A FRAMEWORK FOR GOAL-BASED TRANSPORTATION ROUTING USING SOCIAL NETWORKING

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ABSTRACT:

To date, common road navigation systems have provided drivers with routing based on shortest distance, fastest time, waypoint analysis, and basic parameter searches. These routes are common to all drivers, and are neither easily customized nor updated in real-time. This project proposes that navigation should consider real-time data regarding weather, traffic, and specific driver patterns in a novel method using profiles of the vehicle, driver, and passengers. Profiles incorporate financial risk metrics, individual goals, and driving preferences. Considerations are given to optimize navigation toward travel cost (fuel, time), route uniqueness, and reduced risk of adverse events while in transit. Proposed navigation paths incorporate spatial and temporal patterns, and situation awareness of activity along projected paths may optimize the nodes to consider in the decision tree and road-network topology. Using Social Networking, data aggregation and computation efficiency can be achieved while also benefiting from identification of drivers with similar driving profiles, waypoints, and goals. The framework described in this research is for short and long term data collection, decision criteria, and calculation methods for driver-unique route proposals. Seven prospective data types (strata) are identified in the framework for all tags, attributes, and computations to be tracked socially, spatially, and/or temporally. Data not tracked in real-time is considered Non-Volatile, and may be updated periodically by service providers. Non-Volatile Data includes legal driving parameters, vehicle configuration, landmarks, topography, infrastructure locations, and population density. Volatile Data may include vehicle position, fuel pricing, weather, driver observations, traffic congestion, warnings and threats, and road conditions. Privacy and security are left to implementation. Significant emphasis is placed on existing models for risk and control objectives.

1.0 Introduction

In this paper, a model for the development and exploitation of geo-social data is explored. The purpose is to propose a data framework relying on generally-available transportation technology resources. The primary function of the framework is to collect, store, and analyze data relative to the needs of the social network base and the profiles of the individual network members. This framework identifies data that can be collected, constraints surrounding that data, details the actors, and defines the decisions that can be made or influenced by the information collected or inferred. Largely, this is a situation awareness system intended for use in the transportation knowledge sphere.
Drivers using social networks, mobile data and phone devices, vehicle sensors, and navigation technology are the target users. Analysis of data is to address driver-specific goals with the intent of improving the driving experience. All goals selected are intended to be computationally derived, i.e. one driver may wish to travel routes that are faster (compute the average time of commute), while another driver's goal may be to reduce the cost of driving. By maintaining a profile for these goals, users (drivers) can identify data that is more relevant toward their driving habits or needs. This includes searching for patterns that will reduce exposure to threats and risks; inputing data regarding the economics for fuel and repair costs; identifying landmarks, road-types, and road conditions; and noting information about the passengers at the time of a routing request.
By introducing this framework with derived mathematical associations, data types can be explored, data-lifetimes are defined, and the collection and storage of information allows algorithm designers to identify datasets necessary to answer user questions. A system based on this framework should be relatively reliable for predictive and suggestive answers to common questions, while giving drivers the ability to override, redefine the parameters, and seek new input from members within their social network. As with any social network, there is an inherent risk that information will be used for the harming of others, for the destruction of property, or to cause unlawful disruption to the public order. Any implementation team must consider the potential negative impacts of their technology and adequately address any legal, regulatory, and safety concerns.

2.0 Background

Social networking services, the internet-based services that allow users to identify common interests, friendships, employers, and skills among the user base, have grown considerably in the last five years. The largest players now support between four hundred and six hundred million people. A growing interest for services to offer is the incorporation of "location-based" information. Because users can "check-in" or notify their network of where they are and what they are doing at a location through mobile devices, individuals can determine if they wish to go to that location, avoid that location, or make no change to their status. Marketing services also can cater more specific advertisements because of interest level, location in a geographic area, and relevance to the user based on his or her profile. (Lardinois, 2010)
While users within the social network are a reliable source of geo-social data (Banks, 2010), in-vehicle devices, home

appliances, and even power grids are gaining location-based services that enable suggestions to users and self-regulation of their activity. The data and suggestions produced have the potential for community sharing. For example, vehicles can monitor weather and adjust lighting and wipers. Vehicle manufacturers now provide both in-vehicle sensors and networks to monitor driving activity and vehicle-perimeter activity. As situations arise, the system can respond by alerting or overriding the driver. An extended opportunity is to distribute data or knowledge regarding on-road events (safety calls), weather conditions, and emergency responder call-outs. (Crane, 2007) Deployment of smart technology within the power grid is allowing homeowners and businesses the insight to regulate their electricity use for economic purposes and to meet environmental goals. Termed smart grids, power systems provide data back to users regarding electricity use by location with granularity at the appliance level over time.

These existing systems often address a specific need or goal, with limited flexibility in the use of the technology, and data aggregation is only made useful for a limited amount of time. (Altan, 2006) For instance, many of the car sensors are in-place for driver and/or passenger safety based on what's happening right now. Navigation networks are generally reliable for point-by-point instruction, but rerouting can be difficult or error-prone. If too many errors arise, the usefulness is diminished and the user may have no other option but to disable or remove the technology, particularly if the technology cannot be upgraded or generally improved at the time of need.

The framework project was undertaken as a way to address risk-based questions using data that could be made available from the combination of a geographic information system and a social network. Risk is an economic measure for a particular event that poses a threat to the specific outcome or goal identified; it is determined by the multiplication of the cost of the event occurring by the likelihood of that event occurring. (Altan, 2006) The occurrence rate is measured in a particular time scale. When risk is compared across multiple events it is best for the same timescale to be used.

Economic factors are an essential component to a framework. Without recognizing the role of the market as an influencer, the framework is incomplete. For an information systems model, an example is the longstanding COBIT (formerly Control Objectives for Information Technology), the framework sponsored by the Information System Audit Control Association (ISACA). Within its four main components are considerations for acquisition and implementation costs, risks, and costs of opportunity. Consideration will be given for similar economic components that can be used for feedback loops, influence, and measurement in calculations. (Altman, 2009)

This project will consider the advantages of data gathering and data-push technology from social networks, coding the data as part of a time-relative geographic information system, with the ability to perform calculations and data aggregation to answer user-specific questions in the form of navigable routes.

3.0 METHODS

3.1 Proposed Framework

The framework for goal based routing includes a data map with identified datasets, expected sensor networks with their associated transmissions, and retention guidelines. Its purpose is to support drivers with navigable routes addressing the set of identified goals (decisions) and actors. Adjoining layers of functionality can be presented based on data availability, data and network connection integrity, user settings, and relevance of information available.

Goals

The relationships presented in this project, constituting the framework, are developed in response to a series of questions that became known as the goals (referenced later as the Goals Dataset). Ten commonplace questions that drivers potentially could ask a system for a reliable answer as they are driving were identified. For mathematical relationships, it was determined that the questions all must relate to routing data. "Who" and "what" would reference social and infrastructure data, and "why" would relate to risk metrics and calculations (this factor is inferred in all risk-centric questions). "How" is generally the answer to the question in the form of a routing suggestion. In the case of question 10, how relates to the use of econometrics for optimization - fuel efficiencies, reduced carbon footprints, least work required; least idling time. In this case, a route may be supplied with additional instruction, such as optimal speed, gearing, or distribution of way-points.

The information necessary to support answers to those goals were collected (see Appendix C), forming the datasets given in the following section. The initial questions, along with their identified interdependencies, are given in Table 1.

Question	Relationship to other Questions
1. How do I get from point A to B?	Bounded topology routing sequence
2. What places should I avoid?	Only places within tolerance area given on route as answer to Question 1; OR all areas within identified region of interest.
3. What places should I be near?	XOR of potential answers from Question 2
4. Who should I avoid?	subset by filtered region of interest of #2
5. Who should I be near?	Social network dependent; may redefine point B, or create an additional point C to consider.
6. What is dangerous to me?	Union of answers to question set {2,4,7,8} as well as triggers from profile data
7. What is dangerous to my vehicle?	Union of answers to question set {2,4}
8. What is dangerous to my passengers?	Union of answers to question set {2,4,7,8} as well as triggers from profile data
9. What can I explore or discover along my route?	Current route or any route suggested to Questions 1-8.
10. How can I benefit my community?	Potential consideration of answers to all other questions and additional socioeconomic factors

Table 1: Questions constituting driver goals, to be answered with routes using the data framework.

Datasets

The data fields involved can be broken down into supporting data (inputs, largely from external sources), observation data, calculation data necessary for routing algorithms, routes suggested, and drivers' solution-selection. Data fields can be rolled into data sets, each of which can be grouped or classified in different ways including: timeliness, sources, security and storage (see Appendices A-C). Because the data is intended to support a decision-making and decision-influencing system, relevancy of the data is strongly correlated to its timeliness; stale data cannot support the full functionality intended by the system. Table 2 shows the data sets with their primary sources. Outside sources are data aggregators or data providers such as governmental agencies, mapping services, and surveyors. Developer Input as a source means that the data is preselected or provided by product developers. User Input is data generated by or manually input by the user. This can include profile data for individuals within the social network, vehicle data, preferences, interests, and condition observations. Calculations is basic quantifiable information based on gathered data, such as traffic counts and intersection use, while Major Calculations denotes data derived through pattern matching algorithms, efficiency models, and/or derived solutions based on other influences desired by the driver.

Data Sets	Sources
Non Volatile Spatial Data	Outside Sources; User Input; Developer Input
Object Data	Outside Sources; User Input; Developer Input
Non Volatile Spatial-Temporal Data	Developer; User Input; Outside Sources; Calculations and Aggregations
Volatile Spatial-Temporal Data	Reported Observations; Calculations and Aggregations; User Input
Volatile Social-Spatial-Temporal Data	Reported Observations; User Input
Influencer Data/ Economic Data	User Input; Calculation based data
Goals	User Input; Reported Observations; Major Calculations
Routes	User Input; Major Calculations; Artificial Intelligence

Table 2: Data Sets and Sources handled within the Framework.

Actors

There are three primary actor groups within the situations monitored and advised through the framework: drivers (primary), passengers (secondary), and advertisers. Drivers play the obvious role of directing the vehicles, selecting the routes taken, and determining the level of compliance to rules, regulations, and laws. Directly and indirectly, drivers also provide data regarding road-use, road conditions, posting observations, and maintaining their social network. Passengers may do or influence most of the tasks that a driver is involved in. Conditions and attributes of some passengers may produce additional flags for vulnerabilities, such as environmental threats (air conditions relative to weather and pollution) and routing needs (appointments, separate invitations from friends).
The third group, advertisers, is an influence group. Their ability to market events, places, and waypoint reminders provide an outside influence on roadway use and routing needs. Thru advanced computation, it may be possible to market alternate locations where parking availability is improved or identifying an optimal time to do shopping based on checkout times. Product marketers could use outside data regarding store inventories to identify shopping locations where users have a higher likelihood to find specific products.
External actors include data providers, who have the ability to refine, correct, and update data; non-driving observers (i.e. automated data collection platforms such as mass transit use monitoring systems); and system implementation professionals (hardware and software engineers) who create algorithms and data collection devices. The implementation group drives the level of interaction a user may have with the data and their social network, which will ultimately drive the acceptance of the framework and the technology.

Data Volatility

Table 2 notes that four datasets specifically relate to the reliance of data within the temporal dimension. While basic routing features only require periodic updates to capture such information as road infrastructure changes and construction, the addition of periodic updates and observations allows for the determination of specific, reliable routing. To increase accuracy and relevance, more data must be captured. Within this framework, that leads to "data volatility", or the opportunity to capture information that falls outside the norm and to consider it for routing. Figure 1 shows Volatility as a function of Routing Requirement Complexity and Dependence on Network, where dependency is based on the need for centralized storage of data or centralized mathematic processing. The volume of data required, and the computational power required exceed what is expected (at present) to function within a single vehicle. It is also possible that a hive-style group calculation mode could be enabled for fleets traveling similar routes.

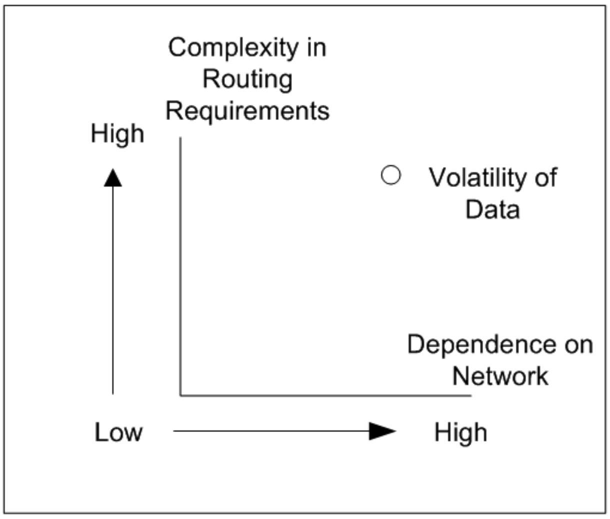

Figure 1: Complexity in routing requirements and greater dependence on the network to collect and disseminate data leads to higher data volatility; conversely, using more observations can lead to a greater number of potential routes to consider.

Transmission

It is not the intention of this design to have all data held at the device level, nor all data held at a server. While periodic updates can be maintained for most processes, it is necessary for near real-time two-way data transmission to be present to support proposed advanced functionality. Figure 2 notes the basic relationship between the rate of change in data points and the frequency with which those changes should be transmitted.

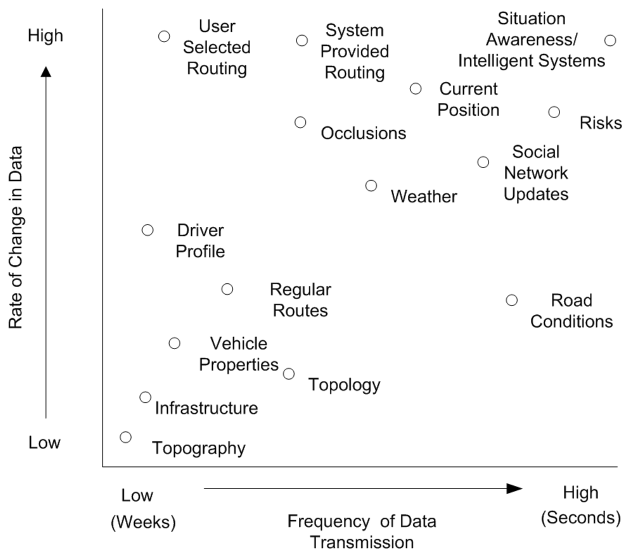

Figure 2: A sampling of data potentially useful to routing, shown relative to the likely rate of change and the frequency with which it should be distributed to users on the network.

By quadrant, data points noted having low change rate and low frequency (considered non-volatile and basis data), should also have low impact from a risk perspective. Data with a high rate of change and low frequency data transmission requirements are often collected or input by the user. This data's relevance is greatest to the direct user, often limited to circumstances similar to that in which it has been recorded or prepared. Examples include user-developed routes (one-time use routes), occlusions to the driver's view, and system prepared routing - which should only be transmitted to the user(s) for which it was prepared. Regarding occlusions, these are probabilistic blockages calculated by the geometry between the observer (commonly the driver), the objects of interest, and the topography of the region of interest. The calculation requires some estimation of placement of all objects in time and space. Some objects and landforms may be pre-calculated, allowing for the loading of some objects and reducing the amount of data to transmit. (Altman, 2009) In the third quadrant, where data must be transmitted frequently but has limited change, the information relevance is related similarly to broadcast emergency messages. An emergency or event occurrence of an unlikely scenario would commonly fit the description of data in this category: an unplanned event occurs which gives rise to a disruption that may influence drivers to change destinations given adequate notice. Examples include changes in the actual condition of the road (i.e. washout) and alerts to drivers regarding traffic disruptions. This quadrant is closely aligned with monitor and report functionality. The last quadrant handles option presentation, decision tracking, and outcome management. In the most rigorous mode of data changes and responses (transmissions), an artificially intelligent transportation management system could be deployed. In all cases, situation management with event escalation is handled. The simplest situation is route generation: how to get from point A to point B. Additional inputs may produce alternate route options; driver decisions must then be recorded to produce routes with greater relevancy.

Retention and Security

From the framework perspective, it is the responsibility of the implementation team to consider security and retention requirements for the data hosted and transmitted. Best practices may include anonymizing data collection; allowing users to setup their profile for the data collected, retained, and transmitted; and the ability to set retention limits on observations. Additionally, the concerns discussed in Table 3 should be considered within any implementation.

Data	Security Concern	Retention Harm
Profile	A joint profile could result in the collection of information not relevant to either driver; the hijacking of an account could lead to data that influences other drivers unnecessarily	Historical data on drivers could become a target for enforcement officers, insurance agents, and corporations wishing to monitor employees
Observations	User observations can be dishonest	Retaining bad data could result in impaired functionality
Decisions	Tracking of driver decisions could be used against drivers in court; the presentation of bad decision options could lead to the driver injury or death	Drivers have the right to change decisions, to not be continuously influenced by past decisions
Risks	Risks are presented, but ignored; likelihood indicators are not correctly calculated; impacts are not accurately measured	Risks are always changing; information provided to the driver may not match information collected across the entire system at the time the risk was presented
Routes	Any route can be used for malicious intent	Availability of route data could lead to the security compromise of infrastructure, the disruption of goods, and increase the threat likelihood

Table 3: Security and retention considerations

3.2 Development

System development and deployment may consider a variety of inputs coming from many different actors. Data should not be collected if it cannot be used to support decisions, either through an inherent ability to answer user questions, or to support computations through mathematical relationships. The complexity of routing that a system can handle (or offer) will be dependent on the data collected, its accuracy, and its applicability to an audience.

Mathematical Relationships

Complex relationships can be derived from data collected. A proposed comprehensive classified data relationship diagram can be found in the appendix. It denotes input items, relationships, sources, and calculations. Unique within this proposal is the collection of data relevant to calculations for expected energy required, intersection use, collective risk to drivers and passengers, and support for goals that are dependent on location-referenced data where relevancy and output is based on user profile. Computations may result in different route answers for similar vehicles, destinations, and routes due to pattern differences between drivers, passengers, and relationships to other drivers and infrastructure.

Data Accuracy, Reliability

As with any data system, monitoring is necessary to determine if data with incorrect attributes, decreasing accuracy, or random errors is being introduced. The two likely sources of errors across the entire data domain are incorrect timestamps and incorrect location stamps. Service providers must take into consideration the need to check for clock drift, alternate methods to gather location information, and quality assurance practices.

Econometrics

Econometrics refers to system input parameters and measurements that are applied at the individual level when computing routes. Specifically this is data meant to be used for loss prevention (efficiencies), risk reduction (minimizing cost or likelihood of event impact), or gain increase (improving sales of an advertiser by catering to network users who are likely to have the greatest interest in the service or products offered).

3.3 Considerations for Data Dimensionality

Data dimensionality is the basis for the complexity that a device can handle, where complexity relates to the amount of input to be used (see also Figure 3 below). Five dimensions are available for computation and fusion purposes when presenting to users. Two additional dimensions are proposed for automation and error correction. (Martenson, 2009)

Dimensional cases:
1D: A single user is routed on a single path at any time.
2D: A single user is given routing path choices without consideration of conditional changes by time OR a single object is routed conditionally by changes in time.
3D: A single user is given path selection with consideration of time-dependent variables
4D: Relationship dependencies are considered, as are paths across time, space, and object-actor interactions
5D: Economic considerations are given to
6D: Simulations are run parallel to actual driving experiences, giving the capability to identify unexpected observations, unlikely data, and other error correction features
7D: Simulations are run parallel to automated driving and driver-assist systems. Automated feature extraction provides real-time data collection independent of observers, and the system works in a continuous feedback loop.

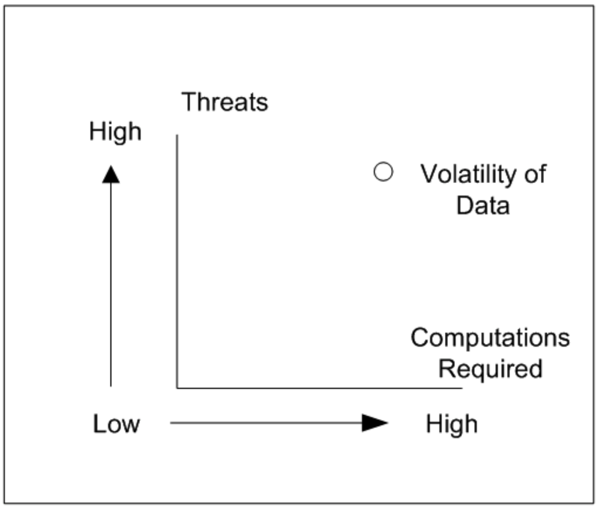

Figure 3: Computations required to address increased threats must also increase, as will the amount of data input.

3.4 Situation Assessment, Awareness

Situation awareness supports autonomous actors through collective intelligence. The intent of situation awareness is to provide information with relevant information to make good decisions. To achieve collective intelligence, collective goals must be decided upon first. An aware system operates within a dynamic environment and is dependent on real-time data. Figure 4 denotes the four critical groups of input for the production of intelligent routing. (

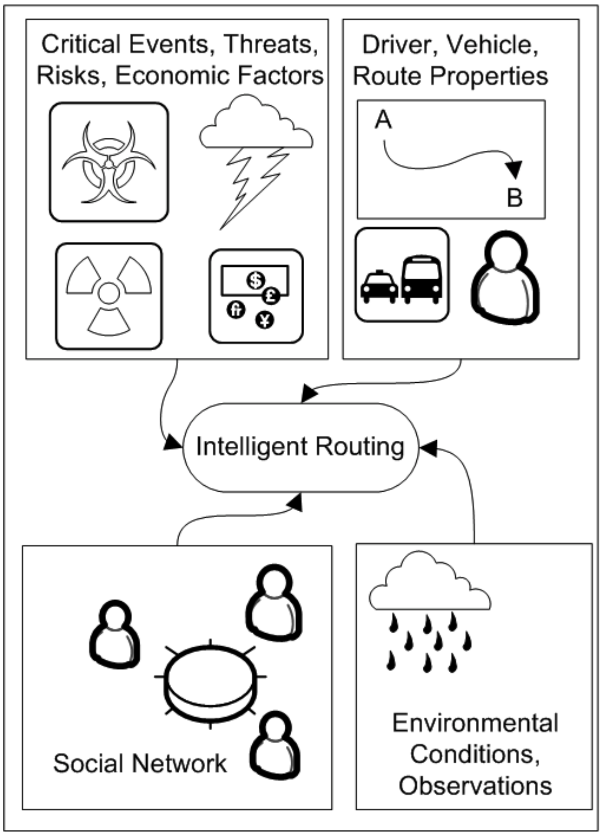

Figure 4: Inputs for an aware system

As an intelligent system, the opportunity exists for manufacturers and system providers to develop monitoring of threats, drivers, and vehicles, and take control of the vehicle. Automated post-event response is already enabled in many vehicles, and newer vehicles are beginning to deploy braking systems based on sensor input regarding lane positioning and proximity sensors. The next generation of these systems will move from driver-vehicle system response to tactical, objective-driven routing and response (override) using driver-driver, driver-car, car-car, and infrastructure-car-driver relationships.

3.5 Decisions

There are two basic levels of decision making to be considered within the goal-based framework: those made by the system as a form of preselection of routing options which produces a knowledge-set, while the other is the actual pathway chosen by the driver based on observed spatial and temporal positioning. A driver may have far more historical and current information for the collective reasoning for following a pathway suggested, or determining a wholly unconsidered route and using it, than any rules-based system will have. Five particular types of determination for transmission of information are available to be used in influencing driver decisions. The determination can be given as predictive, suggestive, warning, alerts, and persuasive. Note that each one of these has an emotive response associated with it. While the system may not have the ability to produce emotive responses, typical driver responses can be tracked, and reflex responses can be monitored. Projected outcomes can be measured and simulated. There is no guarantee that any driver or vehicle will be able to respond with exactness to the suggested routing given by the system due to uncertainties and untracked changes.

Predictive routes are given based on a ruleset that requires historical data, averages, and projections to meet the questions given in Table 1 that relate to speed, time, and efficiency.

Suggestive routes may use social and economic data to influence a driver to an alternate path. These routes may add new waypoints, consider alternate locations, and identify potential new passengers. Routes within this category can also be proposed by other members of the social network.

Warnings are positive identifications of threshold violations within a spatial or temporal region of interest for which a driver should consider immediate action. This is commonly related to the danger questions referenced in Table 1. Warnings must give immediate action steps. Depending on the time nature of a warning, there may be limited changes possible in the routing.

Alerts are notifications that may require additional attention from the driver. Alerts can be positive, such as a notification of a route change that can give a smoother ride or better weather.

Persuasive routes operate at a command and control level, where the outcomes to be delivered are tactical in nature. These routes give substantiation for their presentation, show the benefit(s) to the driver and/or the passengers, and are calculated strongly against risks and the odds of an adverse event occurrence. These routes also relate to simultaneous simulation of the operational space wherein the outcomes of selected propositions are used for mutually assured benefit.

3.6 Decision Outcomes

After the presentation of routes, a route may be selected (chosen and tracked), or the driver may proceed without making a selection. The tracking of the vehicle will be matched against the route options in the latter case. If no match is found, a new series of options must be calculated, the route must be stored, and the final destination matched against the original destination provided. By tracking the driver's route selections, data will be collected to determine driving patterns, common influencers, common routes used, and a risk and threat profile. Knowledge of driver decision and driving patterns can be used to alter routing suggestions, disregard certain risk categories, and train the system for producing relevant results for similar drivers.

3.7 Expectations

Certain expectations are necessary for any system deployed on this framework to produce the intended results. First, social network relationships are accurately depicted, in that friends are not individuals to avoid because they do not pose a danger. Second, there is no assumption that all data is accurately reported, nor that the observations are comprehensive to always give a predictive outcome with high certainty. Third, suggestions can sometimes be classified as educated guesses. Sparse data, loss of network connectivity, or even an abundance of information can result in untested hypotheses as routes for drivers to consider. Fourth, impact costs associated with risks can be quantified, and other economic costs can be given in at least qualitative (low, medium, high) degrees of measurement. and the last expectation is that users agree not to use it for malicious intent but that interceptive monitoring must be performed to identify disruptors who do perform malicious actions using the system.

4.0 DISCUSSION, USEFULNESS

It is the intent of the author to propose a framework that can be adopted by the many different location-based service providers that are experimenting with social networking technology. The usefulness of the framework will be found as development continues, allowing for greater contributions, sharing of data, and integration between multiple manufacturers. Without an integration framework, dependencies become confused for computations, data definitions are not consistent, and inadequate numbers of observations are collected to provide a user experience that can address the large number of locations across the worldwide road network.

With competition in service providers ranging from social networking entities to car manufacturers, along with the long-standing rivalry between mobile device manufacturers, the adoption of a framework may be mutually beneficial. The market can handle multiple service providers. The range of collection devices on-market already allow for different degrees of data accuracy, handling of more complex situations, and different forms of transmission. Security, retention, and long-term effects on decision making are the three areas that will require additional study.

5.0 CONCLUSIONS

There are abundant opportunities for social networks to provide new sources of data that can benefit massive groups. The ability to deploy devices, collect, and immediately use the data is only now being explored. Contextual references built into datasets allow for search, distribution, computation, and responses. By deploying a framework for common observation collection, processing, and measurement, systems will be more robust and data will have greater value. Users are likely to embrace this technology if it is portable and nonrestrictive between vehicles; collaboration between multiple vendors can improve the acceptance of geosocial networking by providing a seamless interface and experience. In the case of this framework, goals can be added, later versions can consider a communicative layer for goal-setting, and quality assurance can address changes to and additional mathematical algorithms or alternative data relationships. Areas that remain unaddressed here are the use and opportunity for mass transit, differing types of automated transportation, and multimode transport.

Integration with light-rail, subways, buses, and even air transportation could allow for local government sponsoring of this form of infrastructure to relieve congestion, increase ridership, and improve environmental conditions. Work in these areas has already begun, and has been extended to the functional use of parking space availability. (Banks, 2010; Lardinois, 2010)

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7.0 ACKNOWLEDGEMENTS

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8.0 APPENDIX

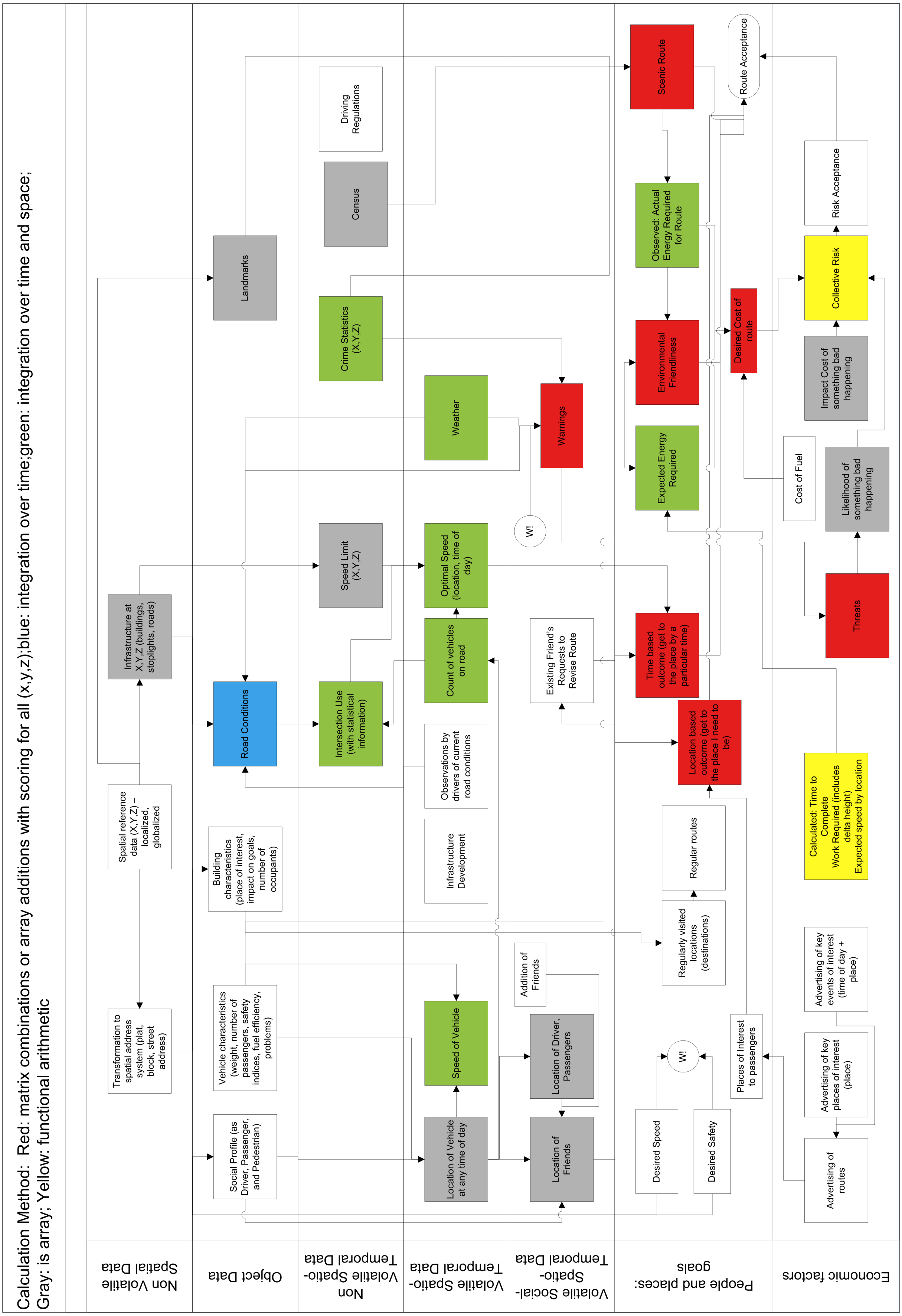
The following are basic descriptors of the documents that follow. Each document is a flowchart of data-interrelatedness, color coded by the features of interest.

Appendix A: Mathematical relationships and dependencies within a proposed dataset.

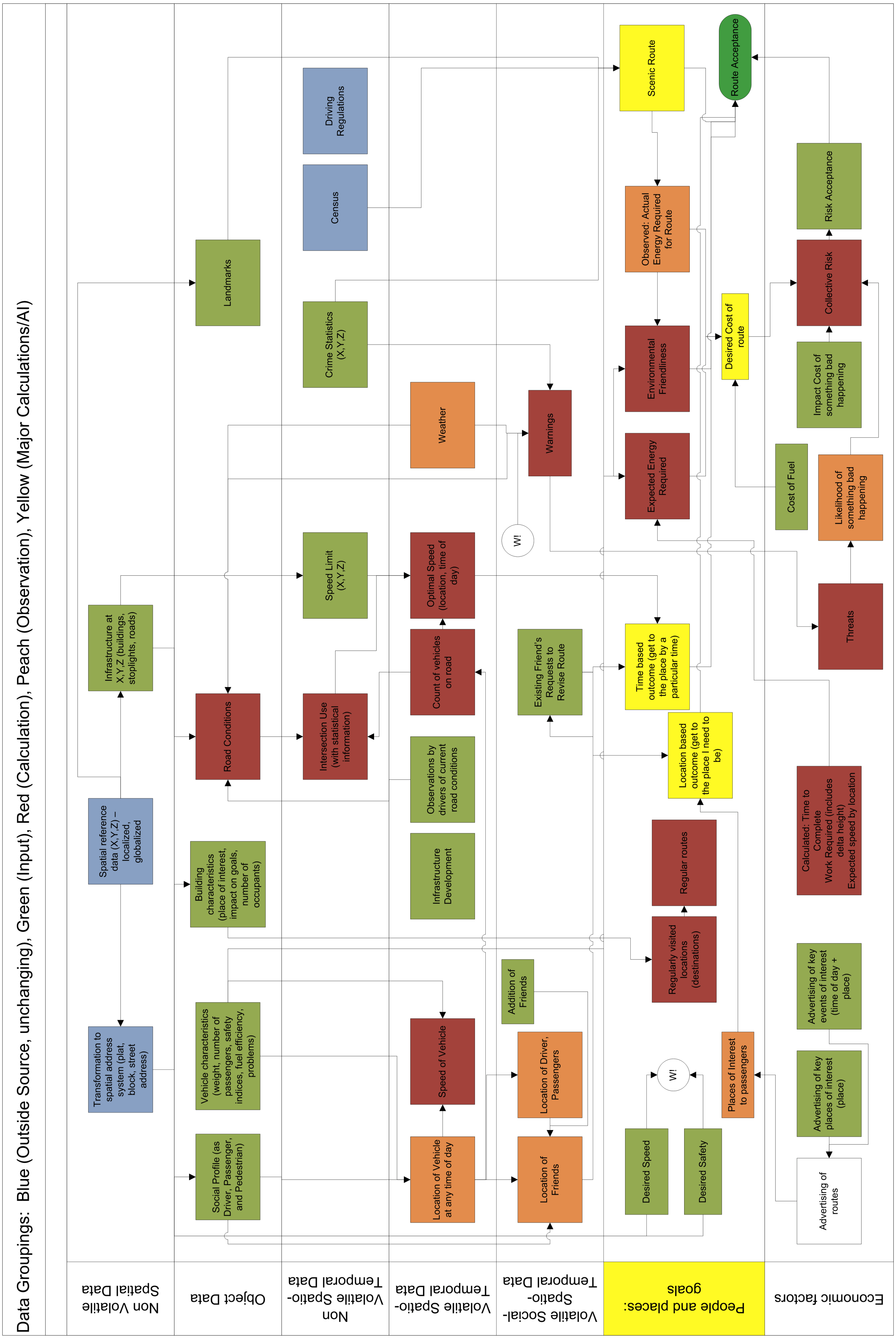
Appendix B: Proposed sources of the information within the proposed dataset.

Appendix C: Marked data elements are those that have the greatest role within the social network concept. This includes the location of network members relative to one another, their individual profiles and settings, determining data to monitor, and matching calculations to desired results.

APPENDIX A

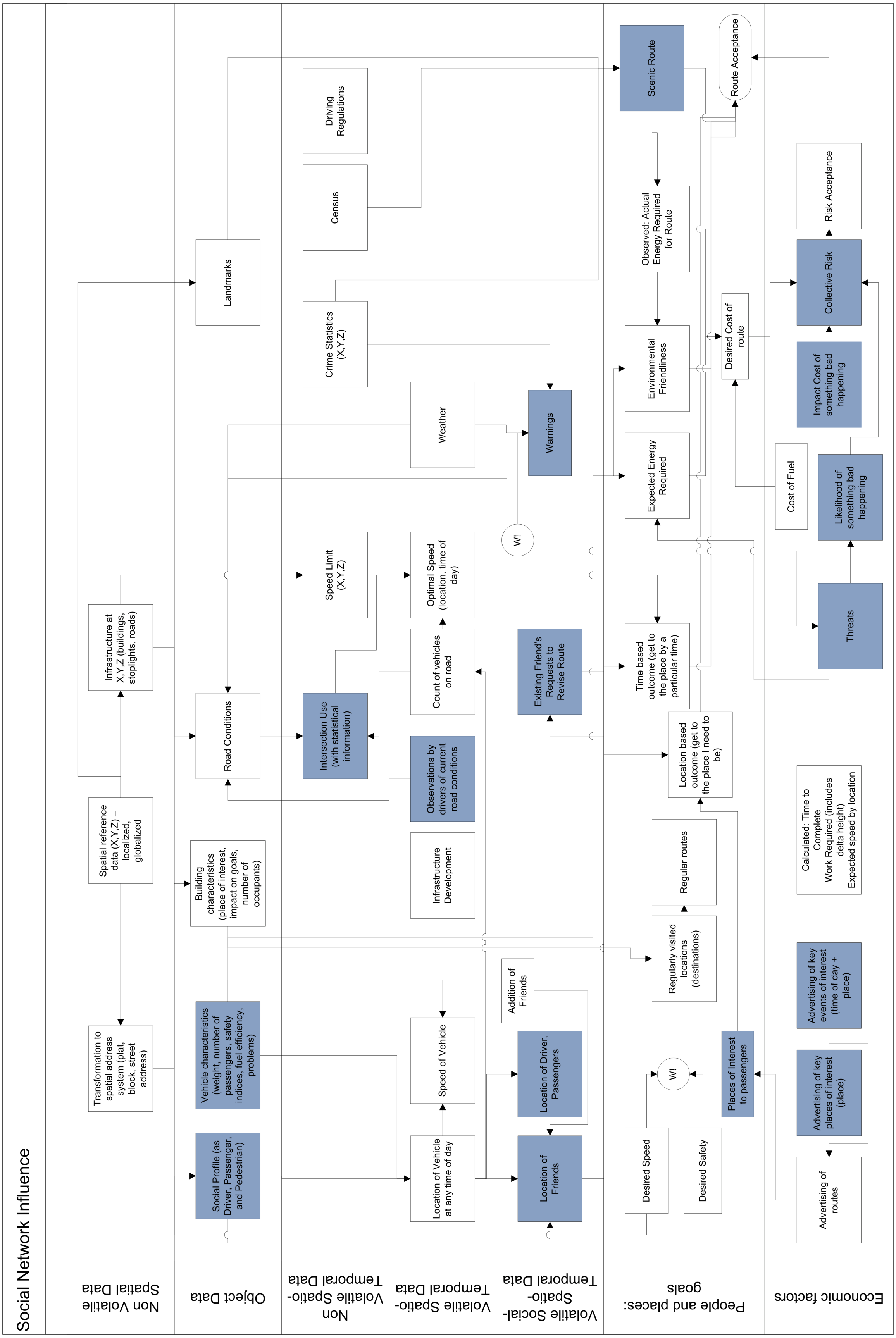

Calculation Method: Red: matrix combinations or array additions with scoring for all (x,y,z);blue: integration over time;green: integration over time and space;
Gray: is array; Yellow: functional arithmetic
Non Volatile Spatial Data
Object Data
Non Volatile Spatio-Temporal Data
Volatile Spatio-Temporal Data
Volatile Social-Spatio-Temporal Data
People and places: goals
Economic factors
Transformation to spatial address system (plat, block, street address)
Spatial reference data (X,Y,Z) – localized, globalized
Infrastructure at X,Y,Z (buildings, stoplights, roads)
Social Profile (as Driver, Passenger, and Pedestrian)
Vehicle characteristics (weight, number of passengers, safety indices, fuel efficiency, problems)
Building characteristics (place of interest, impact on goals, number of occupants)
Road Conditions
Landmarks
Intersection Use (with statistical information)
Speed Limit (X,Y,Z)
Crime Statistics (X,Y,Z)
Census
Driving Regulations
Location of Vehicle at any time of day
Speed of Vehicle
Infrastructure Development
Observations by drivers of current road conditions
Count of vehicles on road
Optimal Speed (location, time of day)
Weather
Location of Friends
Location of Driver, Passengers
Addition of Friends
Existing Friend's Requests to Revise Route
W!
Warnings
Desired Speed
Desired Safety
W!
Regularly visited locations (destinations)
Regular routes
Location based outcome (get to the place I need to be)
Time based outcome (get to the place by a particular time)
Expected Energy Required
Environmental Friendliness
Observed: Actual Energy Required for Route
Scenic Route
Places of Interest to passengers
Desired Cost of route
Route Acceptance
Advertising of routes
Advertising of key places of interest (place)
Advertising of key events of interest (time of day + place)
Calculated: Time to Complete Work Required (includes delta height) Expected speed by location
Threats
Cost of Fuel
Likelihood of something bad happening
Impact Cost of something bad happening
Collective Risk
Risk Acceptance

APPENDIX B



Data Groupings: Blue (Outside Source, unchanging), Green (Input), Red (Calculation), Peach (Observation), Yellow (Major Calculations/AI)
Non Volatile Spatial Data
Object Data
Non Volatile Spatio-Temporal Data
Volatile Spatio-Temporal Data
Volatile Social-Spatio-Temporal Data
People and places: goals
Economic factors
Transformation to spatial address system (plat, block, street address)
Spatial reference data (X,Y,Z) – localized, globalized
Infrastructure at X,Y,Z (buildings, stoplights, roads)
Landmarks
Social Profile (as Driver, Passenger, and Pedestrian)
Vehicle characteristics (weight, number of passengers, safety indices, fuel efficiency, problems)
Building characteristics (place of interest, impact on goals, number of occupants)
Road Conditions
Intersection Use (with statistical information)
Speed Limit (X,Y,Z)
Crime Statistics (X,Y,Z)
Census
Driving Regulations
Location of Vehicle at any time of day
Speed of Vehicle
Infrastructure Development
Observations by drivers of current road conditions
Count of vehicles on road
Optimal Speed (location, time of day)
Weather
Location of Friends
Location of Driver, Passengers
Addition of Friends
Existing Friend's Requests to Revise Route
W!
Warnings
Desired Speed
Desired Safety
Places of Interest to passengers
Regularly visited locations (destinations)
Regular routes
Location based outcome (get to the place I need to be)
Time based outcome (get to the place by a particular time)
Expected Energy Required
Environmental Friendliness
Observed: Actual Energy Required for Route
Scenic Route
Desired Cost of route
Route Acceptance
Advertising of routes
Advertising of key places of interest (place)
Advertising of key events of interest (time of day + place)
Calculated: Time to Complete
Work Required (includes delta height)
Expected speed by location
Threats
Likelihood of something bad happening
Cost of Fuel
Impact Cost of something bad happening
Collective Risk
Risk Acceptance

APPENDIX C


Social Network Influence
Non Volatile Spatial Data
Object Data
Non Volatile Spatio-Temporal Data
Volatile Spatio-Temporal Data
Volatile Social-Spatio-Temporal Data
People and places: goals
Economic factors
Transformation to spatial address system (plat, block, street address)
Spatial reference data (X,Y,Z) – localized, globalized
Infrastructure at X,Y,Z (buildings, stoplights, roads)
Social Profile (as Driver, Passenger, and Pedestrian)
Vehicle characteristics (weight, number of passengers, safety indices, fuel efficiency, problems)
Building characteristics (place of interest, impact on goals, number of occupants)
Road Conditions
Landmarks
Intersection Use (with statistical information)
Speed Limit (X,Y,Z)
Crime Statistics (X,Y,Z)
Census
Driving Regulations
Location of Vehicle at any time of day
Speed of Vehicle
Infrastructure Development
Observations by drivers of current road conditions
Count of vehicles on road
Optimal Speed (location, time of day)
Weather
Location of Friends
Location of Driver, Passengers
Addition of Friends
Existing Friend's Requests to Revise Route
W!
Warnings
Desired Speed
Desired Safety
W!
Places of Interest to passengers
Regularly visited locations (destinations)
Regular routes
Location based outcome (get to the place I need to be)
Time based outcome (get to the place by a particular time)
Expected Energy Required
Environmental Friendliness
Observed: Actual Energy Required for Route
Scenic Route
Desired Cost of route
Route Acceptance
Advertising of routes
Advertising of key places of interest (place)
Advertising of key events of interest (time of day + place)
Calculated: Time to Complete Work Required (includes delta height) Expected speed by location
Threats
Likelihood of something bad happening
Cost of Fuel
Impact Cost of something bad happening
Collective Risk
Risk Acceptance