Cartography M.Sc.

Evaluation of Methods and Tools for Interactively Visualizing and Exploring Traffic Data

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Definitions

- **Traffic**: movement of motorized vehicles, mostly referred to at a specific location and time
- **Traffic Congestion**: “reduction in mean speeds, increase in travel time or increase in vehicle density” (Zhicai et al. 2004).
- **Visual Analytics**: “the science of analytical reasoning facilitated by interactive visual interfaces” (Andrienko et al., 2017).

Outline

- Introduction and Motivation
- Research Objectives
- Methodology
- Phase I – Visualization methods and tools from literature
- Phase II – Determining design concepts and the development of traffic visualization prototype
- Phase III – Evaluation of the prototype and discussion
- Conclusion and Recommendations

Introduction and Motivation

- Increase in traffic is leading to growth in traffic related problems e.g. congestion, higher emissions and fuel usage
- Efficient traffic management is necessary to better utilize existing road infrastructure
- Increased collection of complex, multidimensional traffic data through modern ITS
- Dynamic and interactive visualization solutions can support traffic planners in visualizing and exploring traffic data to identify traffic congestion times, and places

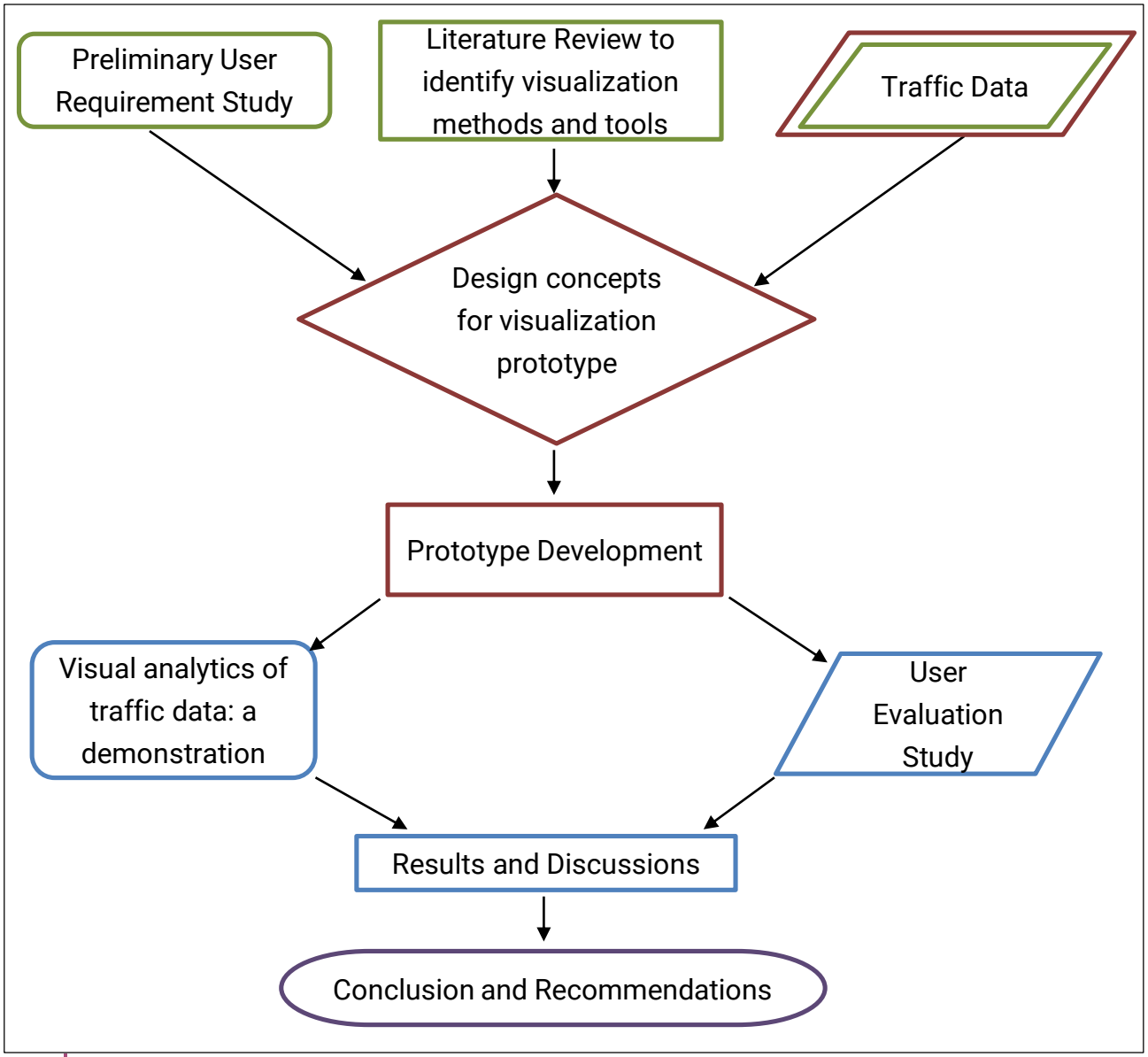
Research Objectives

1. Evaluation of methods and tools for visualizing traffic data
2. Development of a prototype for visualization and exploration of traffic data with focus on traffic congestion identification
3. Evaluation study of the developed prototype

Traffic congestion identification tasks:

- Where is traffic congestion at a specific time?
- When was a road/part of road most congested?
- Extent of congestion? (duration, or length)
- Patterns in traffic congestion i.e. rush hours, bottlenecks etc.

Methodology



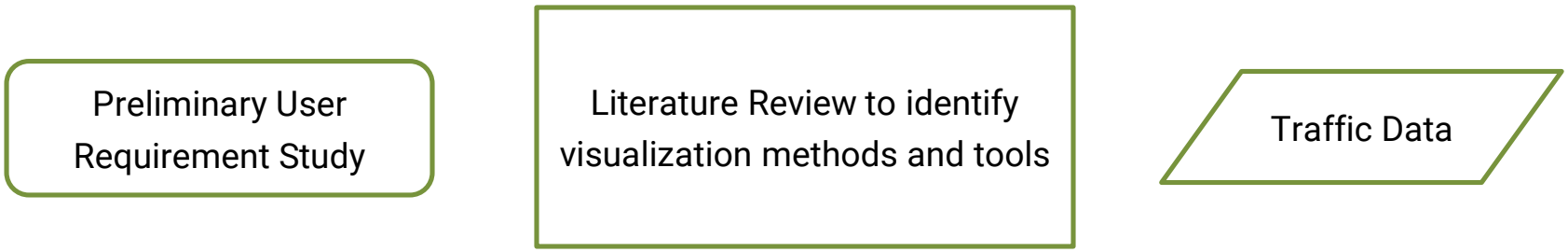
Phase I

Phase II

Phase III

Phase I – Research Objective 1

1. Evaluation of methods and tools for visualizing traffic data:
   a) Which data categories and visualization methods exist for traffic data?
   b) Which tools are used to explore and understand traffic data?

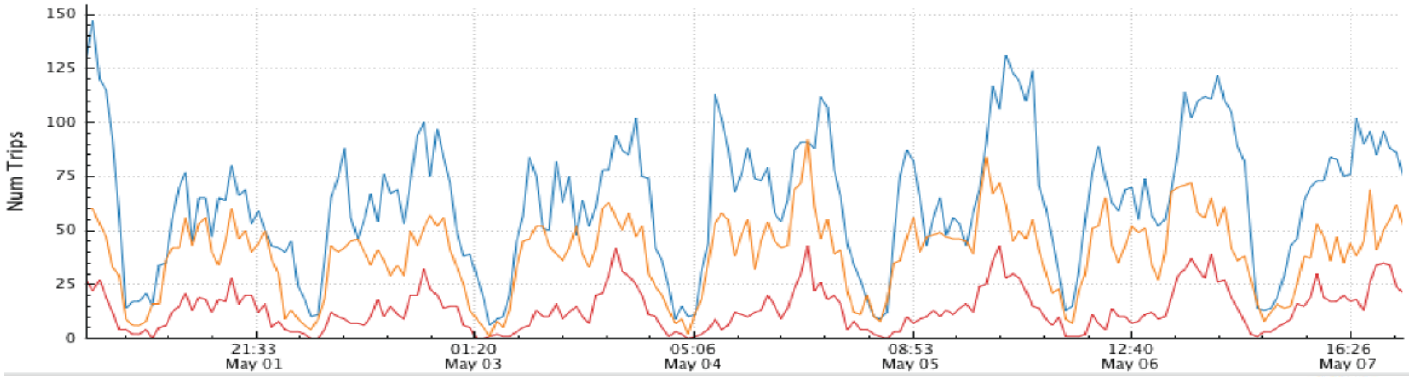


Traffic Data Categories and Visualization Methods

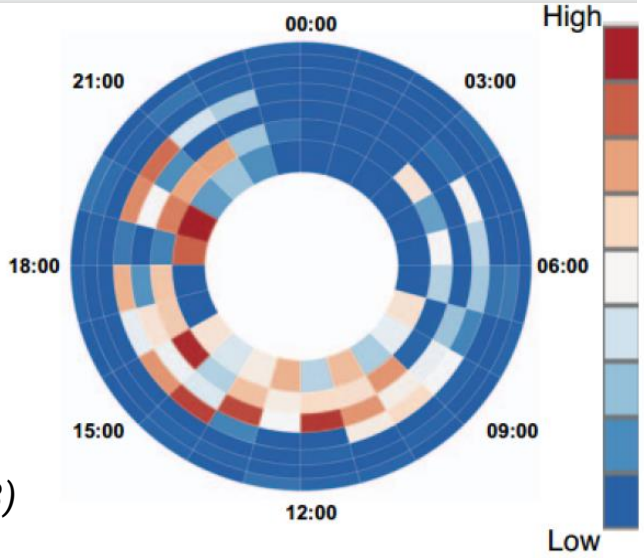
Data Category		Visualization Methods
Temporal	Time Range	Line/Bar Charts Radial Charts
Spatial	Point Based Map (at a specific time)	Point distribution maps
	Line Based Map (at a specific time)	Road network Origin Destination Trajectory
	Polygon Based Map (at a specific time)	Choropleth Maps
Spatio Temporal	Spatial & Time	Space Time Cube

Temporal Traffic Data Visualizations

- Linear Time (Line, Bar Charts)
  - Visualization across time
  - Peaks in data e.g. Rush Hour



- Recurring Time (Radial Charts)
  - Cyclic temporal patterns e.g. weekly patterns

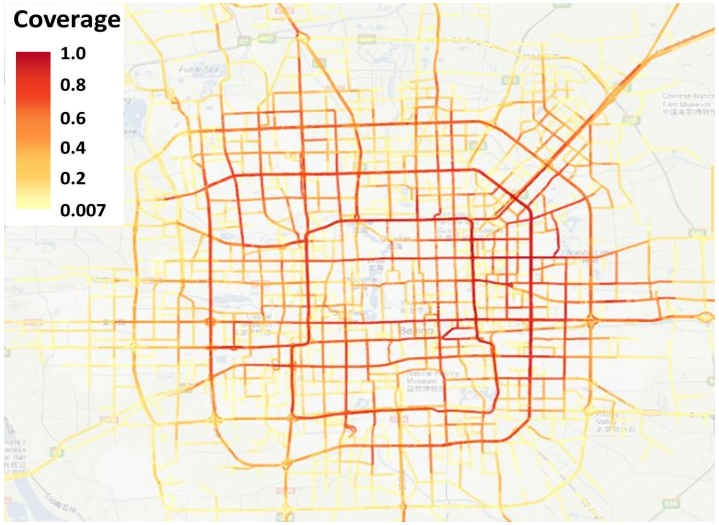


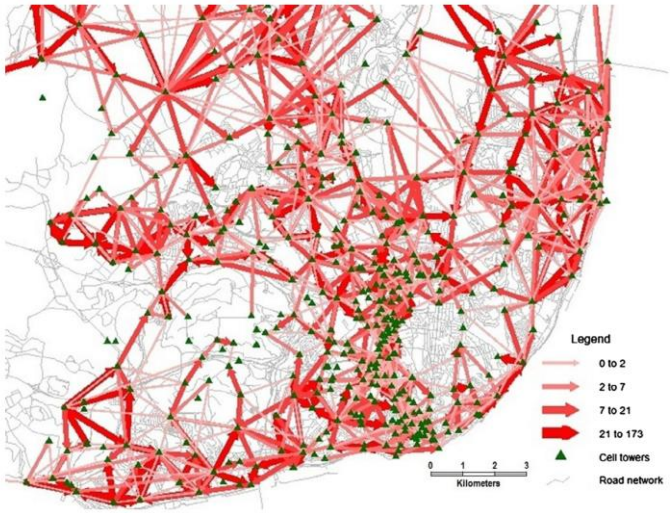
(Source: Pu et al., 2013; Ferreira et al., 2013)

- However, temporal visualizations only focus on the time dimension, and not space
- Can be useful as supporting visualization to show numerical traffic attribute data across time

Spatial Traffic Visualizations (*Line Based Data*)

- Visualization of spatially continuous traffic data as lines
  - Traffic data over the road network (color visual variable mostly used)
  - Origin-Destination (O-D) pair trajectory data (size visual variable mostly used)





(Source: Zuchao Wang et al., 2013; Andrienko et al., 2017)

- Traffic Speeds, traffic flow, congestion on the road network. Less visual clutter as visualization over roads only
- O-D pairs are useful to show spatial patterns e.g. flow maps (Large dataset causes visual clutter)

Tools to Interpret and Explore Traffic Data

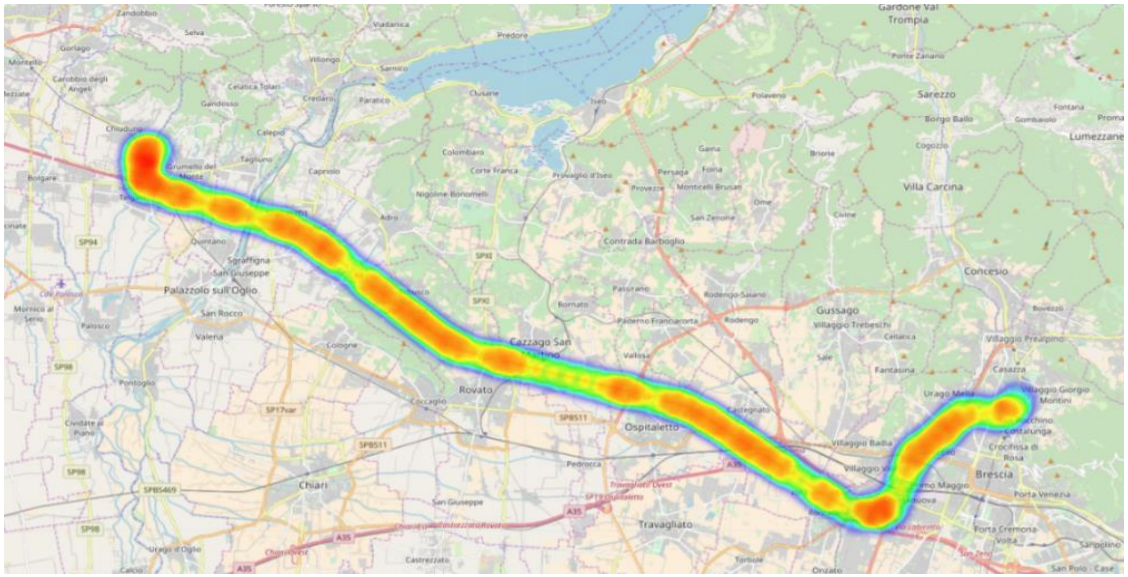
- Enhance the functionality achieved from visualization methods
- Support the users to explore different dimensions of the data and extract information
- Allow the users to communicate with the visualization, forming a link between human and computer intelligence

Interactivity:

- Most pivotal tool for exploring data
- Sobral et al (2019) mentions brushing, semantic zoom and linking as common interactions in traffic visualizations

Heatmaps:

- Commonly used tool for traffic data visualizations
- Quick and easy visual interpretation of data distribution and identifies hot spots
- However, with road based visualizations, the heatmap will hide the road network itself



(Source: Silva et al., 2018)

Filtering and Selection (Brushing):

- Allows users to make temporal or spatial queries i.e. filtering of specific time (day, hours etc.) or spatial region
- Subset of data from a large dataset can be focused and individually explored, reducing visual clutter as well

Data Aggregation:

- Refers to the user being able to change the resolution or level of detail of the data to show data overview or detailed ‘drill down’ view
- Limited to mostly temporal dimension in previous works

Multiple Coordinated views (Linking):

- Interactively linked views in a dashboard interface
- Serves multi dimensionality of traffic data by providing dedicated spatial map view linked with supporting time graphs in abstract space
- Allows users to further explore each dimension of traffic data

(Source: Picozzi et al. 2013)

Preliminary User Requirements Study

- Small user requirements study among traffic experts to gather traffic data and visualization framework in use, and functionality required from a visualization prototype:
  - Currently used visualization systems are (majorly) static
  - Users focused on requirement of dynamic visualization; allowing change in time e.g. mean speeds at different times of the day
  - Aggregated historical data and more detailed recent data
  - Spatially based on the road network
  - Capable to visualize large dataset
  - Ability to identify bottlenecks in roads, and explore rush hour times
  - Traffic congestion event propagation through time

Traffic Data Attributes

Traffic Attribute	Description
Traffic Incidents	Events related to traffic e.g. accidents or traffic jams
Traffic Flow	Number of cars passing a point
Distance	Distance covered by a moving vehicle
Travel Time	Time taken by a specific journey or road length
Average/Mean Vehicle Speed	The average speed over a certain time and space

Travel Time Index (TTI):

- Travel Time Reliability (TTR) measure that gives an idea of congestion on the road
- Ratio of mean travel time to estimated free flow travel time

$$\mathrm{TTI}_{s,t} = \frac{\text{average travel time}_{s,t}}{\text{freeflow travel time}_{s,t}}$$

- Innovative for traffic data visualization

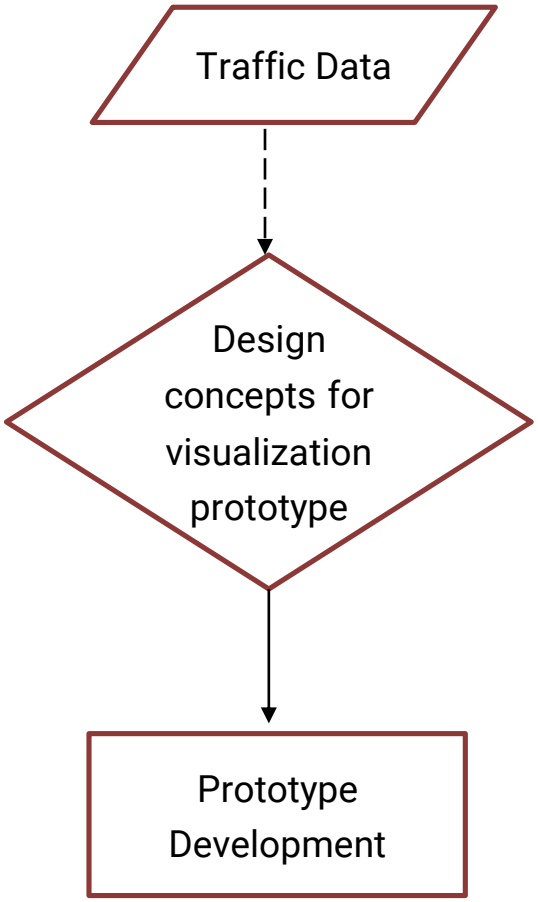
Phase II – Research Objective 2

2. Development of a prototype for visualization and exploration of traffic data with focus on traffic congestion identification:

   a) Which visualization concepts will be used in the prototype visualization?

   b) Which spatial and temporal aggregates will be applied to traffic data?

   c) Which interactive elements will assist users to explore the data?



Traffic Dataset (Salzburg Research)

- Traffic data on road network derived from Floating Car Data
  i.e. Line based spatial visualization
- Supporting temporal data in linear time charts

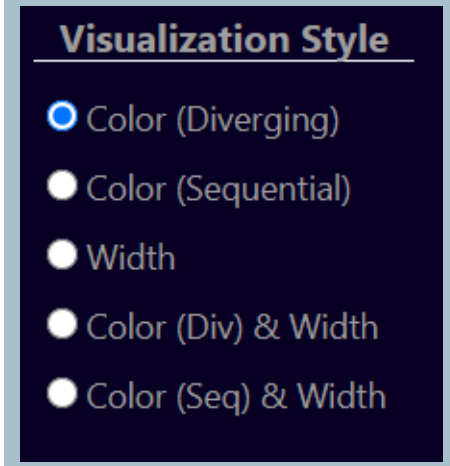
Technologies Used in the Prototype:

- Deck.gl and Mapbox GL JS (Spatial View)
- AmCharts (Temporal View)
- Languages: JavaScript, jQuery, HTML, CSS
- Editing: Sublime Text, Visual Studio Code
- Hosting: GitHub

Visualization Styles

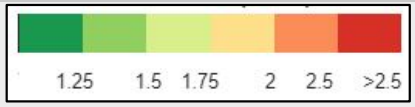
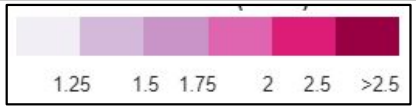
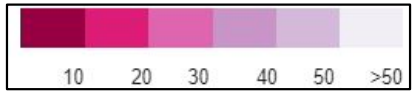
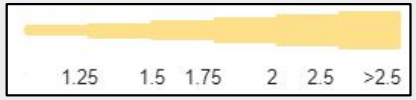
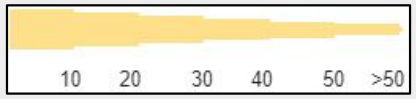
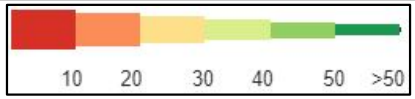
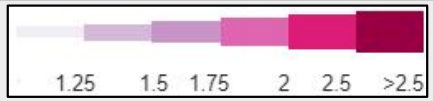
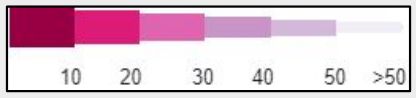
- Visual variables: Color and Size (on line based dataset)
- Size: Changing the line width (10m - 60m)
- Color Scheme (from Color Brewer):
  - Diverging Color Scheme:
    - Green to red color scheme, useful for focus on higher (critical data classes)
    - Familiar to users in traffic visualizations
  - Sequential Color Scheme:
    - Good visualization for ordered dataset
    - Color blind friendly
- Combination of both visual variables

Interactive Selection Menu

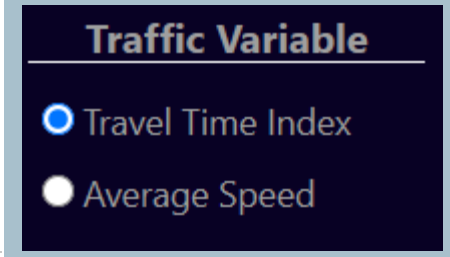


Traffic Attributes and Data Classes

- Travel Time Index: (introduced earlier)
- Average Speed: familiarity with users

Visualization Style	Visual Variable	Scale for TTI	Scale for Speed
Color (Diverging)	Color		
Color (Sequential)			
Width	Size		
Color (Div) & Width	Color & Size		
Color (Seq) & Width			

Interactive Selection Menu

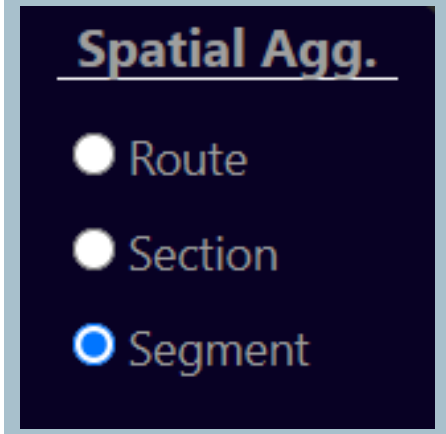


Legend updates dynamically according to selected traffic attribute and visualization style

Spatial Aggregates

- Innovative for line based traffic visualization
- Allows users to do micro or macro visualizations over 3 spatial aggregations:
  - Segments (825): between each intersection with the route
  - Sections (120): between major intersections with the route
  - Routes (9): full length of the route

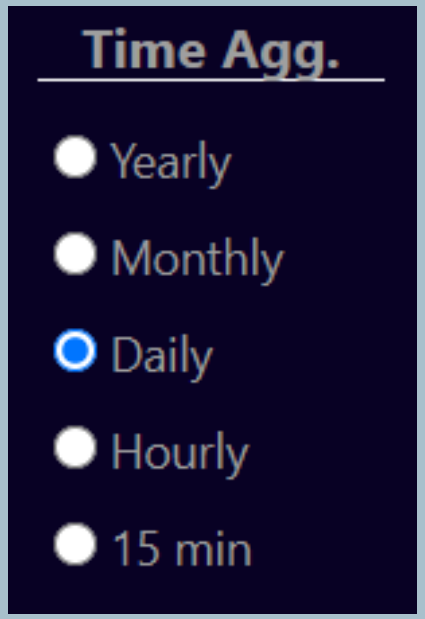
Interactive Selection Menu



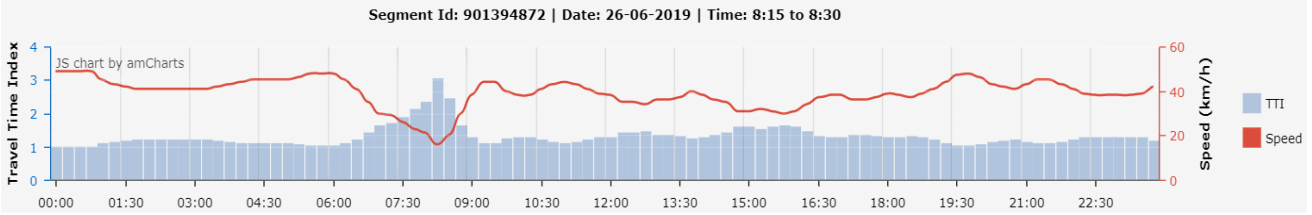
Temporal Aggregates

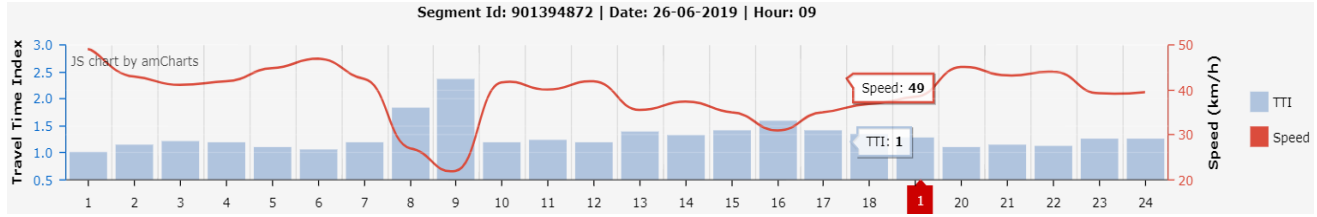
- Raw data in 15 min time intervals.
- Aggregated over 5 temporal aggregates.
- Allowing users overview (summary), as well as drill down to detailed visualization.
- Linked through clicking on spatial feature.

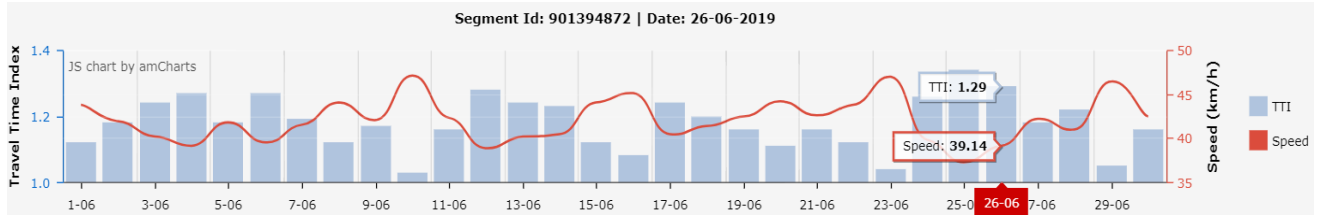
Interactive Selection Menu

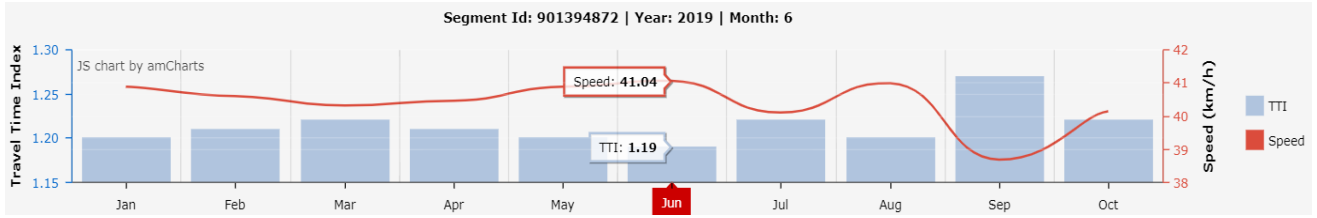


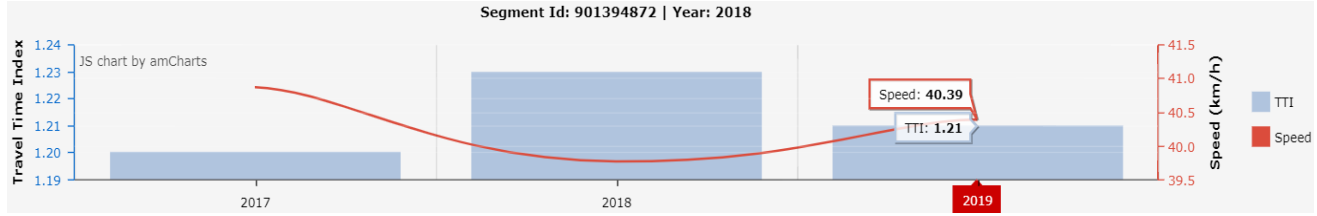
Temporal Aggregates



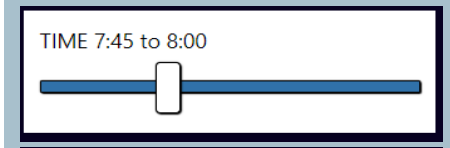


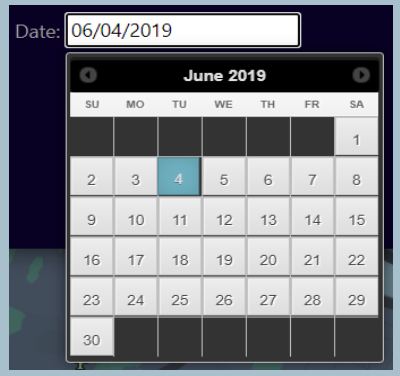






Interactive Selectors:





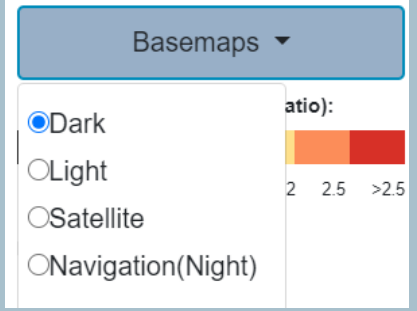
Basemaps

- Basemaps from mapbox that contrast well with the visualization styles were used

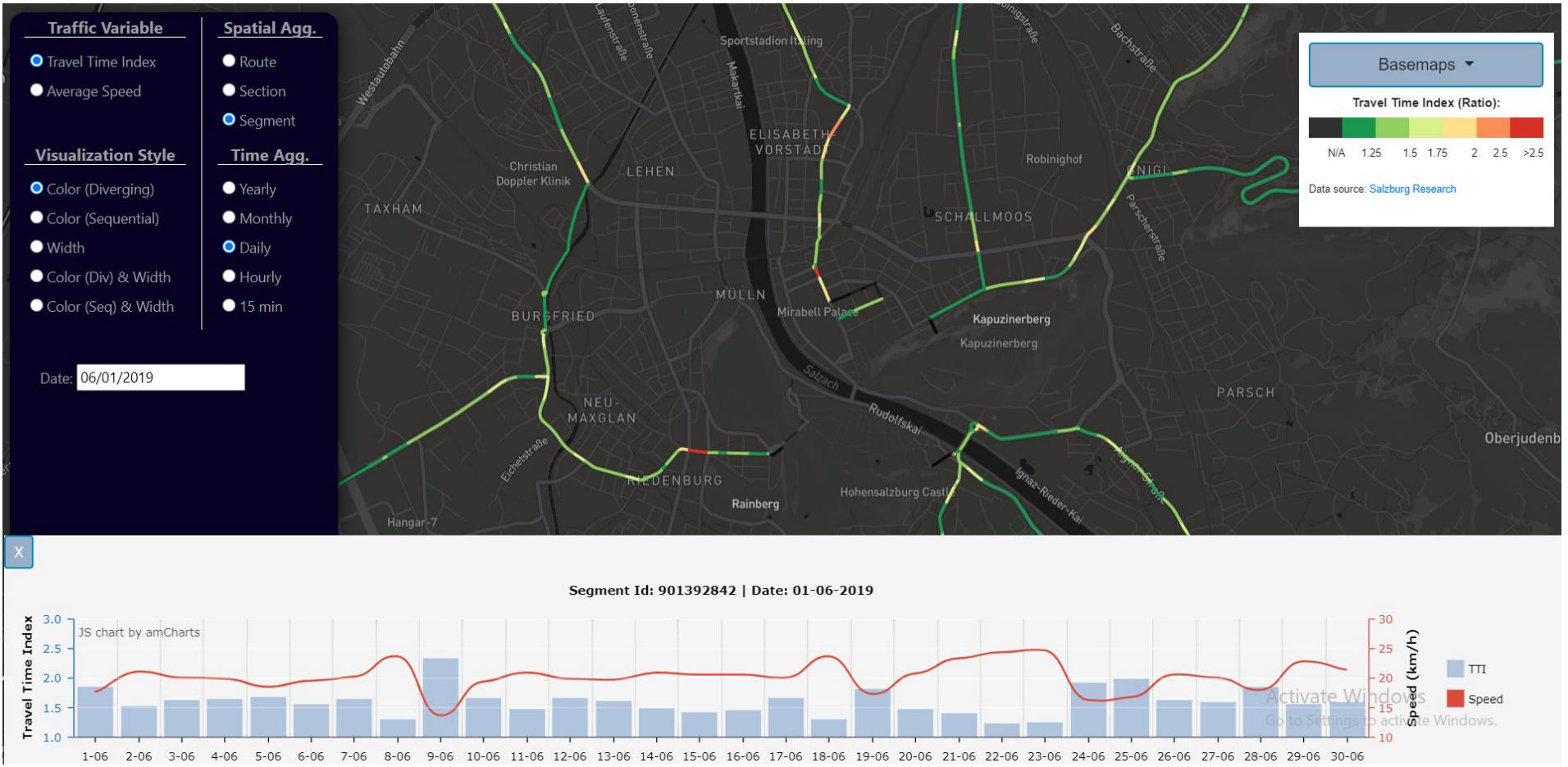
Other interactive elements

- Default view manipulation by deck.gl
- Details on demand through mouse hover over spatial feature
- Highlighting segments on mouse hover

Interactive Selection Menu



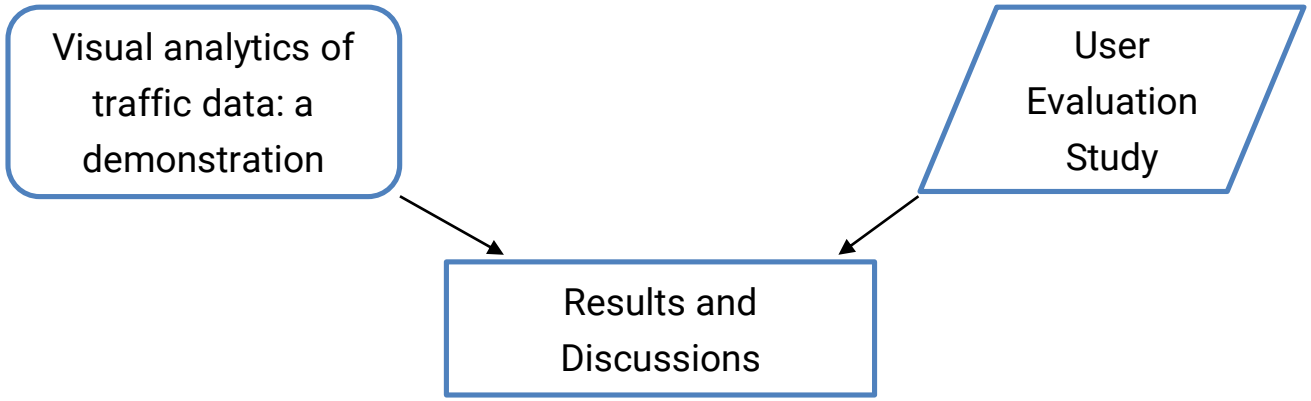
Prototype Overview



https://arslanaslam92.github.io/Traffic_Visualization/

Phase III – Research Objective 3

1. Evaluation study of the developed prototype
   a) Evaluation of visualization methods and interactive tools in the prototype.
   b) How capable and efficient is the visualization tool for identifying and exploring traffic congestion?



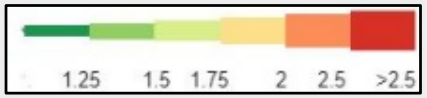
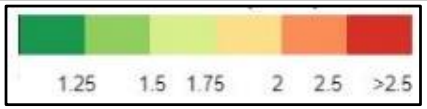
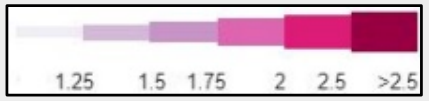
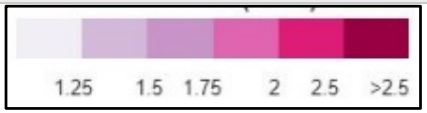
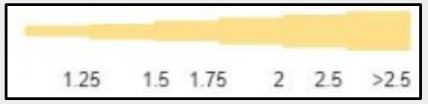
User Groups

- ‘Traffic Users’: Experts from domain of traffic analysis and traffic planning, and academic research departments in field of traffic planning – 10 respondents (15-20 planned initially)
- ‘GIS Users’: Professionals and research academia in the domain of GIS and cartography. – 35 respondents
- The study was performed using SoSci survey and Likert ranking of 1-4 was mostly used.

Results from evaluation study

Visualization Styles

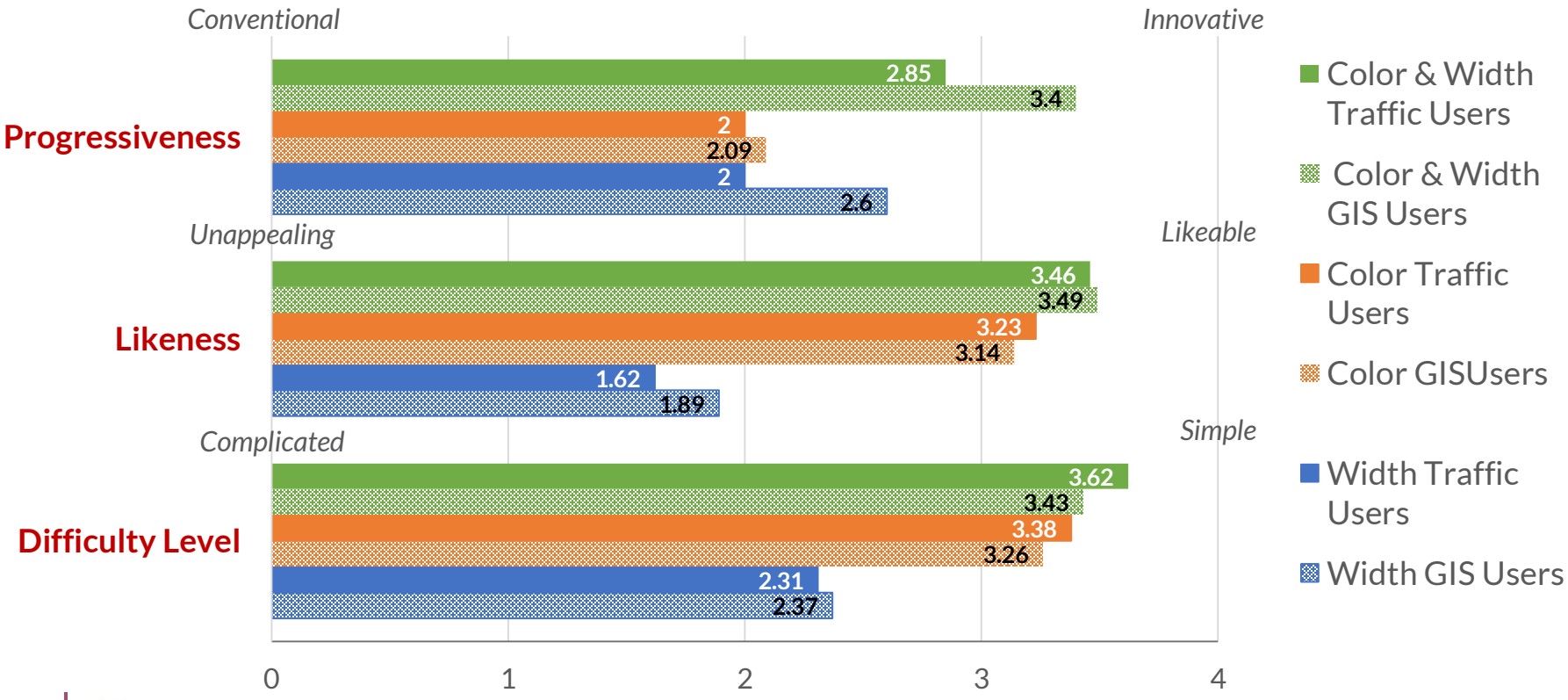
- Users were given small tasks to explore traffic data using each of the 5 visualization styles
- Combination of color and width (size) with diverging color scheme was most popular among both user groups

Visualization Style		Average Rank (GIS Users)	Percentage Rank 1 (%)	Average Rank (Traffic Users)	Percentage Rank 1 (%)
Color (Div) & Width		1.51	84.0	1.62	61.5
Color (Diverging)		2.46	36.0	2	30.8
Color (Seq) & Width		2.74	16.0	3.08	0.0
Color (Sequential)		3.89	0.0	3.54	7.7
Width		4.40	4.0	4.77	0.0

Results from evaluation study

Visualization Styles

- Visualization styles were further ranked over 3 characteristics
- Here as well color and width received best rankings



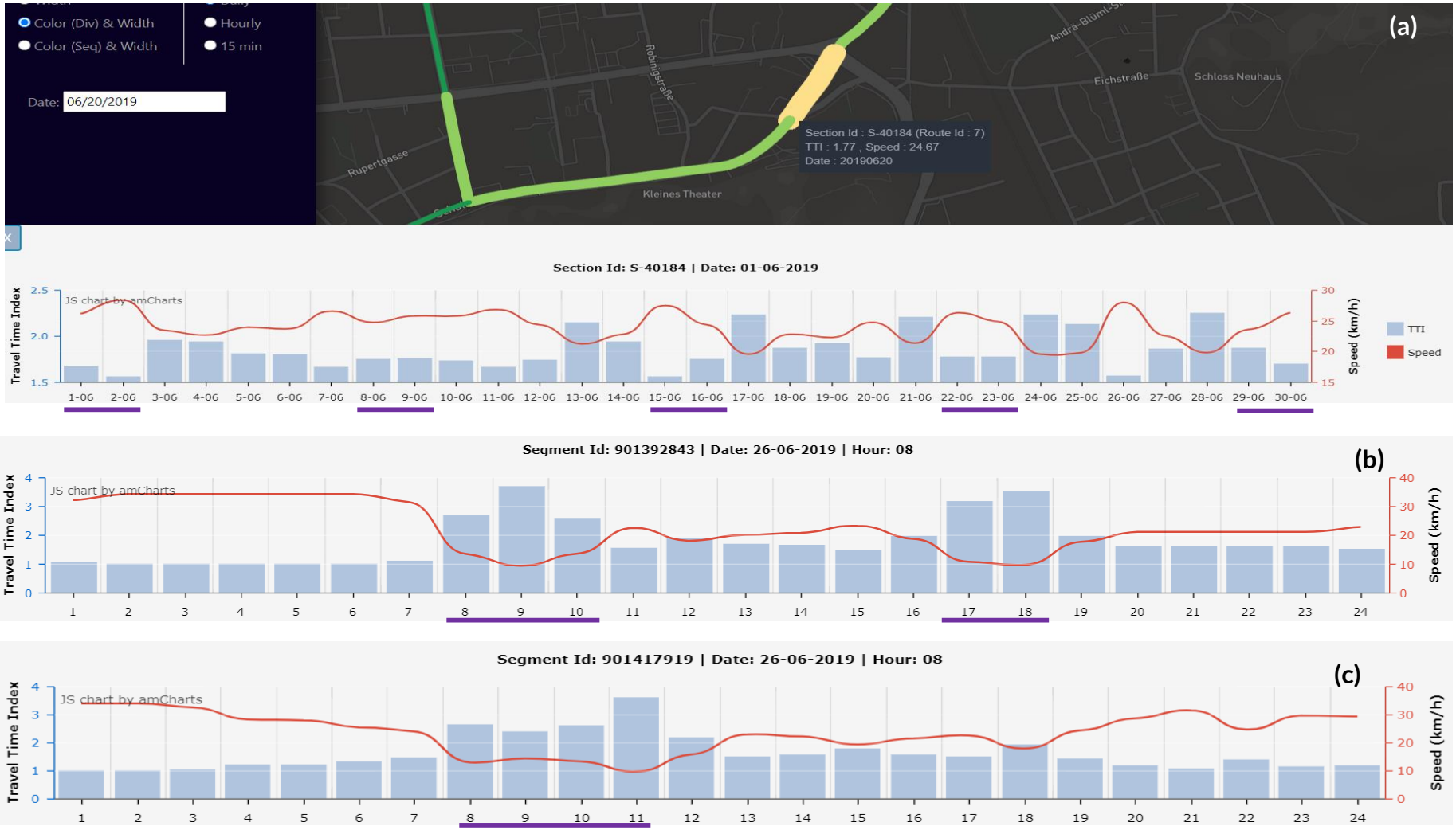
Demonstration of Results

Traffic Congestion Identification Tasks

- Temporal exploration of traffic congestion
- Spatial exploration of traffic congestion
- Congestion extent (duration or length)
- Identification of temporal patterns (e.g. rush hour, traffic on weekdays vs weekends
- Identification of spatial patterns (e.g. traffic bottlenecks)
- Traffic congestion event over time

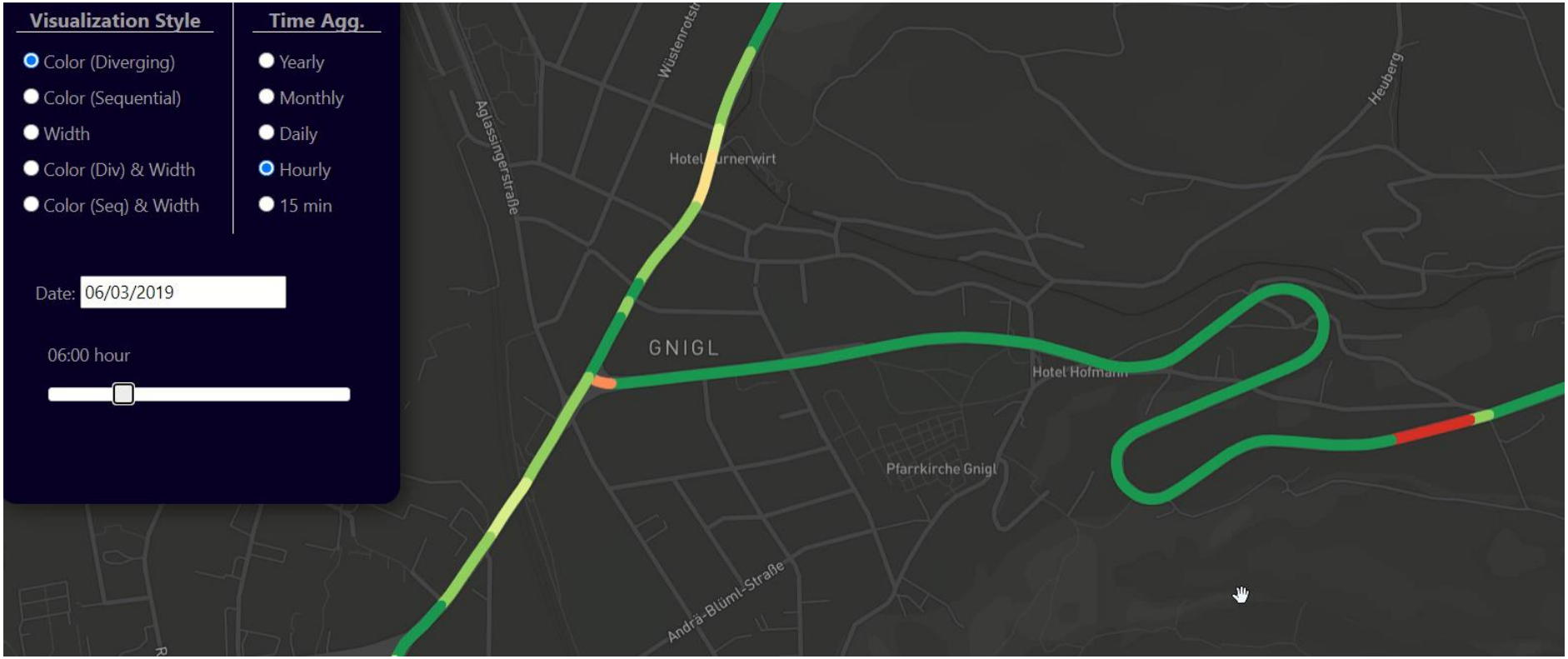
Demonstration of Results

Identification of temporal patterns



Congestion Event Across Time

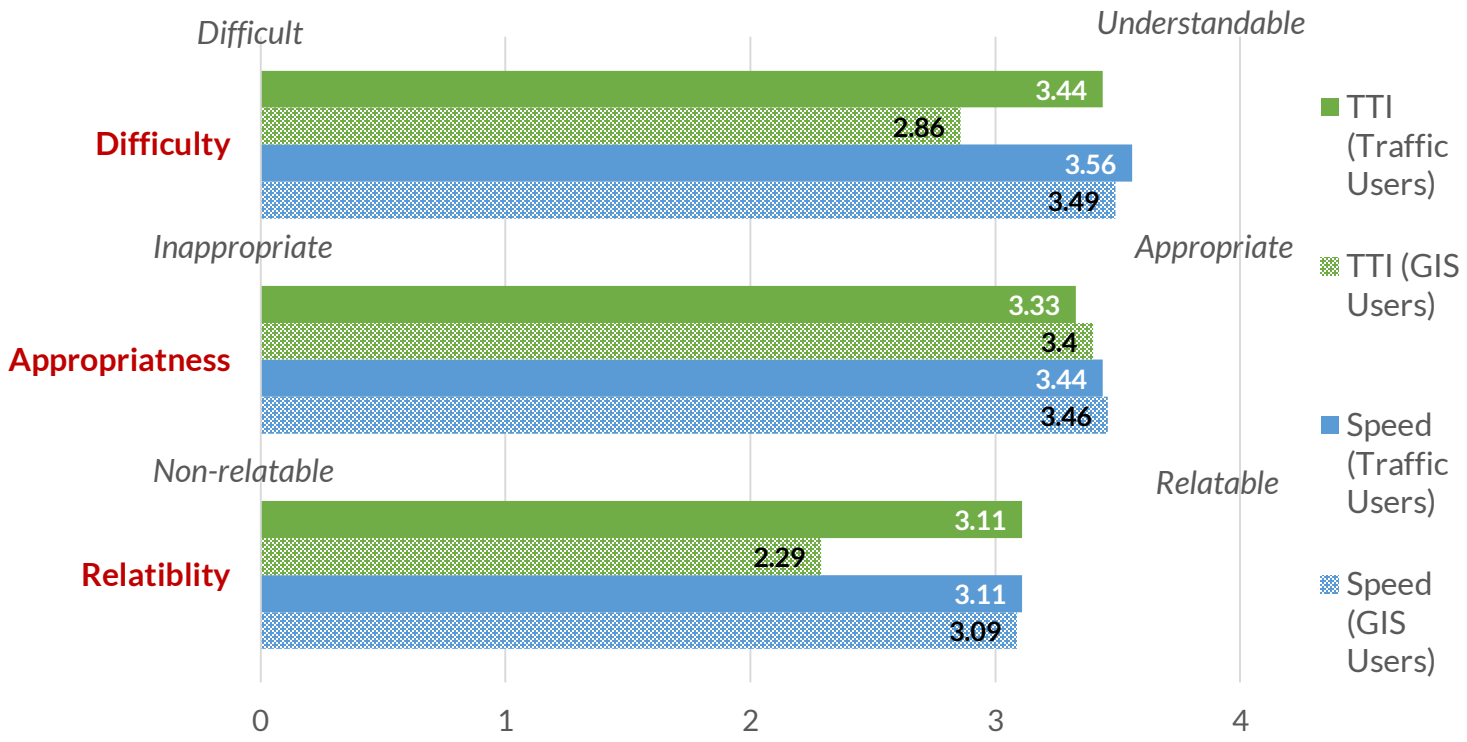
- Animation of congestion event on 3 June, 2019, hourly temporal aggregate, segment spatial aggregate

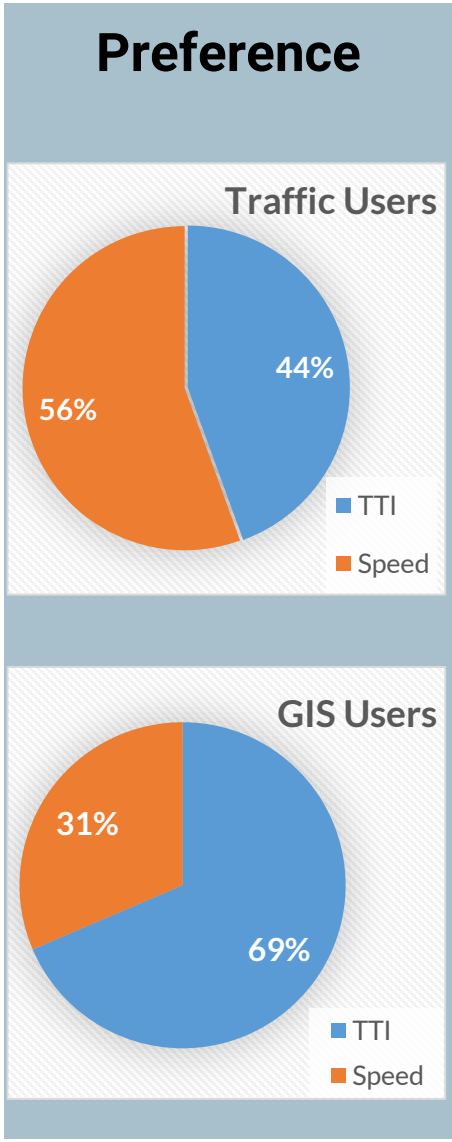


Results from evaluation study

Evaluation of Traffic Attributes

- Traffic congestion identification tasks performed in user study used both traffic attributes
- Users were asked preference and evaluation over 3 characteristics

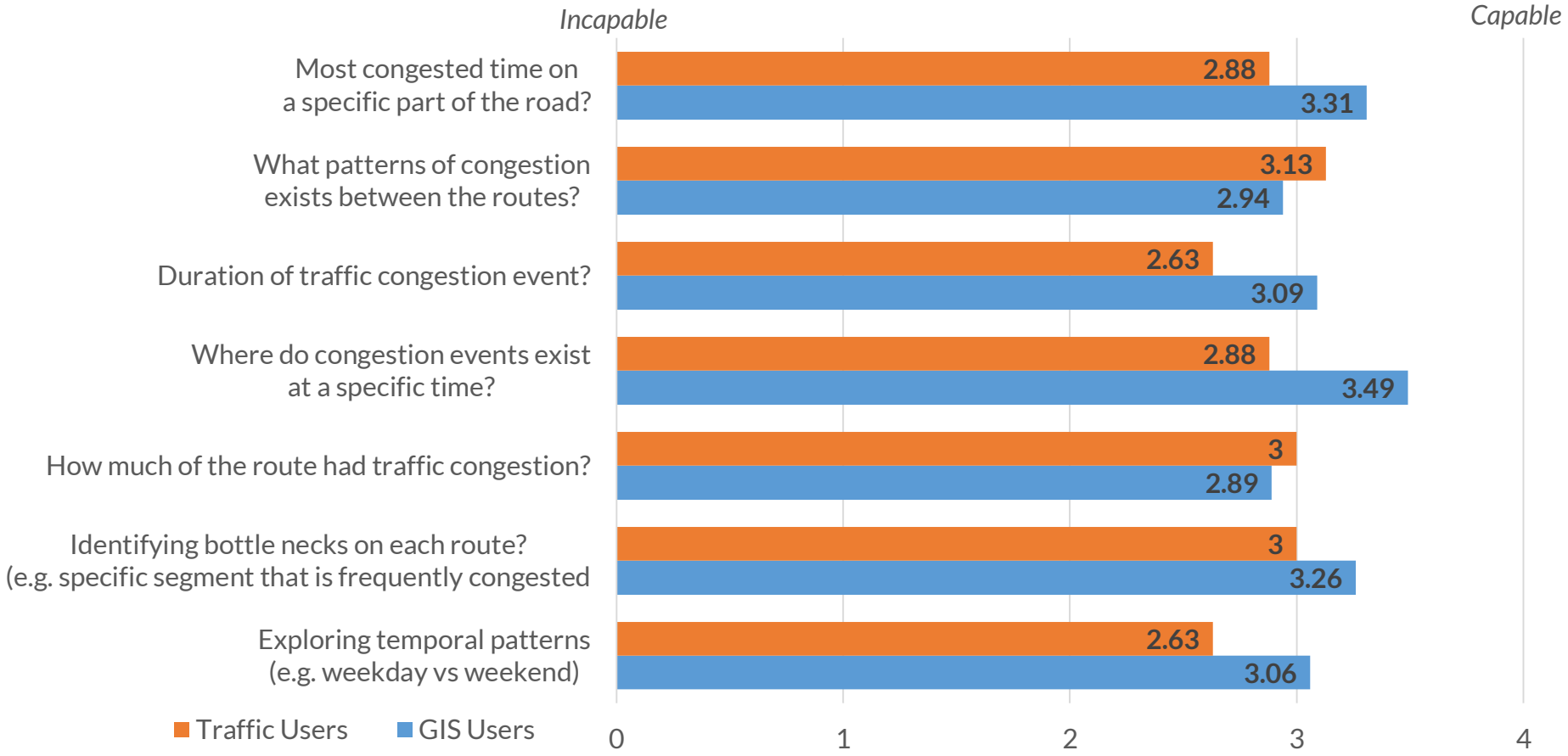




Results from evaluation study

Evaluation of capability to identify traffic congestion

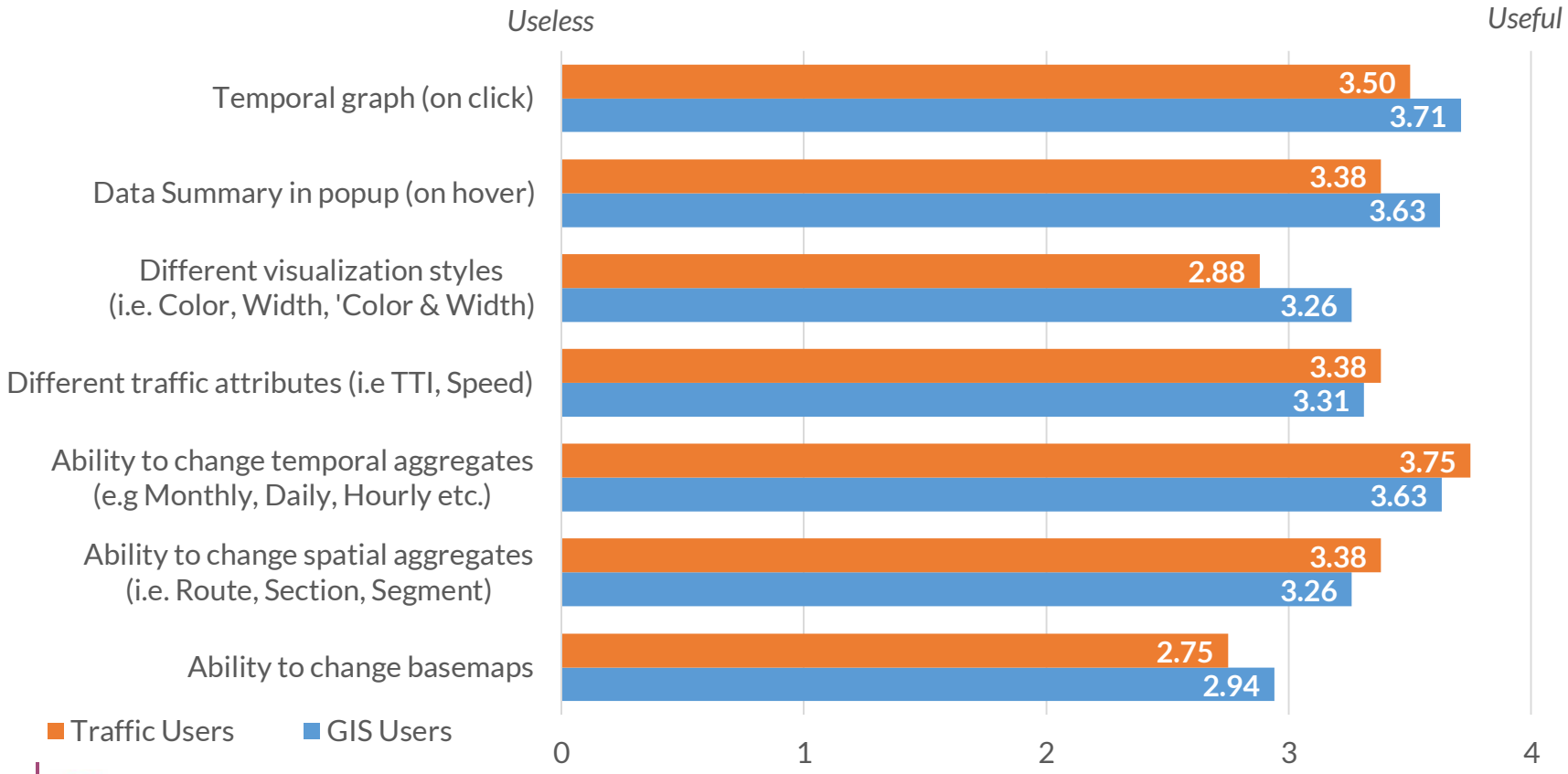
- Users were asked capability of the prototype on these questions



Results from evaluation study

Evaluation of interactive elements of prototype

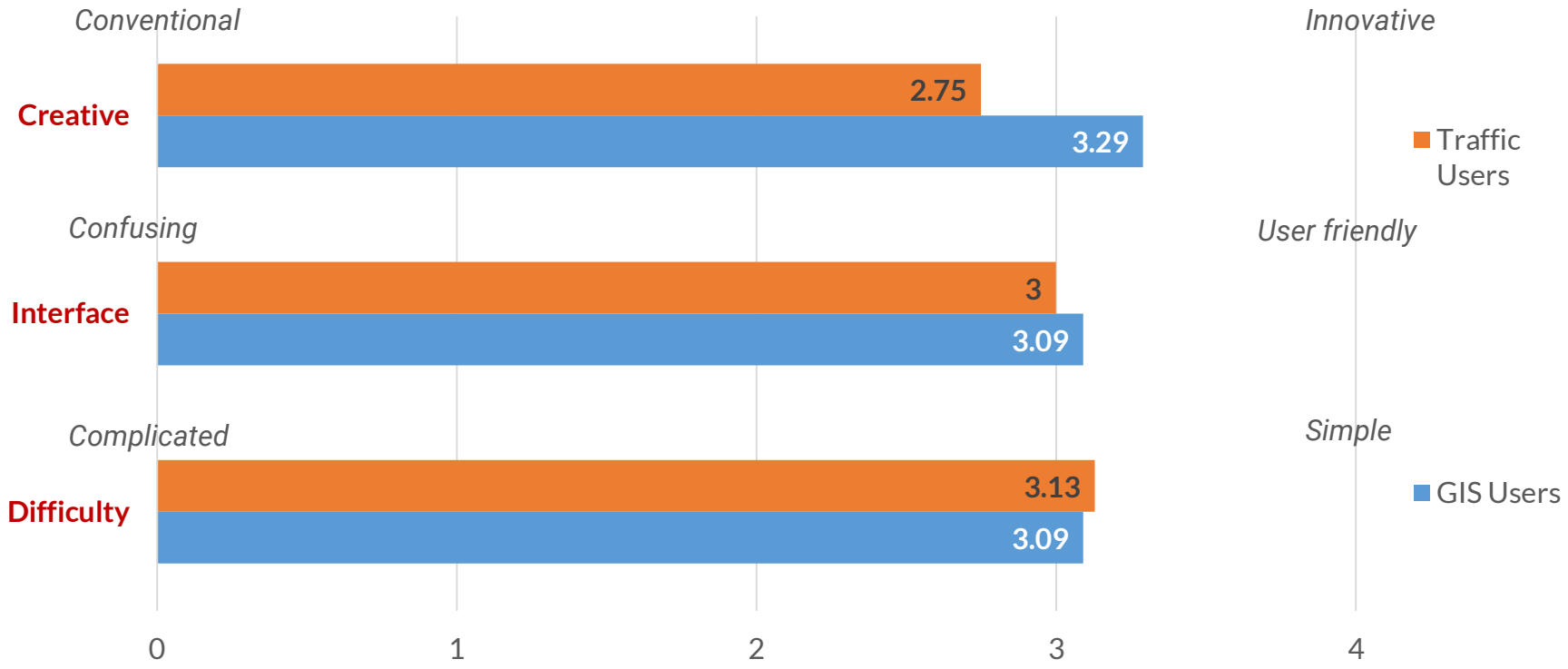
- Overall good rankings, specially features of: temporal graphs, and temporal and spatial aggregates and data summary on hover



Results from evaluation study

Overall evaluation of prototype

- Overall evaluation of the prototype on 3 characteristics



Conclusions

- 2-D line visualization over the road network is a good approach for exploration and identification of traffic congestion.
- Users preferred visualization styles involving combination of line color and line width. Users found it more innovative, likeable and simple to understand.
- As an innovative traffic visualization attribute, TTI is equally preferred to the traditionally used average speed. Users found it understandable, appropriate and relatable for traffic congestion identification
- Visualization and exploration of traffic data is incomplete without supportive time dimension elements, in our case users ranked temporal graphs and dynamic time aggregates selections highest among other interactive elements.

Conclusions

- Spatial aggregations within line based data can be a useful visualization tool to explore traffic congestion between major or minor road intersections.
- Provision of interactive tools is the cornerstone of a traffic visualization framework for help in exploring the data and supporting in simple visual analytics tasks for domain experts, to aid them in decision making.
- The developed prototype is capable of performing basic visual analytics for traffic congestion identification. The design concepts can be adapted to be used with traffic data of for other cities.

Recommendations

- Improve the spatial overlap issue for width visualization stlye, which is a technological limitation of deck.gl
- Add capability for comparison of 2 segments/sections/routes
- Spatial query function could be useful for users to select and explore specific spatial features
- Implementation of more advanced visual analytics such a algorithms for pattern identification, or correlation between different traffic attributes.

References

- Andrienko, G., Andrienko, N., Chen, W., Maciejewski, R., & Zhao, Y. (2017). Visual Analytics of Mobility and Transportation: State of the Art and Further Research Directions. *IEEE Transactions on Intelligent Transportation Systems*, *18*(8), 2232–2249. https://doi.org/10.1109/TITS.2017.2683539
- Chen, W., Guo, F., & Wang, F.-Y. (2015). A Survey of Traffic Data Visualization. *IEEE Transactions on Intelligent Transportation Systems*, *16*(6), 2970–2984. https://doi.org/10.1109/TITS.2015.2436897
- Ferreira, N., Poco, J., Vo, H. T., Freire, J., & Silva, C. T. (2013). Visual Exploration of Big Spatio-Temporal Urban Data: A Study of New York City Taxi Trips. *IEEE Transactions on Visualization and Computer Graphics*, *19*(12), 2149–2158. https://doi.org/10.1109/TVCG.2013.226
- Juan Zhicai, Zhang Xiaoxiong, & Yao Hongwei. (2004). Simulation research and implemented effect analysis of variable speed limits on freeway. *Proceedings. The 7th International IEEE Conference on Intelligent Transportation Systems (IEEE Cat. No.04TH8749)*, 894–898. https://doi.org/10.1109/ITSC.2004.1399022
- Kraak, M. (2003). *The Space-Time Cube Revisited from a Geovisualization Perspective*. 9.
- Picozzi, M., Verdezoto, N., & Pouke, M. (2013). Traffic Visualization—Applying Information Visualization Techniques to Enhance Traffic Planning: *Proceedings of the International Conference on Computer Graphics Theory and Applications and International Conference on Information Visualization Theory and Applications*, 554–557. https://doi.org/10.5220/0004291605540557
- Pu, J., Liu, S., Ding, Y., Qu, H., & Ni, L. (2013). T-Watcher: A New Visual Analytic System for Effective Traffic Surveillance. *2013 IEEE 14th International Conference on Mobile Data Management*, 127–136. https://doi.org/10.1109/MDM.2013.23
- Silva, M., Vieira, E., Signoretti, G., Silva, I., Silva, D., & Ferrari, P. (2018). A Customer Feedback Platform for Vehicle Manufacturing Compliant with Industry 4.0 Vision. *Sensors*, *18*(10), 3298. https://doi.org/10.3390/s18103298
- Sobral, T., Galvão, T., & Borges, J. (2019). Visualization of Urban Mobility Data from Intelligent Transportation Systems. *Sensors*, *19*(2), 332. https://doi.org/10.3390/s19020332
- Zuchao Wang, Min Lu, Xiaoru Yuan, Junping Zhang, & Van De Wetering, H. (2013). Visual Traffic Jam Analysis Based on Trajectory Data. *IEEE Transactions on Visualization and Computer Graphics*, *19*(12), 2159–2168. https://doi.org/10.1109/TVCG.2013.228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