event involving a wheeled or tracked vehicle resulting in damage, bodily injury, death, or the disruption of transportation service.

Temperature		An event related to extremes in temperature.
Wind		An event related to dangerous and damaging winds.
	Infrastructures	
Communications & IT Infrastructure		The electronic systems used in transmitting messages, as by telegraph, cable, telephone, radio, television or computer.
Education Infrastructure		A building or collection of buildings or places that provides knowledge.
Energy Infrastructure		Includes infrastructure to support electrical power, natural gas, oil production and utility transmission systems.
Finance Infrastructure		The management of money and other assets and their protection.
Food Infrastructure		Production and retail services of foodstuffs.
General Utility		An infrastructure component owned or operated by a public or private utility. Specific water, electric, and gas utilities, and similar organizations.
Government Infrastructure		The location where executive, legislative and-or judicial activities take place in the service of the government.
Manufacturing Infrastructure		An industrial site used for the commercial production and selling of manufactured goods.
Military Infrastructure		Property directly owned and operated by and/or for the military that shelters military equipment and personnel, and facilitates training and operations.

Public Site		Unrestricted buildings or sites open to the public.
Safety Infrastructure		A facility or structure used to provide safety to workers or the general public.
Significant Site		A site or location of significant cultural, historical or environmental importance.
Special Care Infrastructure		A facility used for people who have specific needs, such as those associated with children, the elderly or those with disabilities. Examples include (but are not limited to) child day care facilities, geriatric long term care facilities, and group homes for people with disabilities.
Transportation Infrastructure		Infrastructure, means of transport, and equipment necessary for the movement of passengers and-or goods.
Water Infrastructure		The storage, disinfection, filtration and provision of drinking water to the consumer/community by means of pipelines, pumps, water towers, wells and other appurtenances.
	Operations	
Emergency Operation		Those actions taken during the emergency period to protect life and property, care for the people affected, and temporarily restore essential community services.
Emergency Fire Operation		Primarily to put out hazardous fires that threaten civilian populations and property, to rescue people from car accidents, collapsed and burning buildings and other such situations.
Emergency Medical Operation		Urgent and unexpected medicinal treatment and/or transport during serious situations which require demands of immediate action.
Law Enforcement Operation		A coordinated operation of insuring obedience to the laws.
Military Operation		Coordinated military actions of a state in response to a developing situation. These actions are designed as a military plan to resolve the situation in the state's favor. Operations may be of combat or non-combat

		types, and are referred to by a code name for the purpose of security.
Sensor Operation		A device that receives and responds to a signal or stimulus.
Other		
Other		An incident, infrastructure or operation that does not belong to any of the currently specified EMS classes.

APPENDIX I – HARDWARE AND SOFTWARE REQUIREMENTS TABLE

	Hardware	Software
Server side	• Processor: Intel Xeon CPU E5540 @ 2.53 GHz • RAM: 48 GB	• Operating System: Windows Server 2008 / Service Pack 2/ 64-bit • Microsoft Office: 2012 • Web Browser: Google Chrome 23+/ Firefox 14+/IE 9+ • ArcGIS Server 10.1
Client side	• Processor: Intel Core(TM) i7-2600 @ 3.40 GHz • RAM: 4 GB • Additional Screen: HP LD4200 wide LCD Monitor	• Operating System: Windows 7 / Service Pack 1/ 64-bit • Microsoft Office: 2012 • Visual studio: 2010 • Web Browser: Google Chrome 23+/ Firefox 14+/IE 9+ • ArcMap 10.1

APPENDIX J – ARCGIS API PREREQUISITES INSTALLATION LINKS

The following table contains the links for ArcGIS 3.0 API for Silverlight and ArcGIS Viewer for Silverlight 3.0 API installation guides, requirements and files. For ArcGIS API 10.1 the requirements are: (1) Visual studio 2010 (VS2010); (2) VS2010 service pack 1 (SP1) for VS2010 should be installed; (3) ArcGIS API for Microsoft Silverlight 3.0; (4) Microsoft Expression Blend Preview for Silverlight 5; (5) Microsoft Silverlight 5 Tools for Visual Studio 2010 SP1; (6) Microsoft Silverlight Toolkit must installed. The requirements are prerequisites for ArcGIS 3.0 API for Silverlight. For ArcGIS Viewer for Silverlight 3.0, API two more installations are needed: (7) ArcGIS Viewer for Silverlight 3.0 x64 and (8) ArcGIS Extensibility SDK for ArcGIS Viewer for Silverlight 3.0.

1	Microsoft Visual Studio 2010 or Microsoft Visual Web Developer 2010 Express	http://www.microsoft.com/visualstudio/eng/downloads#d-2010-express
2	Visual Studio 2010 SP1	http://www.microsoft.com/en-us/download/details.aspx?id=23691
3	ArcGIS API for Microsoft Silverlight	http://resources.arcgis.com/en/communities/silverlight-api/
4	Microsoft Expression Blend Preview for Silverlight 5	http://www.microsoft.com/en-us/download/details.aspx?id=9503
5	Microsoft Silverlight 5 Tools for Visual Studio 2010 SP1	http://www.microsoft.com/en-us/download/details.aspx?id=28358
6	Microsoft Silverlight Toolkit	http://silverlight.codeplex.com/releases/view/78435
7	ArcGIS Viewer for Silverlight 3.0 x64	http://www.esri.com/apps/products/download/index.cfm?fuseaction=download.main&downloadid=878
8	ArcGIS Extensibility SDK for ArcGIS Viewer for Silverlight 3.0	http://www.esri.com/apps/products/download/index.cfm?fuseaction=download.main&downloadid=879

APPENDIX K – SILVERLIGHT BASED SYSTEM BRIEF USER GUIDE

The following appendix is a brief user guide for users to use Silverlight Viewer. Developed tools and user interfaces regarding the proposed methodology are explained in Chapter 4. The website of the developed application can accessed at:

URL: http://infosys.ciise.concordia.ca/apps/cbsa%20viewer

User ID: CBSA

Password: **********

In the map viewer you will be able to see many different features and functions which essentially visualize data that have been processed and optimized for certain specific applications and functions. The viewer runs on a framework called Silverlight which is typically supplied with the web browser or may require an additional download through the web browser. It should be noted that the web-based viewer has only been tested on Windows operating systems and may not work properly on Apple products or operating systems.

VIEWER FUNCTIONS

- Zoom

  This tool located on the top left section of the Viewer will enable the user to zoom in and out of the map extent. The button located at the top is to reset North orientation and the globe icon at the bottom allows the users to view the full extent of the source map, which in our case is the entire world view.

- Function Bar

  In the top right section of the CBSA Viewer, you will see several icons which provide different functions within the Viewer. More details about developing functions are explained in Section 4.4 and expanded user guide is provided by research team as an internal report.

- Map Contents

  Map Contents allow the user to see the various data layers that are accessible via the local viewer server and its embedded layers, or via ArcGIS data servers. These can include project specific data or user added data sets/layers from ArcGIS.com. The Map Contents window allows users to toggle layers On/Off by checking/unchecking the checkboxes for each layer. There can be multiple data layers active.

- Choose Basemap

  This function will allow you to choose from several different basemaps to view/overlay your data upon. There will be a default map set by the development team for effectively presenting the data and functions required for the project.