Visualizing the Sociotechnical System as an Urban Democratic Resource; the iCity User - centered project case study

Working paper

Jeremy Bowes, Manpreet Juneja, Carl Skelton, Michael Carnevale, Minsheng "Davidson" Zheng, Marcus Gordon, Sara Diamond

OCAD University, Toronto, Canada

Abstract

The increasing dependence of individuals on sociotechnical and technological systems in urban life today, has provided an enormous amount of data that reveals user stories, and provides individuals with choices around how they integrate these systems into the quality of their urban life. Visualization and visual analytics tools can provide critical support for researchers, designers and stakeholders to understand these democratic choices related to human activities. Correlating and representing quantitative data from human actors provides insight, explanations for patterns and anomalies that aid in decision support as a democratic resource.

The iCity urban transport project focuses on the development of data analytics transportation and transit planning tools that could increase individual and community participation to the development, planning, and design of transportation systems interfaces as a democratic resource. Through the combination of social media and mobile data with GIS, demographic, socio-economic, and transit data iCity researchers use tools to develop evidence-based User (persona) and Use types (scenarios) through data collection and form stakeholder and related individual user and community engagement profiles. As an interactive system resource iCity sets out the conditions for individuals and groups to highlight their needs /wants /values, participate in strategic planning opportunities as a democratic resource to realize outcomes.

In this way designers and users can identify requirements, provide expertise around more general and fundamental matters of quality, equity, and social values, and a perspective rooted in the experience of urban systems as human experiences. This paper focuses on the comparative methodology and integration of user needs to create a more democratic system resource.

Author Keywords
Democratic design resources, Sociotechnical systems, Transportation planning, Urban systems, Visualization

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1. Context & Rationale

The increasing dependence of individuals on sociotechnical and technological systems in urban life today, has provided an enormous amount of data that reveal user stories. The recent focus on socio-technical information systems and data mining provides insight into the use of technology to augment daily activities and provide socio-technical support for people in their daily lives.

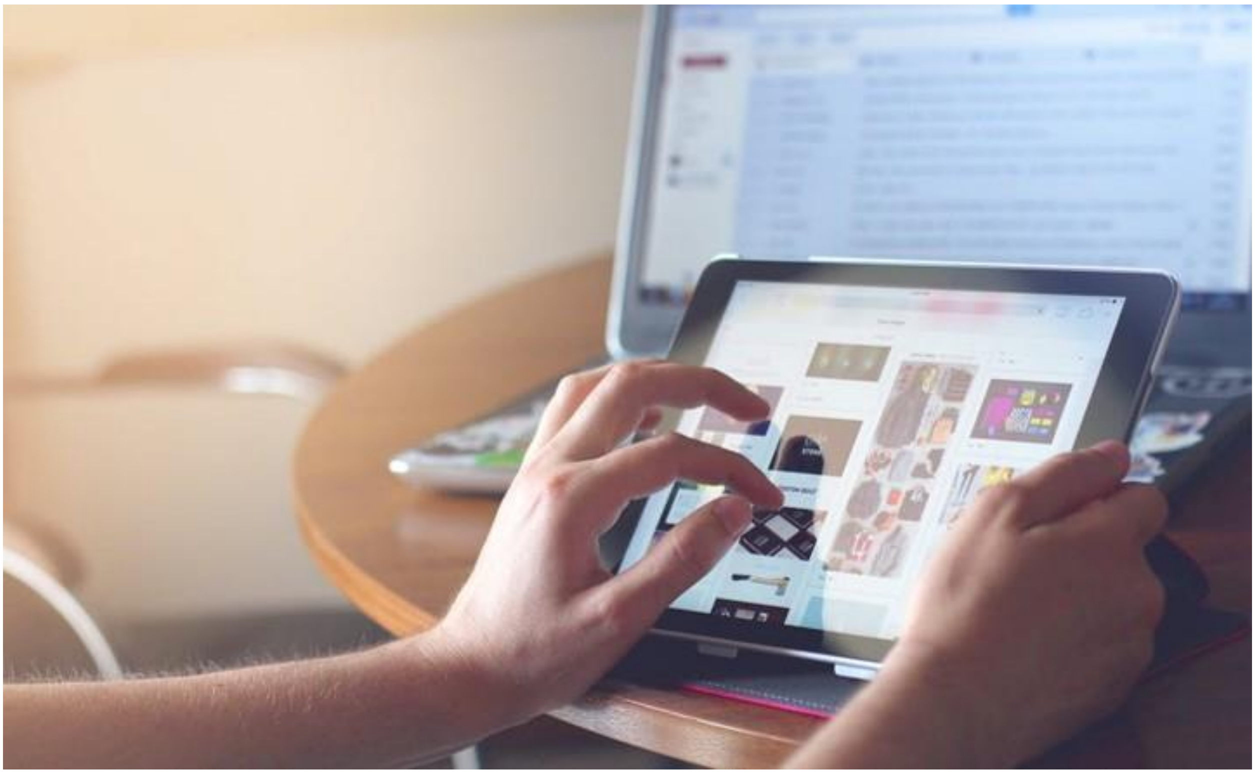


Fig. 1: **Socio-technical interfaces and data** , open source image.

The user stories provide insight into how individuals make choices around how they integrate these systems into the quality of their urban life. These user stories and habits are captured as recurring patterns of behavior; likes and dislikes, preference algorithms, and identification of shared user behaviors. The accessibility of sociotechnical systems provides individuals with choices around how they integrate these systems into their urban life, and how these choices influence the outcomes, decision making, and quality of life.

Visualization and visual analytics tools can provide critical support for researchers, designers and stakeholders to understand these socio-technical systems and the democratic choices related to human activities. Good visualization tools aid our ability to understand and visualize the data related to decision making can influence our choices, by correlating and representing quantitative data to provide insight for decision making processes, (Pike W. A. et.al., 2009), to understand trade-offs and possibilities, and through analysis provide explanations for patterns and anomalies, and this can be a valuable aid in decision support.

Fig. 2: **Socio-technical interfaces and data,** open source image.

Research in visual analytics shows that knowledge is created, verified, refined and shared (Pike W. A. et.al., 2009) through the interactive manipulation of the visualization. There exists a relationship between human cognition and interaction with visualizations, whereby visualizations supplement human insights.

In recognizing the value of understanding the user and their desires, design can be used to facilitate a participatory and democratic development of these needs in a user-centred process. This paper discusses the design process and the development of a prototype for a user-centered visualization support for urban transportation applications developed by the Visual Analytics Lab (VAL) at OCADU, through the iCity project, a collaboration between academic researchers, industry partners, city transportation planning departments and transit authorities that seeks to develop software support systems for transportation planning.

2. Users and Visual Analytic Tools

Over the last decade, the adoption of smart urban software and information technology infrastructure systems have had profound economic and societal impacts, while multiplying the complexity of data and the variety of domains of practice called upon to interoperate within. One of the key challenges is to ensure that diverse groups of users have appropriate levels of accessibility of data in usable forms. This requires an understanding of the visualization needs of user groups.

How could we focus our work and design process tools on the development of **Visualization and visual analytics tools** to provide critical support for researchers, designers and stakeholders through individual and community participation?

Focusing on a user centred process, the iCity visualization group explored visualization techniques from the context of users, user tasks and their level of interaction or engagement, and data type (Mahyar, et.al. 2015) within urban transportation applications. As an approach to the visualization; a taxonomy was developed as part of the iCity research project, from a literature review of related Taxonomy which included various papers and journal articles under the broad categories of data types, user tasks, representation type, human-centered taxonomy for visualization, urban design, urban transit, interaction type, etc. The taxonomy recognizes the importance of user tasks and data type, and we have framed this discussion in the relationship with use domains of the visualizations required for diverse user groups of the iCity project, that serves expert technical users, researchers, urban planners, civic leaders and public users of urban-visualizations. Whether experts or casual users, different user groups can have varied information-seeking motivations and objectives, and desire diverse representations of urban data.

These three categories, *User Task*, *Level of Interaction or Engagement* and *Data Type*, (Mahyar, et.al. 2015) served as the foundation for our work towards defining a taxonomy for urban transportation applications.

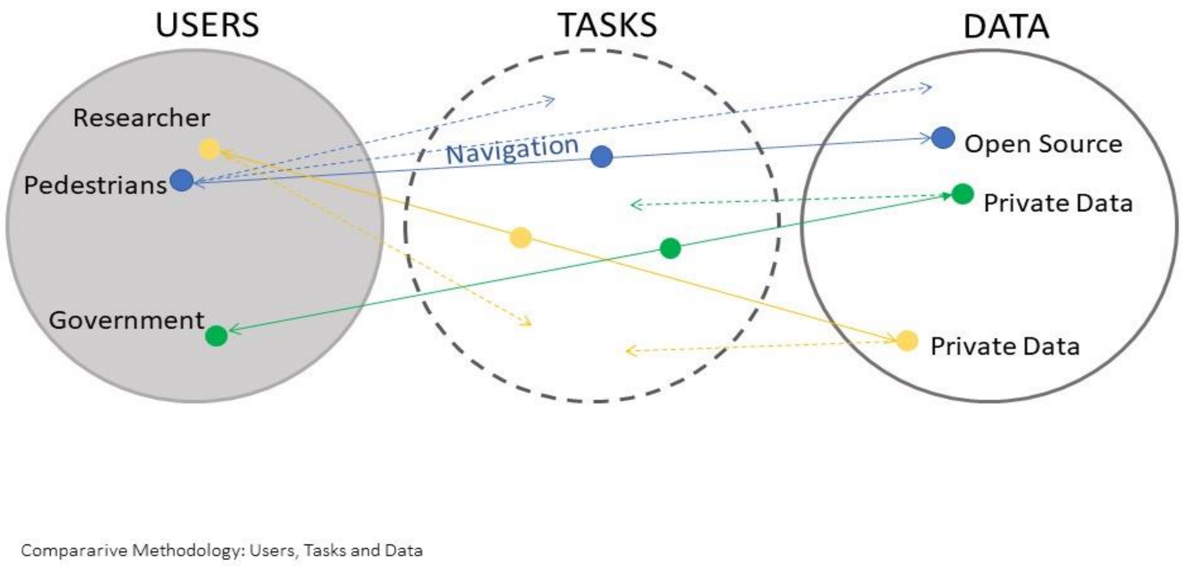


Fig. 3 Taxonomy for Visualization - Sketch showing essential aspects of visualization – relation between users, tasks and data type, iCity team image resource.

User tasks can be defined and classified based on the context and scope of the tasks. Wehrend (1993) defined ‘visualization goals’ as actions a user may perform on their data and presents nine such goals: identify, locate, distinguish, categorize, cluster, rank, compare, associate, correlate. Amar et al. (2005) present a list of low-level tasks, such as retrieve value, filter, find extremes and sort. Zhou and Feiner (1998) extend this work by defining “visualization techniques” as low level operations and “visual tasks” as interfaces between high-level presentation intents such as ‘inform’ and low-level visual techniques such as ‘highlight’ without describing ‘how’ an operation is performed

Brehmer and Munzer (2013) discuss tasks related to abstract visualizations, which focus on three questions: (1) Why is the task performed? (2) What are the data inputs and data outputs? And, (3) how is the task executed? In the context of visualizations targeted to multiple user groups, the taxonomy of user engagement proposed by (Mahyar, et.al. 2015) is noteworthy, as it frames user tasks in relationship to ***user interaction*,** both ‘types of interactions’ and ‘quality of interactions’, also referred to as ***engagements***. (Mahyar, et.al. 2015) argue that there is a spectrum in the degree of engagement (user interaction) with the visualizations varying from a low level engagement, such as simply viewing a data visualization, to a high degree of engagement which requires analysis, synthesis and deriving decisions. The rating of levels of engagement enables the assessment of user engagement for various categories of user groups which can prove beneficial when designing visualizations targeted to multiple user groups.

Our effort with this research has been to synthesize existing knowledge to propose a taxonomy for visualization for urban transportation applications that is user-centered with user motivations and needs at the center of the design. Our case study approach outlines the design process and proposes a User-centered approach to visualization for urban transportation applications that contextualizes the three major components of *data, visual and navigation* with Mahyar et.al’s levels of user engagement.

iCity as a Case Study with a User-Centred Methodology

Since the iCity project is client centred in it’s application, it is about developing decision support tools that combine social media and mobile data with GIS, demographic, socio-economic and transit data with the intention of this process to create a framework where users are at the centre of the designed socio-technical system. We found it necessary to study comparative methods, tools and applications within the context of our visualization framework, and the related disciplines in order to identify and understand the current visualization environment.

Comparative Applications & Tools

We began with a scan of urban transit applications, to understand the environment, and surveyed a wide range of software applications being used in urban transportation focusing on tasks being performed by the users in transportation and related uses. This was accomplished in tandem with a literature review of approaches to visualization tools, which helped us to define the criteria for evaluation for each of the applications we were studying, and provided categories of use domains to group application methods and functionality, as outlined in Figure 4.

Comparative Methodology: *A survey of the landscape of use domains to understand the types of software that exist and the functions already being served.*

The environment scan gave us broad classifications of software applications and tools (both of which from this point forward will be referred to as 'toolsets') serving urban transportation analysis, research, and planning along with the application of systems in related fields. The categories of toolsets were defined under the following headings:

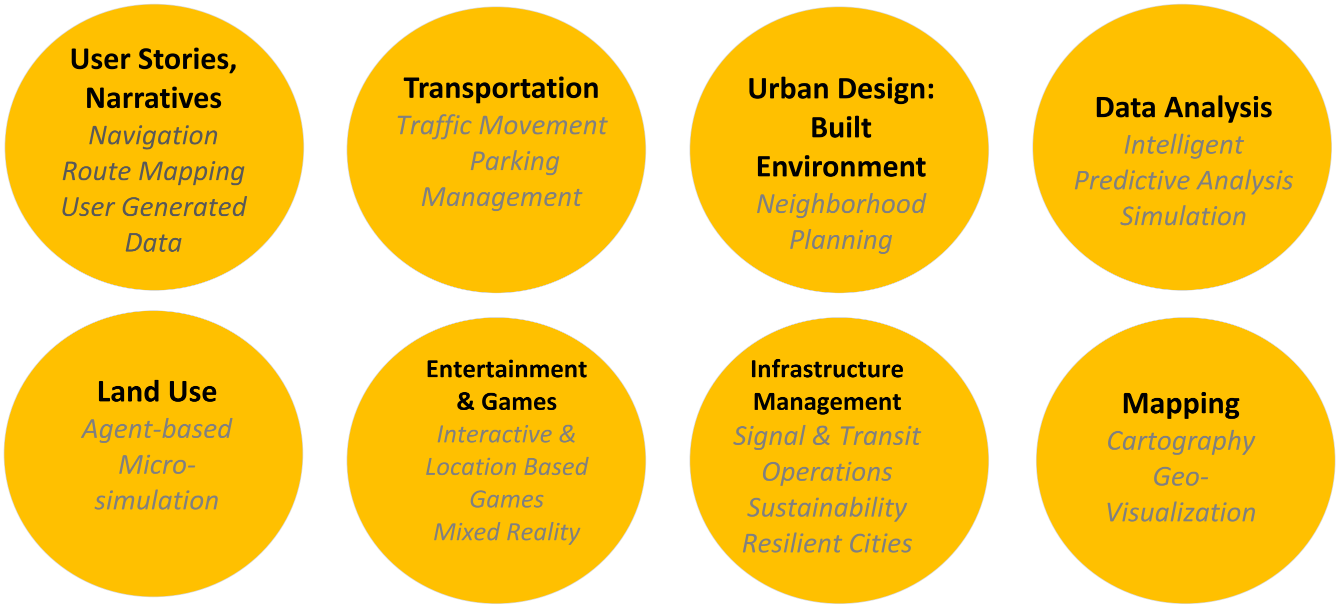


Fig. 4: **Software Application Categories: *Use Domains***

Many of these headings were subject to special focus, serving specifically the mandate of the iCity, and as our research progressed, it resulted in the following two amendments: Urban Design included Built Environment and Neighborhood Planning; Infrastructure Management included Sustainability and Resilient Cities, iCity Image Resource.

This list provided us with a baseline for the high-level **use domain categories** in which to aggregate both currently listed and future listed application tools (toolsets) within urban transportation. With this list, we created a comparative chart as a means to begin the organizing and visualizing of our findings. This chart helped us compare and contrast each toolset against similar criteria, thus understanding the nuances and major attributes that each was programmed to serve. The process also helped us to gather more information about the users being served by the toolsets, the tasks being performed, the data type, and other specifications such as file formats, data formats, and differentiating features within the toolsets serving similar use cases. This chart in Figure 5 (partial view) became a master document for our reference.

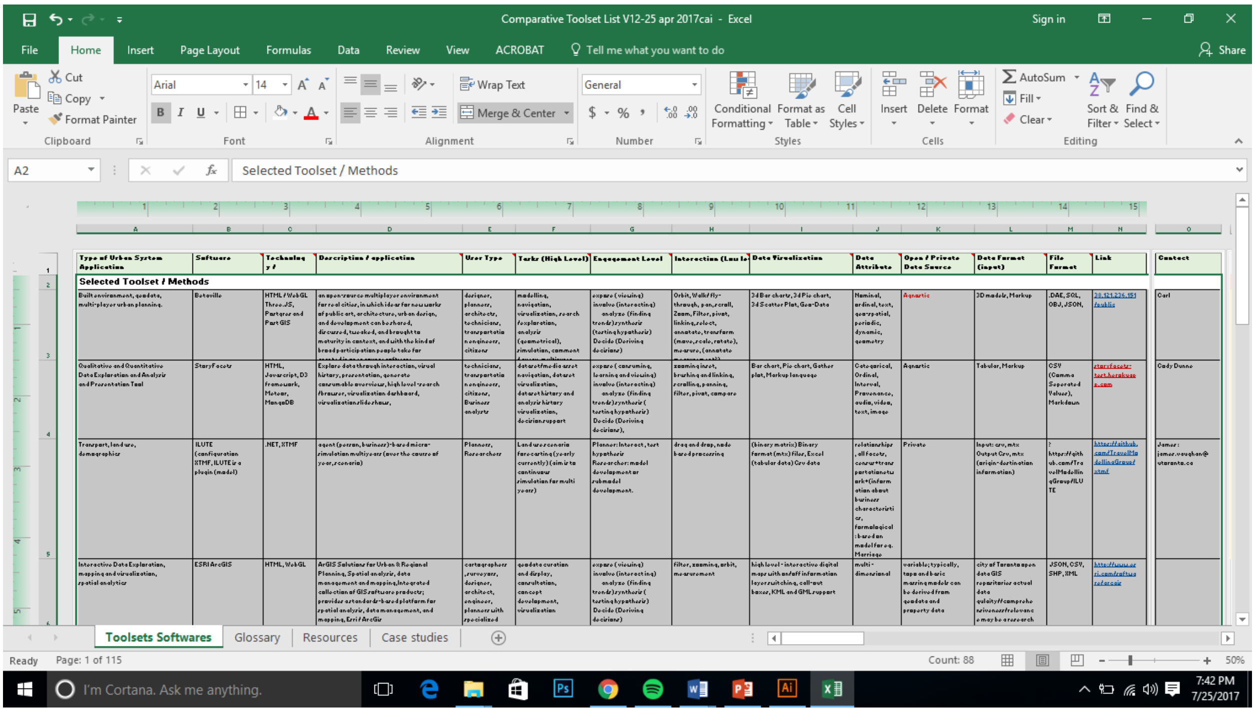


Fig.5: **Comparative methodology and tools chart** includes an environment scan of various urban transportation applications, iCity Team Resources

The intention of the comparative chart and the environment scan of the toolsets is to define a path towards identifying common needs of multiple users. This method helped us to document the user groups, tasks, existing and required data types, source of the data, and the level of engagement or interaction that the various applications currently provide. Although this environment scan will serve further stages of our research and support our work on a dashboard design, it's primary role at this stage, is to confirm that users, user tasks, data types, data source and user engagement are captured in the chart attributes.

Armed with this information we began a process of correlating various users with applications, to identify common toolsets, application functionalities and tasks between user groups, and the associated data sources, generating diagrams to correlate information as Fig 6 below.

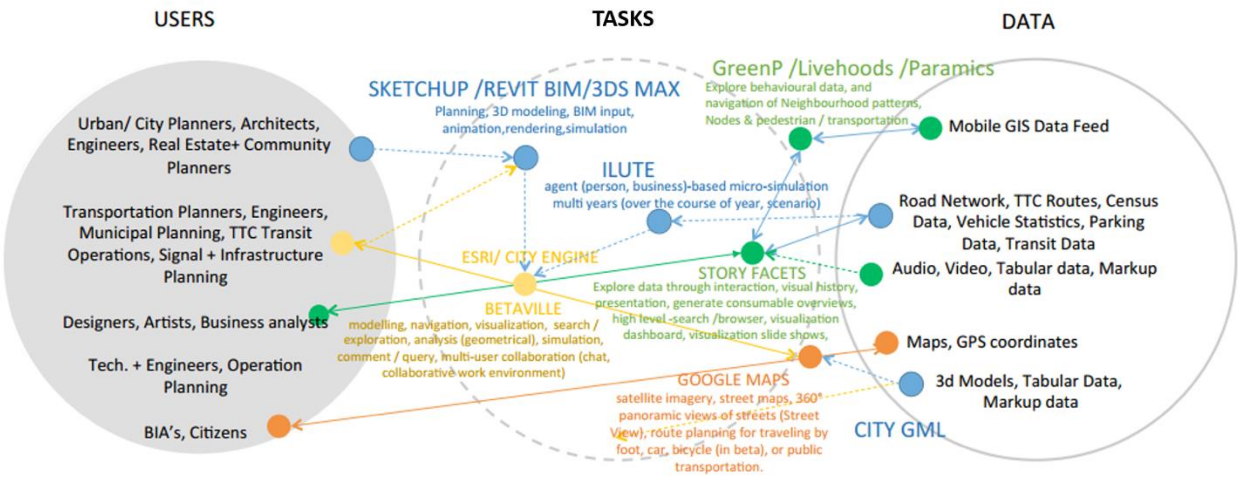


Fig. 6: **Diagram of comparative users, tasks, data, and applications,** iCity team diagram

3. User Types and Use Cases: Expert Interviews

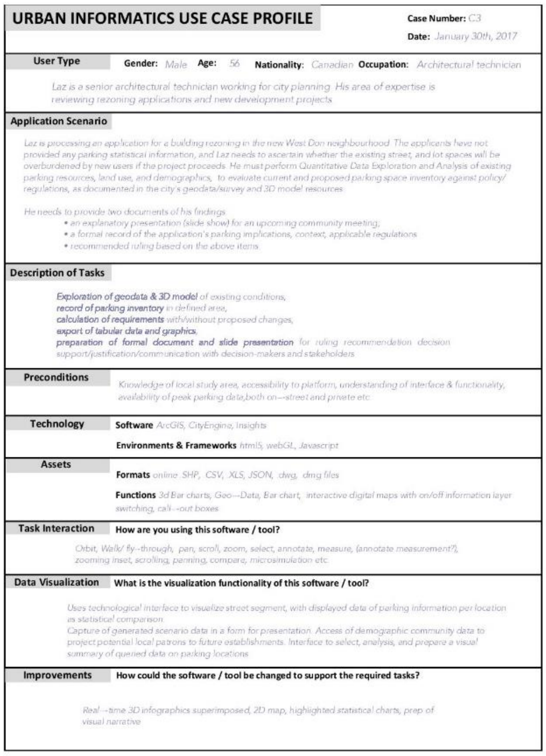
We followed the comparative applications environment scan with a series of interviews with groups of experts from fields within the urban transportation sector to better understand their visualization needs and challenges. These included iCity transportation researchers, urban planners, and computer scientists. With each group we developed **evidence - based user profiles (persona)** and **Use types (scenarios)** through discussions, to develop more information about task interaction, data visualization functionality, supporting data and technologies necessary in their current and future practices.

The interviews identified gaps in the existing visual representation of urban data in relation to user needs. The experts also shared visualization challenges they were struggling to address in their day-to-day visual analysis tasks. The interviews helped to map the landscape of visualization possibilities for different types of users, but we needed further clarity to understand the overlaps in requirements listed by various user groups. For example, our discussion with the transit research group indicated an inability to visualize scenarios such as accidents that may affect the route of a street car and therefore would constrain their capacity to re-route streetcars and avoid delays. This was a specific 'use case', which in turn needed a very specific type of representation, that may not be useful for any other use domain. This highlighted the need to research use cases.

A '**use case'** is a series of related interactions between a user and a system that enables the user to achieve a goal; it is an effective method to capture the functional requirements of a system (Shrivathsan M., 2009).

A use case template (survey sheet) was developed and circulated to the group of iCity project researchers to identify user profiles that corresponded to specific user scenarios. The researchers had the freedom to include as many scenarios as possible to illustrate their visualization challenges. The intention was to filter and aggregate user-types, user tasks and therefore existing and required visualization techniques. This initial survey was a preliminary request for the groups to identify specific use cases, and we collected this information for the preparation of a working session and design charrette with the user groups. The Figure 7 below shows the survey form "Urban Informatics Use Case Profile", with a summary of some of the question topics. While we received a limited number of Use Cases from each group, it was adequate for us to prepare a working design charrette with the groups to set priorities, and identify overlapping functionality needs.

USE CASE SURVEY
User Type
Gender, Age, Nationality, Occupation
Application Scenario
Description of Tasks
Preconditions
Technology
Software, Environments and Frameworks
Assets
Formats, Functions
Task interaction
How are you using this software/ tool?
Data Visualization
What is the visualization functionality of this software/ tool?
Improvements
How could the software/ tool be changed to support the required tasks?


URBAN INFORMATICS USE CASE PROFILE

Case Number: C3
Date: January 30th, 2017

User Type **Gender:** Male **Age:** 56 **Nationality:** Canadian **Occupation:** Architectural technician

Laz is a senior architectural technician working for city planning. His area of expertise is reviewing rezoning applications and new development projects

Application Scenario

Laz is processing an application for a building rezoning in the new West Don neighbourhood. The applicants have not provided any parking statistical information, and Laz needs to ascertain whether the existing street, and lot spaces will be overburdened by new users if the project proceeds. He must perform Quantitative Data Exploration and Analysis of existing parking resources, land use, and demographics, to evaluate current and proposed parking space inventory against policy/ regulations, as documented in the city's geodata/survey and 3D model resources

He needs to provide two documents of his findings
- an explanatory presentation (slide show) for an upcoming community meeting;
- a formal record of the application's parking implications, context, applicable regulations
- recommended ruling based on the above items

Description of Tasks

Exploration of geodata & 3D model of existing conditions,
record of parking inventory in defined area,
calculation of requirements with/without proposed changes,
export of tabular data and graphics,
preparation of formal document and slide presentation for ruling recommendation decision support/justification/communication with decision-makers and stakeholders

Preconditions Knowledge of local study area, accessibility to platform, understanding of interface & functionality, availability of peak parking data,both on--street and private etc

Technology **Software** ArcGIS, CityEngine, Insights

Environments & Frameworks html5, webGL, Javascript

Assets **Formats** online SHP, CSV, XLS, JSON, dwg, dmg files

Functions 3d Bar charts, Geo--Data, Bar chart, interactive digital maps with on/off information layer switching, call--out boxes

Task Interaction **How are you using this software / tool?**

Orbit, Walk/ fly--through, pan, scroll, zoom, select, annotate, measure, (annotate measurement?), zooming inset, scrolling, panning, compare, microsimulation etc

Data Visualization **What is the visualization functionality of this software / tool?**

Uses technological interface to visualize street segment, with displayed data of parking information per location as statistical comparison
Capture of generated scenario data in a form for presentation. Access of demographic community data to project potential local patrons to future establishments. Interface to select, analysis, and prepare a visual summary of queried data on parking locations

Improvements **How could the software / tool be changed to support the required tasks?**

Real--time 3D infographics superimposed, 2D map, highlighted statistical charts, prep of visual narrative

Fig. 7: Sample template "**Urban Informatics Use Case Profile**" content describing a use case, iCity Team

The list on the right outlines the areas of information collected. By the end of this process, we compiled a list of requirements, possible user groups and their visualization needs gathered from each research group, which provided enough information to create a tentative structure of task needs for urban transit data.

Design Charrette: Gathering User Centred Information for Transportation Applications

Guided by the synthesis of our findings from the chart, the expert interviews, and use case surveys, we created a list of user priorities by group, to test our first iteration of a taxonomy for urban transportation applications. We prepared an outreach through a design charrette that focused on our actual user groups, with an aim to refine our categories of users, user tasks, data representation, and interaction type.

The design charrette included the diverse user groups, and worked through a series of activities in a "world cafe format" to establish priority visualization needs for each group, and worked with different user groups to establish priorities and map shared priorities between user groups onto charts and sticky notes, from which we produced a summary of priorities and user - group needs. The design charrette also helped us to rework the taxonomy of visualization categories based on the suggestions from the iCity research teams. Shown below in Figure 8, are a few key images from the charrette.

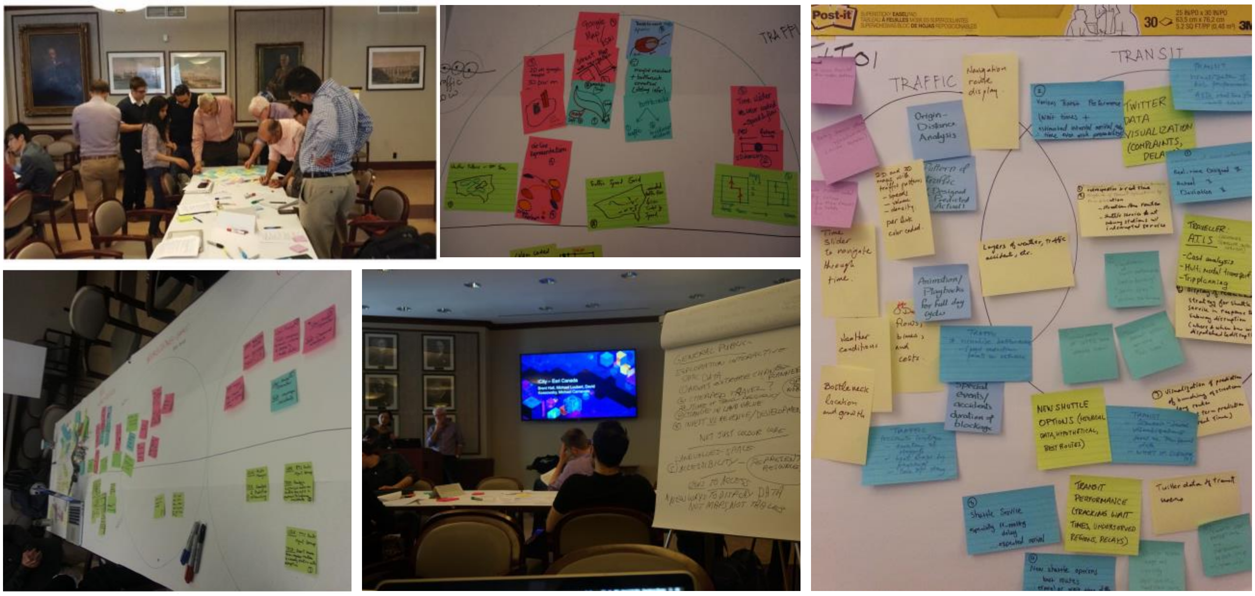


Fig. 8: **Design Charrette Photos,** iCity team images.

Breakout sessions, in a round table discussion with each of Traffic and Transit, Complete Streets, and the ILUTE / TASHA representatives. Some additional stakeholders from the City of Toronto, and Waterfront Toronto were also invited to provide a broader perspective of users.

For example, we combined user types with corresponding tasks and included levels of engagements; detailed 'data representation' as a category to enhance understanding around the data type and the techniques of representations. We recognized a need to detail 'engagements' in order to match intended tasks and the representations to the user. Since these users belonged to different domains, it highlighted the possibility to detail use domains further. It was necessary to define a taxonomy for visualization that clearly outlined user engagement goals against the components of visualizations, to clarify to designers the types of users, use domains and detailed context of use, and build its relationship with the components of visualization. By bringing these two essential pieces of visualization together, we highlight the importance of understanding the **end user and their intended interactions with the visualization,** for the Visualization designers.

We explored a definition and way of categorizing user engagement for our comparative chart, to identify the level of engagement required. 'User engagement' can be defined as the willingness to invest effort to explore and gain information from a visualization (Boy et. al. and Haroz et. al.) Mahyar et. al (2015) outlines six stages of engagement from high to low level; Decide (deriving decision), Synthesize (testing hypothesis), Analyze (finding trends), Involve (interacting), Expose (viewing). In our research with experts in the urban transportation applications we found that 'author' or authoring content is another type of user engagement missing in the list suggested by Mahyar et. al, (2015). Authoring content may include activities like uploading 3D models on Google Earth etc. and so we placed this activity between 'involve' and 'analyze'. User tasks are listed next to their corresponding level of engagement for the clarity in understanding user intentions at each stage of engagement.

In order to identify, and ensure a level of user engagement to support decision – making it was necessary to define and describe the level of user engagement required. This research around key components of visualization being Data, Visual representation, and Navigation needs, was important to understand inputs and outputs for any future dashboard framework.

Data, Visual and Navigation are described as components of visualizations by Sorger et.al. (2015) and we use these categories to describe integration techniques between the inputs and outputs in a visualization. For eg.: If an excel spreadsheet of a population of a city is 'Data' input, its representation as a Bar chart is a 'Visual' output.

Another way of understanding the relationship between Data, Visual and Navigation proposed by Sorger et.al (2015) is through the concept of "interactive controls" (Pike et.al., 2009) defined as the control points or elements of interaction in any visualization, for example tool sets, menu options, etc. The interactive controls of any display device should provide access to a set of low-level representation and interaction techniques that support higher-level intents (Pike et.al., 2009). The relationship between these techniques of representation to the user tasks include low-level choices of manipulating interactive components and higher-level goals related to the problems investigated. These controls form a feedback loop between the user and the visualization which the user should be able to further manipulate based on their intent. The distinction between techniques and intent helps in the development of analysis support tools, as a technique is never an end but a means to support the user's understanding of the data. (Pike et.al., 2009).

4. Applications: Visualization Prototypes for Data Analysis Interfaces

We are developing interactive prototypes that allow the visualization of data in many cases in a 3D interactive geo-visualization (GIS) environment. For example, through the provision a realistic virtual model of city of Toronto of multiple views of a generated 3D model, a dashboard interface can assist transportation authorities to run real time simulations and share the outcomes of the predicted scenarios with the wider audience to collect participant inputs into the decision-making processes.

While our focus has been on understanding the use cases, and the associated visualization needs for each group thus far, we have begun a process of visualization prototype testing of specific use cases. In some cases, this involves mapping data onto a geo-visualization map, to create an integrated data and GIS model. The integration of data onto a geo-spatial representation provides a powerful pairing of data representation with geo-spatial location, and this combination of **visualization and visual analytics tools** can provide critical support for researchers, designers and stakeholders, as a way of understanding the data.

We are also exploring how this can then be coupled with a user interface (dashboard) that allows individual and community participation and feedback, around urban issues, to set up the conditions for individuals and groups to highlight their needs /wants /values, to create a strategic planning interface. In the figure 9 below, we diagrammed the analytic tools needed for a number of the use cases with respect to one of the iCity groups; the Complete Streets group concerned with the functional, and qualitative aspects of an urban street environment, that desire a participant feedback surveying functionality along with the visualization capabilities.

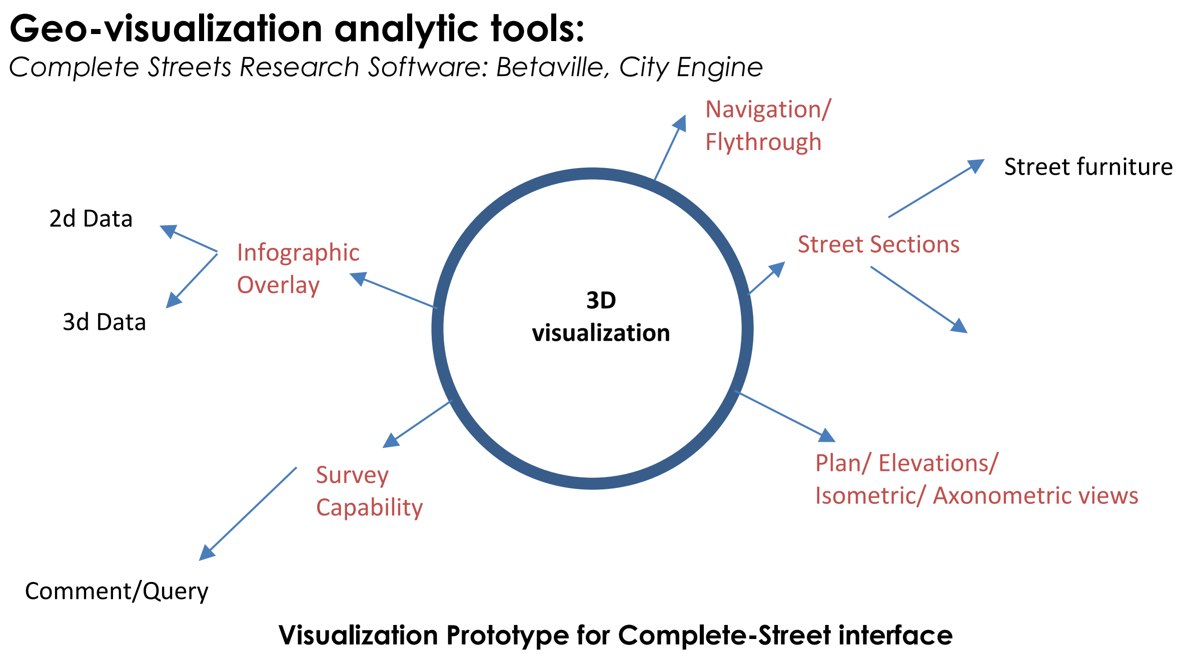
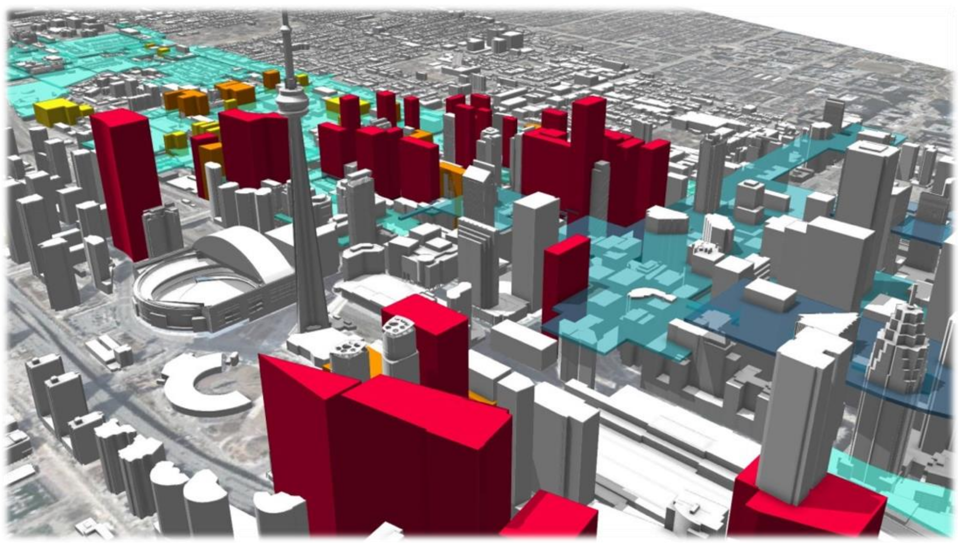


Fig. 9: **Geo-visualization analytic tools**

Diagram showing the various information, and functional aspects necessary to consider in a visualization model for one of the iCity groups: Complete Streets, iCity Team Visual Resources.

The choice for a visualization model needs to consider the user, the key attributes to be displayed, along with the data available, and desired level of interaction, navigation and engagement with the visualization. In some cases, the visualization may be a comparative representation of conditions with a limited toolset, as in the Figure 10 and 11 below.



Building development height restrictions by zone

Fig. 10: **Integrated infographics** overlay on 3d Map of the City of Toronto, Betaville iCity image resource.

Use of analytical data to augment the 3D mapping layers, Creation of a 3dimensional portrayal of graphical data analysis in the model, integrating geo-viz with data analysis. In this case the exemptions to city zoning can be portrayed in a visualization depicting relative height exceptions.

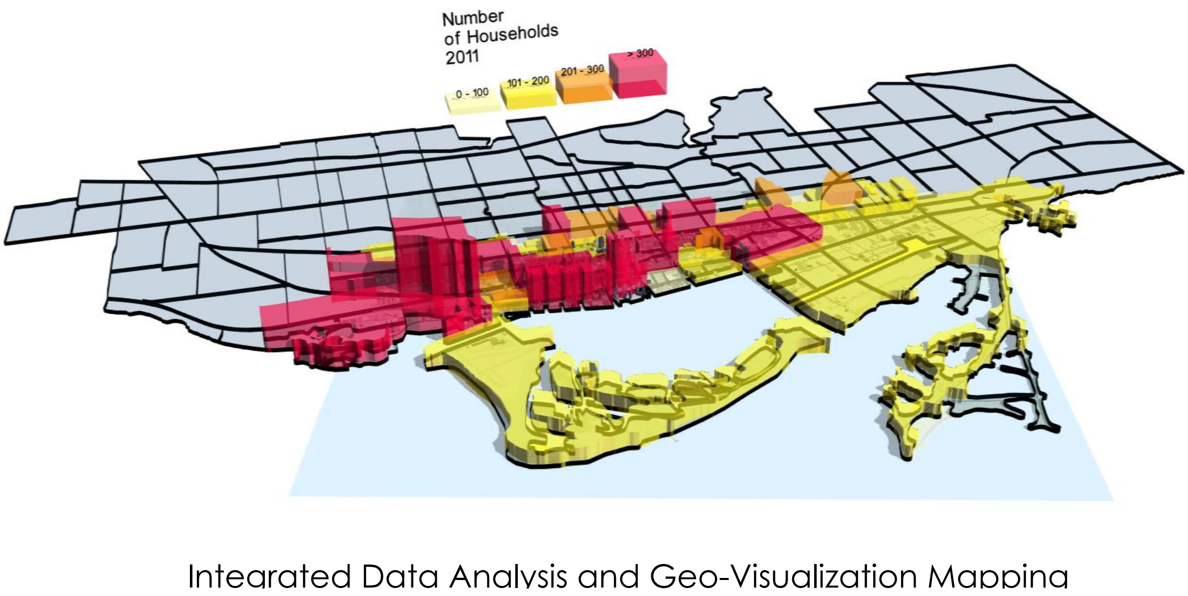


Fig. 11: **Integrated infographics overlay** on 3d Map of the City of Toronto

Use of analytical data to augment the 3D mapping layers, Creation of a 3dimensional portrayal of graphical data displaying the number of households per zone in the city of Toronto for 2011, iCity image resource.

We are also exploring how this can then be coupled with a user interface (dashboard) that allows individual and community participation and feedback, around urban issues, to set up the conditions for individuals and groups to highlight their needs /wants /values, to create a strategic planning interface, integrating narratives, infographic overlays, geo-spatial visualization, real time display, along with a comment / query functionality diagrammed in Figure 12.

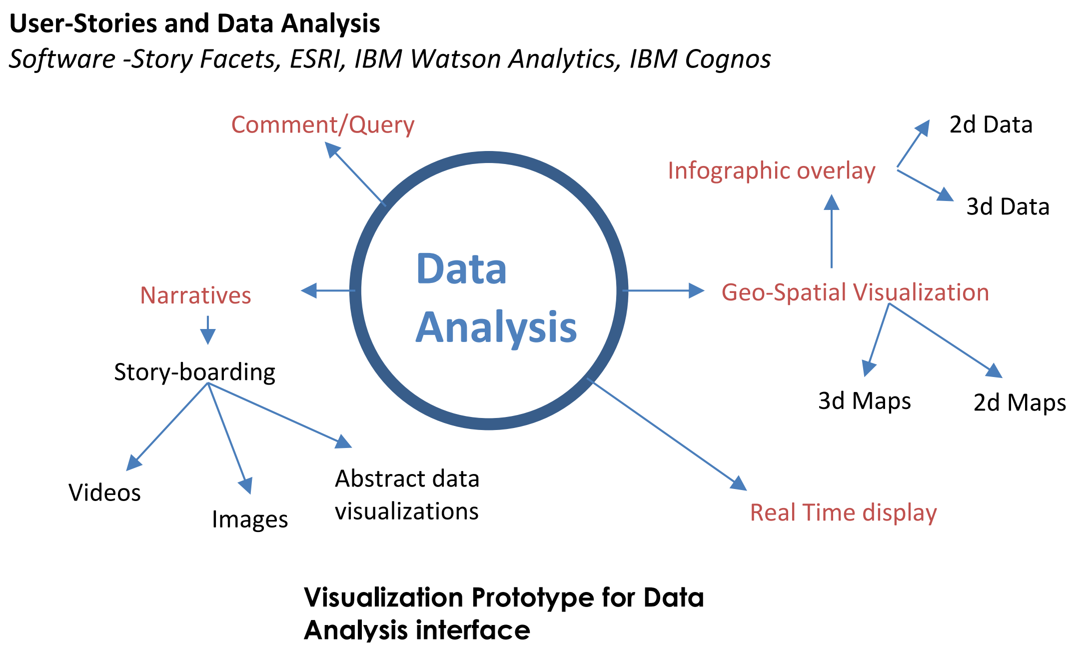


Fig. 12: **User Stories and Data Analysis -** Diagram showing various information types, and data uses necessary to consider in a visualization model for some of the iCity groups: Data Analysis Interface.

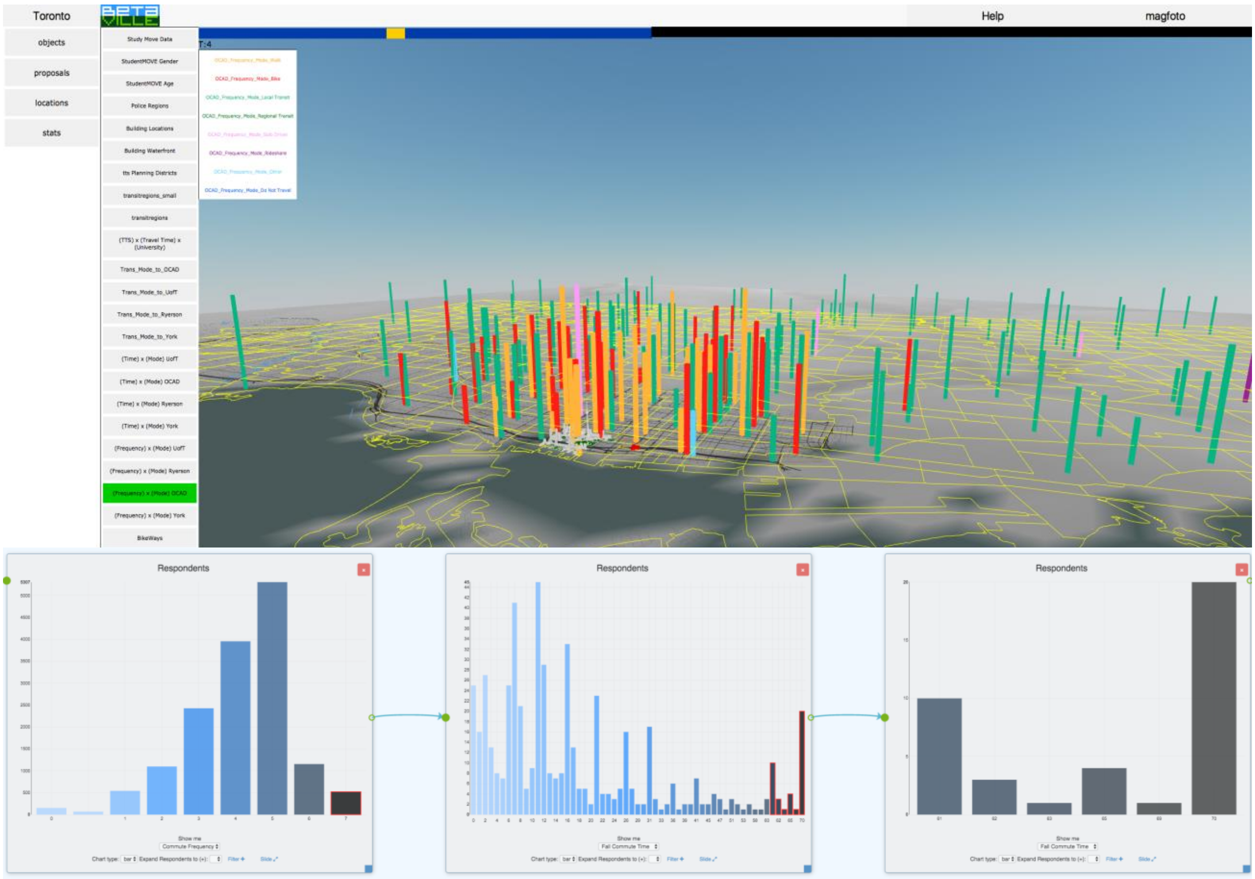


Fig. 13: **User Stories and Data Analysis** Example

This image shows the beta-version of Betaville currently being tested at the lab, where we used it to visualize StudentMoveTO (Toronto) survey data which was conducted in the fall of 2015 by Toronto's four universities with the goal of collecting detailed data to understand travel behaviour and its effect on the daily routines of the students. Three-dimensional visualization shown with graphs generated in a program called Story Facets representing a narrative sequence. iCity Betaville & Storey Facets resource images.

Conclusions

Our research process of working through a comparative methodology; a series of stages from a preliminary environment scan of applications and toolsets helped us to understand, and analyze, urban transportation software application systems, while emphasizing the importance the role visualization plays, to help designers of urban transportation applications understand essential elements and needs.

This approach of developing evidence-based User (persona) and Use types (scenarios) to form client stakeholder and related individual user and community engagement profiles, provided a user - centred process for design. Through the integration of a combination of social media and mobile data with GIS, demographic, socio-economic, and transit data, as an interactive system resource, iCity sets out the conditions for individuals and groups to highlight their needs /wants /values, and to participate in strategic planning opportunities to realize outcomes. It also serves as a starting point for designers of urban transportation visualizations to address categories of users, their tasks, level of engagements, data types and interaction functionality needs as part of a user centered approach to data analytics transportation and transit planning tools to increase individual and community participation.

In this way designers and users can identify requirements, provide expertise around more general and fundamental matters of quality, equity, and social values, and a perspective rooted in the experience of urban systems as human experiences, and demonstrates how design can facilitate a more democratic and participatory process for the design, development, and planning of a socio-technical system resource like transportation.

As next steps, we will utilize the results of the research towards our efforts to create further visualization dash board prototypes that serve the multiple user groups within the iCity research project, as a user – centred and driven methodology to provide enhanced decision support.

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