Transforming Big Data into Knowledge: Experimental Techniques in Dynamic Visualization

By

Stephen James Kennedy

B.S. in Industrial Design
Georgia Institute of Technology
Atlanta, Georgia (2009)

Submitted to the Department of Urban Studies and Planning
in partial fulfillment of the requirements for the degree of

Master in City Planning
at the
MASSACHUSETTS INSTITUTE OF TECHNOLOGY

June 2012

Author ______________________________
Department of Urban Studies and Planning
May 24, 2012

Certified by ______________________________
Professor Eran Ben-Joseph, Department of Urban Studies and Planning
Thesis Supervisor

Accepted by ______________________________
Professor Alan Berger, Chair, MCP Committee
Department of Urban Studies and Planning

TRANSFORMING BIG DATA INTO KNOWLEDGE: EXPERIMENTAL TECHNIQUES IN DYNAMIC VISUALIZATION

BY

STEPHEN JAMES KENNEDY

SUBMITTED TO THE DEPARTMENT OF URBAN STUDIES AND PLANNING ON MAY 24, 2012 IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN CITY PLANNING

ABSTRACT

Information visualizations, especially those utilizing web-based platforms, are becoming an increasingly common medium for exchanging ideas. This emergent class of tools enabling web-based, interactive platforms for visualizing data should be considered by urban planners and designers as an opportunity to create new modes of disseminating and communicating information.

This thesis provides an overview of new visualization tools: how they are being developed and combined, their applications, and their potential future uses. It also explores the implications of such tools in contexts where technology is not yet mainstream. This is illustrated through a case study of using mobile phones to gather data on the bus system in Dhaka, Bangladesh.

The research draws from literature written on critical cartography, visualization, and visual culture in urban design and planning. The work first develops a best practices workflow of existing and emerging visualization tools and platforms. It then constructs prototypes of products for various audiences that illustrate the outputs of data collected on Dhaka's bus system, showcasing the potentials of these new tools and platforms.

THESIS ADVISOR

ERAN BEN-JOSEPH

PROFESSOR OF LANDSCAPE ARCHITECTURE & URBAN PLANNING

HEAD OF CITY DESIGN & DEVELOPMENT GROUP

THESIS READER

CHRISTPHER ZEGRAS

ASSOCIATE PROFESSOR OF TRANSPORTATION PLANNING

TABLE OF CONTENTS

TABLE OF EXHIBITS

GLOSSARY

choropleth map: a thematic map in which areas are shaded or patterned in proportion to the measurement of the statistical variable being displayed on the map, such as population density or per-capita income.

dashboard: an interactive single-screen view for displaying real-time data aggregated into different visual formats

dynamic (visualization): refers to two dynamic aspects of visualizations, (1) interactive graphics that allow users to provide input and change in response, (2) visualizations that automatically update based on real-time input feeds

filter: a interactive feature that allows users to select or highlight subsets of information (Yau 2011)

flocksourcing: a process of data collection using guided volunteers equipped with well-designed sensors to collect data for a specified place and time[1]

infostructure: embedded and mobile network of transmitters, sensors, and receivers that provide feeds of data about the built environment, systems, and human activity

mouse-over: a computing term that refers to the response while hovering over an object or area on a digital interface

overlay: the superimposition of multiple layers in a visualization[2]

real-time (data): data responses immediately recorded or transmitted based on actions or events as they are happening

shapefile: a geospatial vector data format for use in GIS applications[3]

slippy map: a web-browser based map that allows users to pan the map by grabbing and sliding the map image in any direction. Modern web browsers allow dynamic loading of map tiles in response to user action without requiring the page to reload.[4]

time-series: a graphical convention for showing changes in a data set with time as a primary axis (Yau 2011)

visual artifact: the product or output of a visualization process[5]

web-based: a term used to describe interfaces or artifacts that exist on digital platforms (computers, mobiles, tablets, etc.) sourced using the Internet

1

CHING, ALBERT. (2012) "A USER-FLOCKSOURCED BUS INTELLIGENCE SYSTEM FOR DHAKA." MCP THESIS, MIT.

2

PISKULIYSKI, TIHOMIR, AND AMRUTH KUMAR. (2007). "A GENERAL FRAMEWORK FOR OVERLAY VISUALIZATION." ELECTRONIC NOTES IN THEORETICAL COMPUTER SCIENCE 178: 161-169.

3

ESRI (JULY, 1998). ESRI SHAPEFILE TECHNICAL DESCRIPTION. RETRIEVED 2007-07-04.

4

HTTP://WIKI.OPENSTREETMAP.ORG/WIKI/SLIPPY_MAP

5

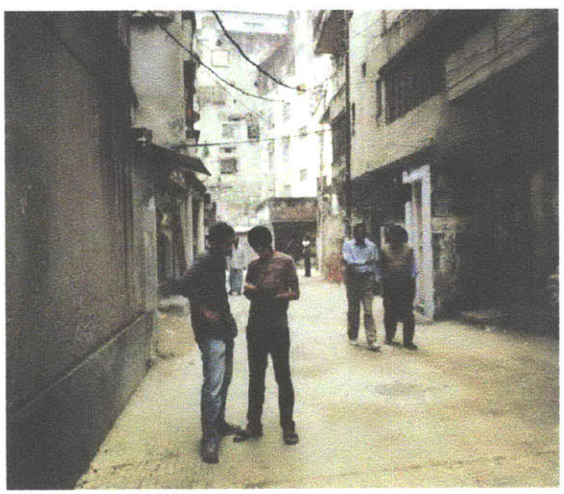
CARD, STUART K., JOCK MACKINLAY, AND BEN SHNEIDERMAN. READINGS IN INFORMATION VISUALIZATION: USING VISION TO THINK, 5.

PREFACE

SUBMITTED TO THE DEPARTMENT OF URBAN STUDIES AND PLANNING ON MAY 24, 2012 IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER IN CITY PLANNING

Dhaka must be one of the liveliest cities in the world, and the contrast between weaving through the din of the main thoroughfares and stepping into a peaceful alleyway for a chai presents a delicate balance that is worth preserving as the city continues to grow. Dhaka has been touted as the slowest city in the world, a superlative that manifested itself immediately upon arrival.

Dhaka's impaired mobility has ramifications for the physical, social, and environmental conditions of the city and the day-to-day livelihoods of each of its 18 million citizens. Here, mobility is provided by many modes, each one catering to different users. In a city without a significant public transit system (the city only operates a single bus rapid transit line), privately owned buses are the most popular form of mid-distance travel (greater than 2 km). As they traverse the city, buses jockey for scarce street space with rickshaws, autorickshaws (locally known as CNGs after the compressed natural gas that fuels them), cars, taxis, bicycles, motorcycles, and pedestrians. Dhaka has one of the highest projected growth rates in the world, so high-capacity transport modes will continue to play a critical role in the city's transport network.



EXPLORING GPS UPLOAD USING MOBILE DEVICES IN AN ALLEYWAY NEAR NEWMARKET, DHAKA, BANGLADESH

Improving mobility while accommodating this massive growth presents one of the most complex planning issues for the city.

Given Dhaka's constrained resources, few data exist about the transit system to inform the city, private bus operators, or entrepreneurs on how best to improve the system. Wealthier cities with more government involvement in transport have used sensing technology to collect data about bus systems, however, these bus intelligence systems are typically too expensive for developing cities to implement and operate.

In selecting a research context, many have chosen the safety, familiarity, and convenience of their home-base for testing and iterating. But the effectiveness of new tools may be better presented in relatively unexplored realms with partners who are equally eager to learn and explore. In initiating the work presented in the following pages, I was lucky enough to partner with a good friend whose explorations in entrepreneurial mobility in South Asia connected him with a charismatic team of change-makers in Dhaka, Bangladesh. Without this team, early explorations of such an unfamiliar territory would have been fruitless, frustrating, and near impossible. Their guidance and deeply embedded local knowledge helped us navigate the chaotic streets of their city. They exposed us to a world previously unimaginable; humanity moving at a scale I could not have fathomed prior to setting foot in Dhaka.

BIOGRAPHICAL NOTE

Stephen James Kennedy is an urban planner, designer, and artist formerly based in Atlanta with a background in Industrial Design from Georgia Tech. Prior to starting the Master in City Planning degree at MIT, Stephen cut his creative teeth designing furniture, packaging, lighting, websites, branding, and maps.

At first a reluctant transplant to Boston, Stephen has enjoyed escaping Boston by working as a hybrid planner-designer on signage initiatives in New Orleans, waterfront greenway planning in the Bronx, urban realm technology in Thessaloniki, participatory planning in Indonesia, stormwater management strategies in West Philadelphia, and New Town redevelopment in Kiryat Gat, Israel. Stephen leverages his design background for both physical planning and spatial information design.

INTRODUCTION

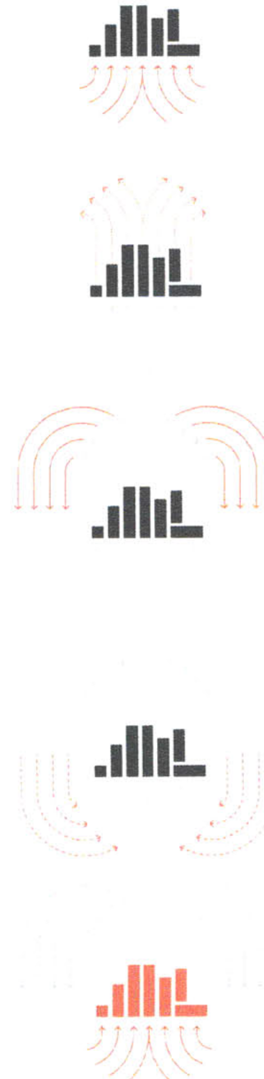
The Industrial Age challenged us to rethink the limits of the human body: where does my body end and the tool begin? The Digital Age challenges us to rethink the limits of the human mind: what are the boundaries of my cognition?

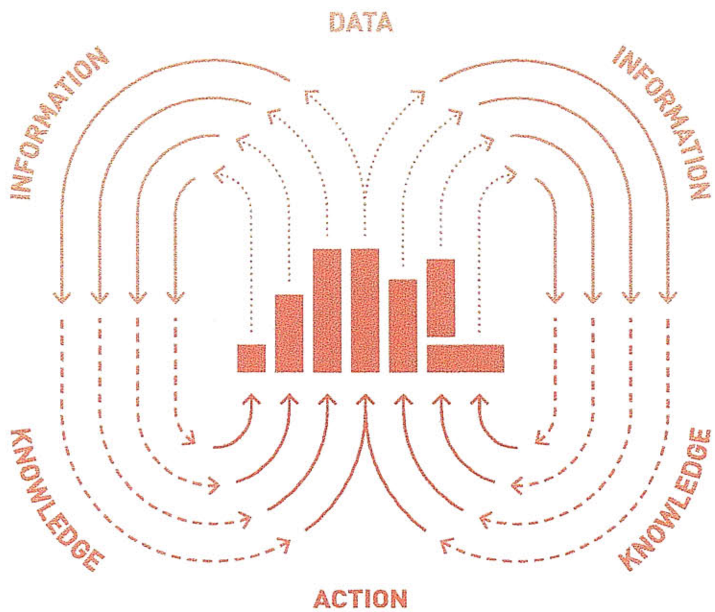
Douglass Rushkoff, in *Program or be Programmed* (2010)

0.0

THE ITERATIVE CITY: URBANIZATION MEETS THE RISE OF BIG DATA

Two important movements are shaping today's world: urbanization and the spread of information technologies. The human population continues to expand rapidly, and cities are the epicenter for this growth. People are flocking to cities seeking economic opportunity and access to the shared resources provided by urban developments. As the world's urban population grows, so too will the complexity of the systems and infrastructure that are necessary to support city life. Urbanization is changing the nature of how people live at scales they are only beginning to understand, with significant implications for the future of the planet. Today's world is infused with digital infrastructure creating a parallel information environment that is "as imperceptible to us as water is to a fish" (McLuhan 1954, 22). Most of the systems that operate within urban environments are now tied to an infostructure of data catalyzed by a series of technologies including the Internet, wireless communication, pervasive computing,





THE ITERATIVE CITY MODEL, SHOWING THE FLOW OF DATA TO INFORM ACTION TO IMPROVE THE CITY

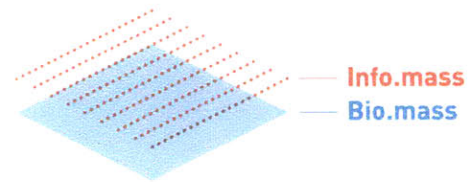
and mobile phones (Ben-Joseph 2011). This information environment has initiated a new era of big data, generating quantities of information so large that traditional techniques of collecting, manipulating, and representing data are no longer adequate. The growth of big data is driving a shift away from management strategies based on instinct or precedent; cities are now placing increasing importance on measurement and analysis in their management practices (Ratti 2011).

These two trends have important implications for the fields of urban planning and design. Anthony Townsend describes the convergence of these two drivers as transforming "every city into a unique civic laboratory—a place where technology is adapted in novel ways to meet local needs" (2011, 1). One of the planner's primary roles is to analyze and understand the city, and now, more than ever, we have the ability to view the city as a whole. Infrastructure and systems that were previously invisible are now revealed through digital information. Big data acts as a proxy for the city, or as described by urbanist William Mitchell it is an 'infomass' that intersects with a 'biomass' (2000). The infomass of big data shifts our perspective of the world, enabling both macro-scale views of larger systems as well as micro-scale details within those systems. Planners' ability to leverage the data describing the city will ultimately determine their effectiveness in shaping the built environment to meet their goals. Data enable planners to base decisions about place-making on analysis and measurement using tools that allow them to better test and understand the implications of different decisions. This is the rise of the iterative city, one shaped by feedback loops that are constructed as planners rely on measurements of urban activity to inform their decisions, implement changes, and measure again to assess their impacts, which in turn serves as the basis for the next set of decisions.

0.1

THE NETWORKED CITY AND ITS CITIZENS

The iterative city is made possible by new tools and methods that allow the measurement of things not previously measurable. One technology in particular has revolutionized the ability to gather data about human activity: the mobile phone. Data collection has been transformed as mobile technology has scaled simultaneously in two directions: the network of wireless infrastructure that has exponentially scaled up to permeate the built environment while the primary information transmitter/receiver, the mobile device has scaled down in relative cost, accessibility, and size (Mitchell 2003). Mobile phones are allowing new, fast, and cost-effective means for gathering data in many different contexts. In the developed world, cell phones are ubiquitous and constantly produce an unfathomable amount of data about patterns of human activity, made relevant by enterprises such as MIT's SENSEable City Lab. Smart phones are equipped today with dozens of sensors that provide everything from time and location to speed and air quality data. In the field of planning, data gathered through mobile phones provides the unique opportunity to study the activities of large populations at a very low cost (Manzoni 2009). "...[T]ruly smart cities will emerge as inhabitants and their many electronic devices are recruited as real-time sensors of daily life" (Ratti 2011, 42). This is an assertion repeated often in today's popular media. The devices that people use for their quotidian tasks produce data to degrees we are only beginning to fully fathom, let alone decipher and make useful.



THE CONVERGENCE OF BILL MITCHELL'S BIOMASS AND INFOMASS

TESTING MULTIMODAL
COUNTING IN OLD DHAKA

0.2

THE EQUITY OF INFORMATION

While information is rapidly changing the way cities develop and respond to needs, exclusion remains a problematic issue (de la Peña 2011). As society continues to be driven by growing global information networks, equity of both inclusion in and access to such information should also be a primary concern for planners. Smart applications of mobiles could provide better means for understanding the conditions of the world's megacities, particularly in the developing world. Mobile technology has the power to transform the nature of data gathering in these resource-constrained environments because it is low-cost, highly adaptable, enables multiple types of inputs and outputs, and has the potential for live and instantaneous data feeds.

But the question still remains: how will the outputs of these technologies "reduce the digital divide and assure equal access to information and communication technology" (Ben-Joseph 2011, 272)? This is particularly significant in the Global South, where the majority of mega-cities face significant barriers to collecting, sharing, and distributing data (Ratti 2011). This thesis has been developed in parallel to exploring new modes of data collection in these contexts through a research initiative, operating as the Urban Launchpad, that aims to answer the question of where the new possibilities of data should be applied: in the places that can afford it, or in the hundreds, if not thousands, of invisible cities that need it the most?

0.3

REVEALING THE HIDDEN DIMENSIONS OF THE CITY

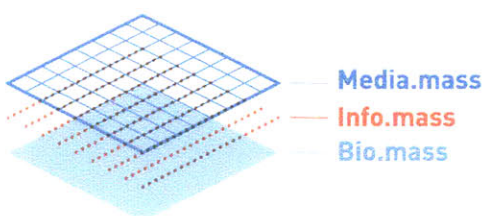
While the outcomes of planning often involve alterations of the physical world, much of the planning process is about understanding the less visible elements of the city and its systems. Tasked with the need to see the city all at once, the role of the planner is to envision and communicate changes and possibilities to a variety of audiences. From utility infrastructure to the impacts of policies and codes, visualization serves to reveal these hidden dimensions of the city and allows them to be considered in the analyses of planners and city agencies, as well as by the general public in the decision-making process.

As planners are gaining ever-increasing access to vast amounts of data that describe the built environment and urban activity, it is time that they also begin to focus on the strategies for representing and communicating the findings enabled by big data. While urban planning is centered around understanding and envisioning the future of places, it is also "about communicative process and educating the public" (Ben-Joseph 2005, 152). While the conditions of the built environment are more easily understood through the expertise of planners and designers, if we intend to develop a more democratic paradigm of the planning process, planners must develop strategies to overcome "the public's difficulty in visualizing the physical ramifications" of planning decisions (Ben-Joseph 2005, 152). Rubin calls for planners to incorporate new tools that enable more personal, impressionistic, and spontaneous understandings of the conditions of the built environment:

> As opposed to immodestly perceiving the city as an object for scientific examination, diagnosis, and curative prescription...the city is instead arrayed as an open field for encounter and engagement... The products or forms of knowledge that are today generated in the planning process need not be absolute or unambiguous. Professional representations that stem from urban encounters need not masquerade as objective or factual 'data.' A compelling alternative is to imagine planning as a collaborative act of listening and storytelling. (2011, 86)

Planners constantly negotiate between art and science, developing rigorous understandings of the built environment while enabling effective communication of planning decisions through narratives that are accessible to the broader public. Communication is a key element of planning, and "as researchers and practitioners we must

WITH THE CONVERGENCE OF THE INFOMASS AND BIO-MASS, IS A NEW MEDIAMASS RISING THAT FORMALIZES INFORMATION VISUALLY?



give far more explicit and systematic attention" to such a central aspect of the practice (Ben-Joseph 2005, 162).

The utility of data remains invisible until it is represented in some way that places a story or a conclusion that informs a directive or proposal in a context that is relevant to a particular audience. The process of visualization allows for the contextualization and application of a narrative through formal representation. In the field of planning, visualization can be defined as "the process of taking abstract ideas or data and translating them into easily understood or interpreted images to enhance planning, urban design and decision-making processes" (American Planning Association 2006, 543). Visualization can be seen to have two primary functions: the exploratory function that "allows us to perceive and recognize patterns... implicitly embedded in the data" and the rhetorical function that makes it possible to "demonstrate a finding in a shared, highly formalized language" (Offenhuber 2010, 367). Visualization in this context has two primary functions: the exploratory function that "allows us to perceive and recognize patterns...implicitly embedded in the data" and the rhetorical function that makes it possible to "demonstrate a finding in a shared, highly formalized language" (Offenhuber 2010, 367). Visualization will play an integral role in "navigating a world inundated with data" (Shepard 2011, 30) because it serves to filter and formalize information, which consequently enhances planning's ability to convey an argument or extract meaning from data. People are visually oriented, and the ability to understand the world is distinctly tied to the powers of perception through which meaning is drawn from dimensions, flows, dynamics, patterns, changes, trends, concentrations, gaps, links/connections, and systems. These are all examples of analytical frameworks for interpreting data that can be used to understand conditions and inform decisions that have implications in the physical world.

0.4

VISUAL DATA AS A PLANNING TOOL

Using design as mediator, the planner is able to select information, construct an argument, and organize it into a story. Visualization's greatest potential thus lies in advancing public understanding of vast amounts of data through its capacity to contextualize and root abstract concepts, which then enables planners to convey complex information in a format accessible to non-experts. It is therefore essential for information visualization to be incorporated as a core function of planning in order to increase transparency and democratic inclusion of the process.

A class of visualization tools on Web-based platforms is emerging that enable dynamic, interactive modes for representing data. By using the native languages of the Web, new programming languages and online mapping tools are laying the groundwork for visualizations that are:

- **Dynamic:** outputs can be updated as data become available, even in real-time. They also allow for data to be viewed at multiple scales, which is particularly relevant for spatial data, allowing users to view both the macro-view of an entire data set or zoom into a micro-view of a particular datum.

- **Interactive:** the visual platform enables searching or filtering of large data sets for specific details relevant to a user. Additionally, multiple layers of information and multiple methods for representing the same data can be incorporated in efficient formats.

- **Distributed:** can be deployed for broad public use on multiple platforms, from mobiles to computers. Even if dynamic visuals exist initially on the Web, they are still fully exportable for use in more static formats.

- **Participatory:** can allow for the direct input of data or feedback from users. This aspect can also refer to the open-source nature of many of these visualization tools and data sources which establish new degrees of customizability and transparency.

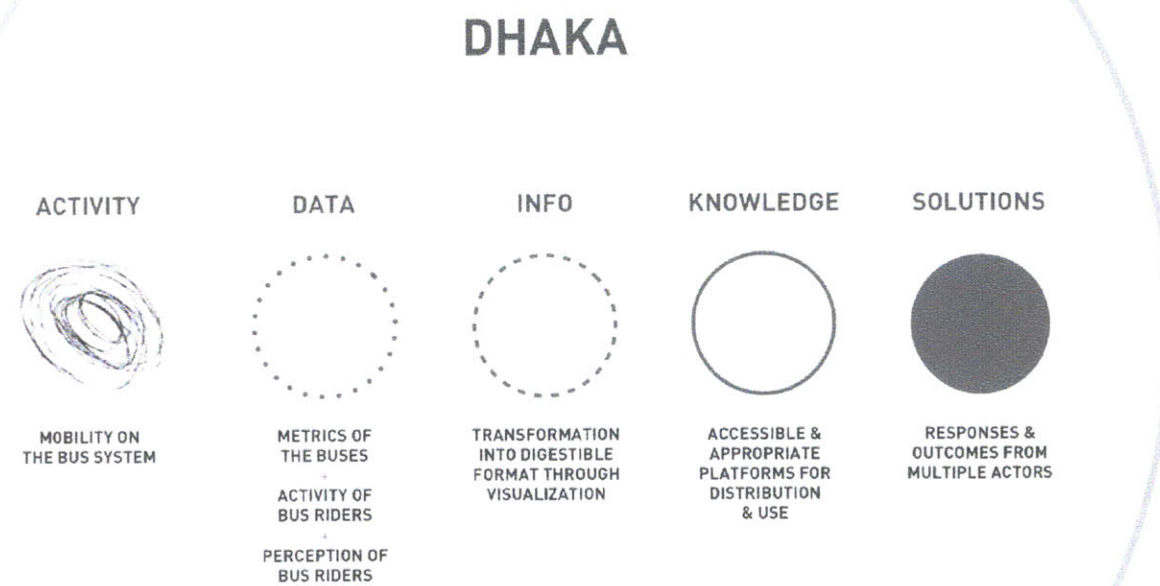
As visualization and Web-based platforms continue to improve the navigation and understanding of complex information, it is worth exploring the role of new tools for dynamically representing data. There are many means of visualization relevant to the work of planning, and as data continues to be a primary device for understanding urban phenomena, planners must adapt their methods for working with data. To be of particular value, then, dynamic visualizations should offer new and distinct ways of interacting with and understanding data. These reveal the hidden layers and processes of the city which better informs the public and further substantiates planning decisions. The question this thesis aims to address is: What are potential techniques for representing and disseminating dynamic big data in a largely analog context, and of what significance and use might it be to urban planners and designers?

0.5

SEEING DHAKA THROUGH DATA

As part of this research effort to uncover the uses of new visualization tools and Web-based platforms, this thesis utilizes a series of projects on mobile data collection in the resource-constrained environments of the developing world, which were coordinated by the Urban Launchpad. This data was collected with mobile technology by an

MOCK-UP OF A WEB-BASED BUS ROUTING MAP FOR DHAKA VIEWED ON A TABLET



organization known as Kewkradong based in Dhaka, Bangladesh, during the first three months of 2012. The data focuses on urban transit issues in Dhaka, and in particular presents metrics of the bus system, the activity of bus riders, and the perception of bus riders through mobile surveys. Using visualization and Web-based platforms as an armature, the thesis attempts to derive utility from big data about Dhaka's bus system.

0.6

AIM AND STRUCTURE OF THE THESIS

This thesis has several aims: (1) to examine how technologies are enabling better understandings of complex systems and human activity; (2) to provide a general guide to the tools available to planners and designers that can add utility to such understandings; (3) to analyze precedent applications of these tools; (4) to illustrate the complexity and resilience of one of the world's most vulnerable cities; and lastly, (5) to propose contextualized application of these tools in Dhaka.

Chapter 1 describes the role of data in understanding the built environment and human activity, and its significance for the field of planning. The Data-Information-Knowledge Continuum will be introduced as a primary framework for converting data into useful knowledge for various actors in the planning process. Visualization is presented as a key activity within this continuum. Finally, new methods for data gathering are reinforced by the convergence of spatial and temporal data.

Chapter 2 provides a brief overview of the history of visualization methods and how they have shifted perceptions of the built environment. The new dimensions of data are exposed, framed in the rise of a global infostructure. The rise of big data and the dominance of the Internet as a medium for exchange present new programming environments for visualizing big data. The chapter concludes with several experimental techniques for dynamically visualizing data collected for the Urban Launchpad.

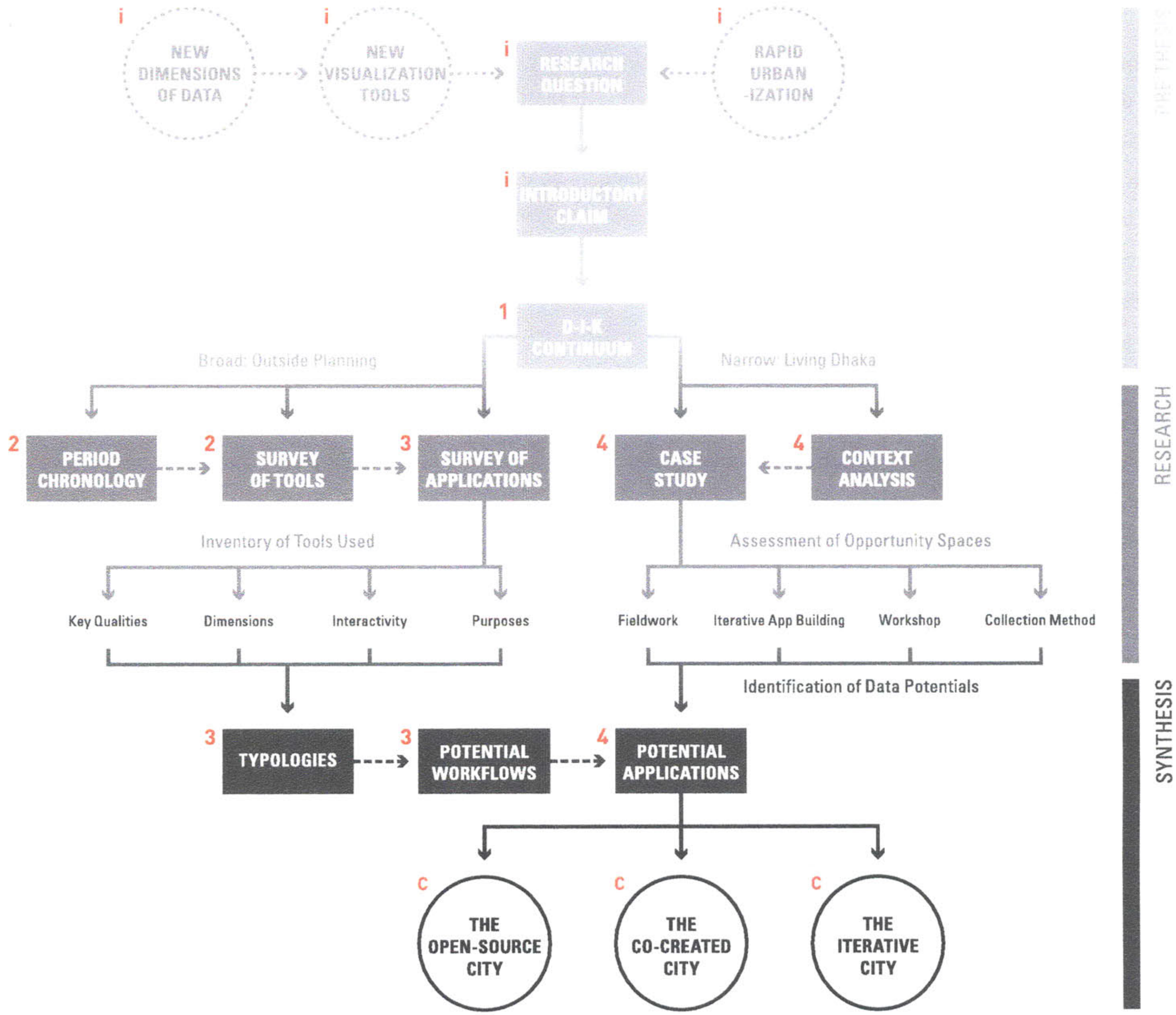
Chapter 3 focuses on methods for visualizing data relative to space, time, and other factors in order to transform this data into knowledge using dynamic visualizations. It presents a survey of key mapping strategies generated from secondary sources about data visualization, mapping, and visual literacy. This chapter will showcase an inventory of maps and diagrams that present best practices for representing multivariate data. In particular, the author will explore how online platforms, such as Google Fusion Tables and the Google Maps API, as well as other visualization tools, enable real-time and/or interactive presentation of data. Additionally, it will explore the importance of map interactivity, which enables the overlay of multiple dimensions of information in online, mobile, and physically-based prototypes.

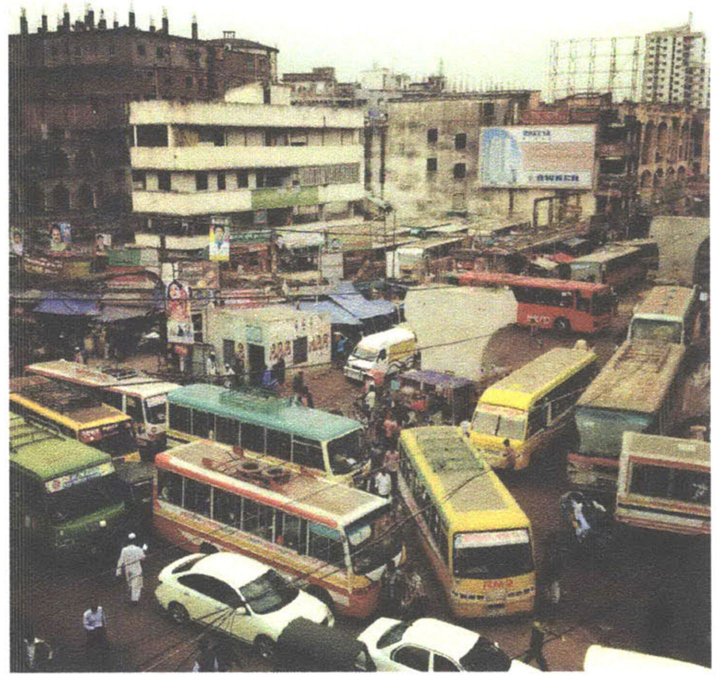
Chapter 4 presents a case study on the conditions of transit in Dhaka, providing a vivid picture of the chaotic, multi-modal environment. This narrative portrays the physical conditions of street life in the city in conjunction with descriptions of the socio-economic conditions, both of which underlie the need for cross-city mid-range commuting using the city's complex bus system. It will then describe an optimal format for visualizing and distributing the collected data. The chapter will close with a narrative that projects how visualization of crowd-sourced data can improve both the user-experience by providing key details about bus conditions and the city's ability to understand and improve one of its most complex and significant mobility systems.

0.6.1

STRUCTURE OF THESIS

- i INTRODUCTION
- 1 CHAPTER 1
- 2 CHAPTER 2
- 3 CHAPTER 3
- 4 CHAPTER 4
- C CONCLUSION





FAR LEFT: FIELDWORK RICKSHAW RIDES

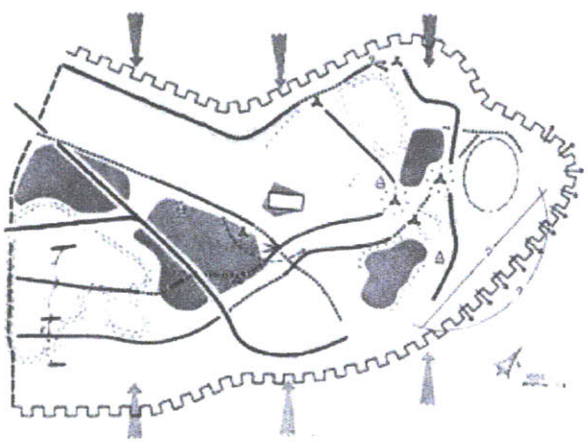
LEFT: 84 PEDESTRIANS, 13 RICKSHAWS, 10 CARS, AND 6 BUSES PER MINUTE, ON AVERAGE—AT FULBARIA, DHAKA, BANGLADESH.

CHAPTER 1

FROM DATA TO KNOWLEDGE

Where is the Life we have lost in living?
Where is the wisdom we have lost in knowledge?
Where is the knowledge we have lost in information?

T. S. Elliot, in "The Rock" (1934)



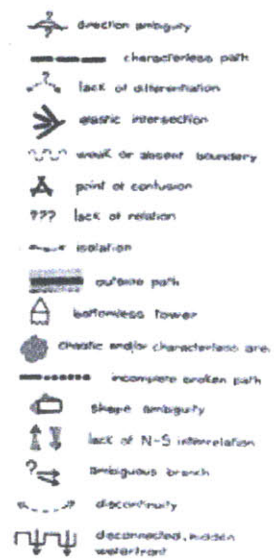
1.0

SEEING TO UNDERSTAND

For as long as humanity has been constructing cities, representing them has been an integral part of the process. Visualization has thus always been an important component of urban planning rhetoric. Given that planning's nominal product is a plan, the strategies for the development or adaptation of the physical environment are often formalized as visual objects through representational methods (Ryan 2011, 311). Visualization goes beyond the synthesis and representation of large data sets to incorporate context, narrative structure, layered functionality, novelty, and intrigue. While information visualization is now quite often cast as a necessary component of communication in today's hyper-connected world, we must be careful to ensure that this strategy is applied with the intent to achieve a new level of understanding that could not otherwise be achieved.

Maps, plans, charts, renderings, drawings, and diagrams are all visual mechanisms for generating dialogue

"PROBLEMS OF THE BOSTON IMAGE" FROM *IMAGE OF THE CITY* BY KEVIN LYNCH

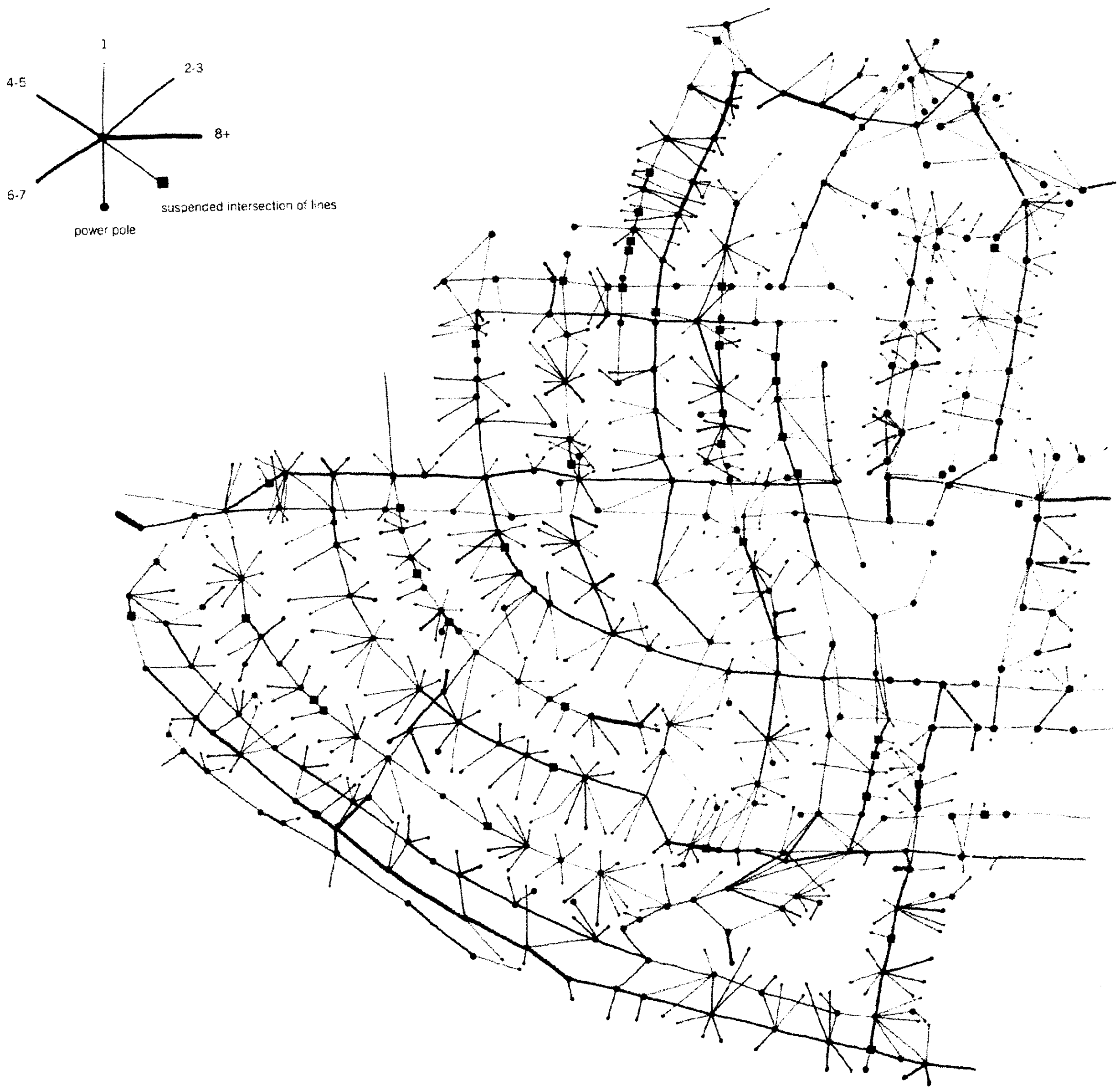


and understanding about the conditions of the built environment. They permit different depictions including narratives and experiences of place, approximations of reality, and statistical metrics, and even simultaneous combinations of these. Visualization can also serve several functions at various points throughout the planning process.

Visualization is first an exploratory act of description. In this function, Offenhuber describes it is an effort to "'amplify cognition' by externalizing thought processes" (2010, 367). In *Representations of Places*, Bosselman concludes that if planners are to suggest improvements for the city, "the designers of urban places first have to describe an existing city" (1998, 204). He proposes that the act of visual representation necessitates a proficiency in combining quantifiable information with sensory information, linking the physical world with the intangible elements that surround, relate, react to, and describe "...the geometry of form with the perception of form: statistical information about climate with a person's feeling of comfort; or the dimensions of buildings and streets with a persons perception of time" (1998, 204). When planners have access to data about a place or activity, the act of formalizing this data through visual structures can reveal its utility. This allows them to describe current conditions and identify opportunities.

Visualization is an effort in simulating what exists but may not be directly visible. It can be used to reveal hidden infrastructures, systems, or processes in order to understand how a city functions or how people are operating within it. This capacity also allows new perspectives to be explored through different visualization methods, such as aerials, wireframes, or x-ray views that reveal what would otherwise be invisible.

Visualization is also an effort to simulate what does not exist. For planning, it is the visionary act of contemplating what the future may hold for a place (Kwartler 2008). Representations can suggest alternatives or depict the impact a decision may have. This function is significant for planning because it adds tangibility and transparency to unbuilt ideas, enabling more informed decisions in



SQUIRREL HIGHWAYS, FROM *EVERYTHING SINGS* BY DENNIS WOOD

TO THE EVERYDAY OBSERVER, THE NETWORKED CANOPY OF TREES, TELEPHONE POLES, AND ELECTRIC WIRES THAT FORM A CANOPY OVER A NEIGHBORHOOD REMAINS OUT OF SIGHT AND OUT OF MIND. WHEN REPRESENTED AS A SYSTEM OF HIGHWAYS FOR SQUIRRELS, SUDDENLY A NEW DIMENSION OF THE BUILT ENVIRONMENT IS REVEALED.

planning processes.

Visualization is also an effective strategy for communication. In presentation, visualizations can serve as a proxy, a substitute for reality. They also allow for the formalization of abstract concepts such as codes, regulations, and processes, making spatial consequences "salient in presentation materials" (Ben-Joseph 2005, 153). This function is particularly significant in exchanges between experts and non-experts.

Finally, visualization can serve to provide narrative to what would otherwise be abstract or non-contextual content. Visuals can provide "human context to...data" or ground information in "personal experience" through the use of narrative techniques. Representations can just as easily be utilized to "[trigger] emotions as well as calculated thought" (Bosselman 1998, xii). E. H. Gombrich argues in *Art and Illusion* that "the mind asks first what a representation means; only when it discovers meaning is it ready to study the order of things in a representation" (Bosselman 1998, 187). This argument about the human reasoning process supports the evocative value of a visualization—the initial goal is to provide meaning to the user, drawing them in before they are ready to engage in the act of extracting information.

Each of these functions suggests that visualization plays a significant role in the transformation of data into actionable knowledge, warranting further attention to this process.

1.1

THE DATA-INFORMATION-KNOWLEDGE CONTINUUM

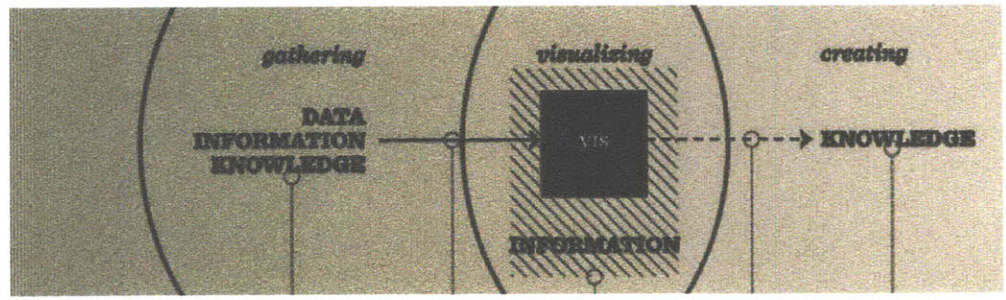
Much of the effort in dealing with data falls on unpacking its latent value into knowledge that is useful for understanding complex phenomena and substantive for decision making. There are many processes through which data can be transformed into knowledge. This thesis, however, focuses on visualization as a primary strategy for realizing the utility of data within a framework known as the Data-Information-Knowledge (DIK) continuum. The

DIK continuum illustrates a hierarchy of information that presents various phases of utility for data. In the domain of information science, the elements of the continuum are typically described as follows:

Data usually describes the initial phase of raw data that "simply exists and has no significance beyond its existence (in and of itself)" (Bellinger 2004). Typically, little can be gleaned from data in its rawest form other than discrete facts; the significance of a data element remains hidden until it becomes linked to other elements, contexts, or systems.

Information is data that has "been given meaning by way of relational connections" (Masud 2010, 446) that allow for a condition or phenomenon to be understood. Contextualizing, comparing, filtering, prioritizing, framing, and ordering represent a few of the relationships that provide meaning to data.

Knowledge is the application of collected information "such that its intent is to be useful" (Bellinger 2004, 1). Knowledge can be internalized for further interpretation, evaluation, and deconstruction in order to take action or make decisions.



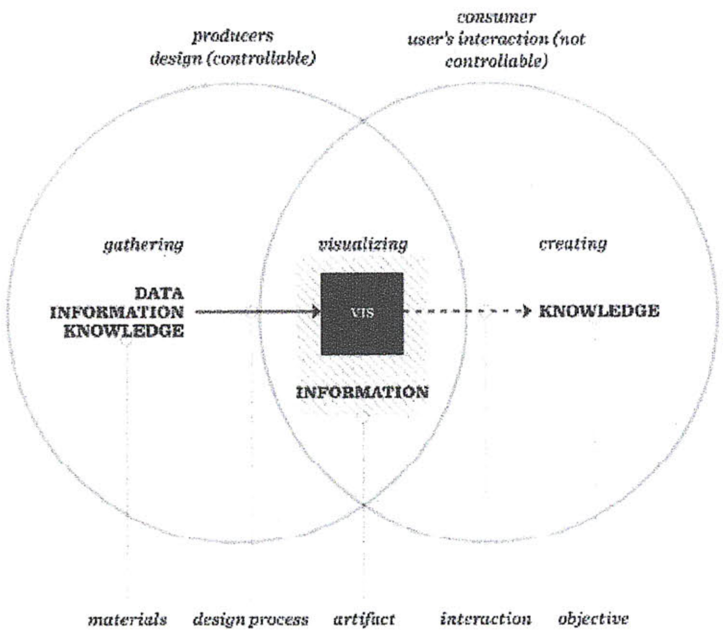
DIK CONTINUUM BY LUCA MASUD, DENSITY DESIGN (2010)

1.2

THE ROLE OF VISUALIZATION IN THE DIK CONTINUUM

Each of these states represents data to a relative degree of abstraction: knowledge from data is less abstract than information from the same data, as knowledge is applied in a way that is meaningful to a particular audience. Planners deal with both explicit knowledge that can be codified and transmitted through "formal, systematic language" and tacit knowledge that has a "personal quality...deeply

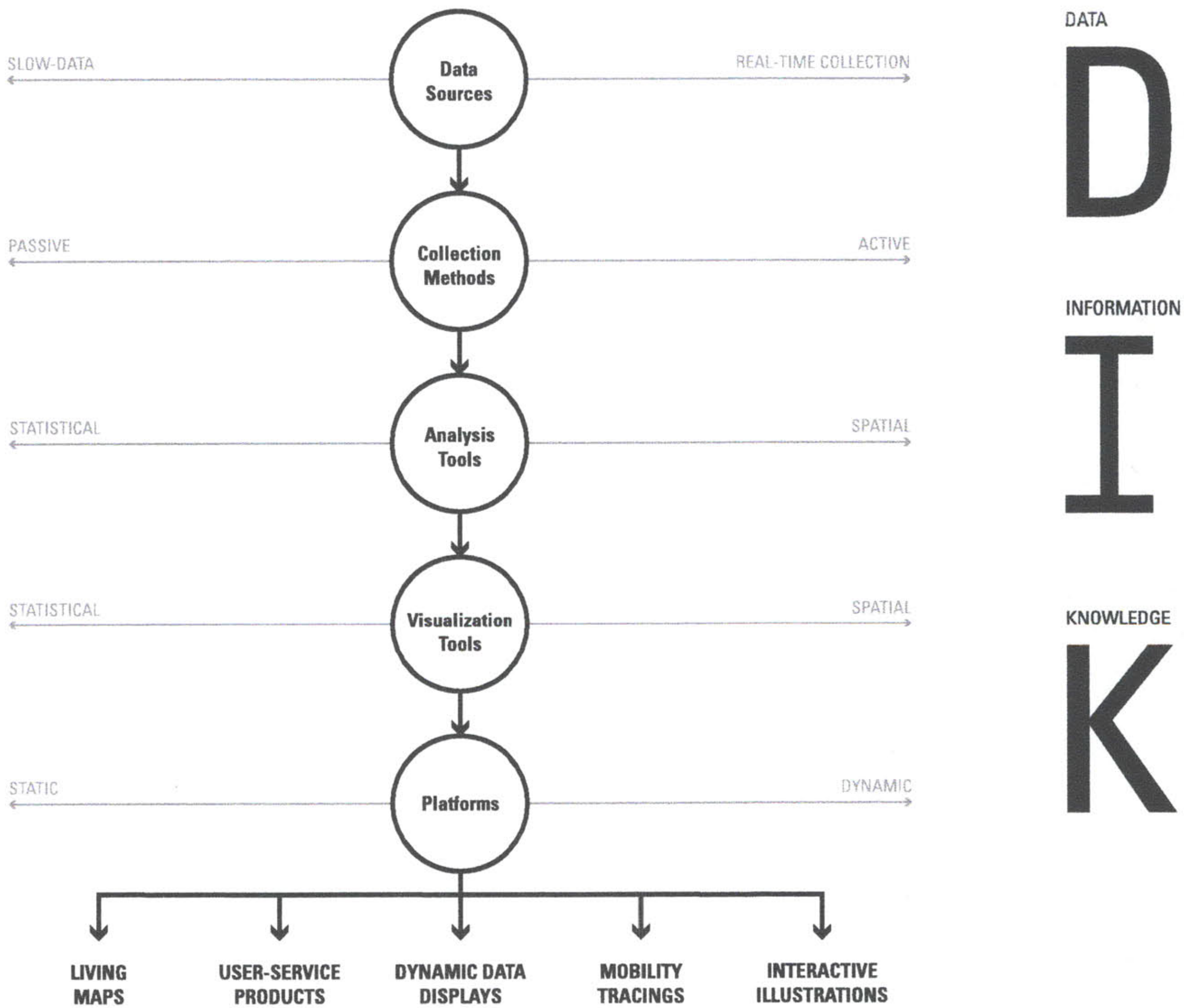
VISUALIZATION IN THE DIK CONTINUUM BY LUCA MASUD, DENSITY DESIGN (2010)



rooted in action, commitment, and involvement in a specific context" (Nonaka 1994, 16). Visualization enables information transfer in the space between these two forms of knowledge: visual techniques can infer actions and practices in context, thereby crystallizing knowledge that may be difficult to transfer through other formal languages, such as written text. Visualization in this sense creates an "artifact" of *information* that is consumed by a user, who is the receiver of *knowledge* (Masud 2010). In the field of planning, these artifacts most commonly take the form of maps, plans, charts, renderings, drawings, and diagrams, encompassing three types of visualizations: analytical, communicative, and formative.

Analytical visualizations generate declarative knowledge that allows users to make base-level assumptions about what data show. Examples of these functionalist visualizations are those used by professionals who perform detailed data analysis in a technical sense on a daily basis: analysts, economists, statistical scientists, etc.

Communicative visualizations are designed to associate meaning within data. These kinds of visualizations generate awareness and insight to users (Pousman 2007) through visual methods akin to storytelling. Illustrative and metaphorical techniques are used since the primary purpose is not the accurate retrieval of data, but to convey relationships and results (Masud 2010). Kevin Lynch's formal diagrams of Boston (see Fig. 8) are examples of communicative visualization because they convey a



1.3.1

TOOLS & PROCESSES WITHIN THE DIK CONTINUUM

TOOLS & PROCESSES WITHIN THE DIK CONTINUUM, AS DEFINED ON A SERIES OF SPECTRUMS BY THE AUTHOR narrative or a means of experiencing place.

Formative visualizations, deeply rooted in their specific context, are oriented toward action and the conditional understanding of *when* and *why* knowledge should be used (Masud 2010). These visualizations are most closely linked to the decision-making process, and represent the transfer of knowledge in a cooperative, social sense.

While this typology of visualization presents an overview of the function of visualizations in the creation of knowledge, specific components of the continuum are outlined in the following section as they relate to a spectrum of tools and platforms for data visualization.

1.3

TOOLS & PROCESSES WITHIN THE CONTINUUM

The Data-Information-Knowledge continuum is a framework that describes the tools used to transform data into knowledge. Each visualization's channel through the continuum is unique, with data being modified to produce specific results dictated by both the types of input as well as the desired output. The following framework describes each step, which illustrates the range of tools, strategies, or methods available. The spectrums illustrated are not the only variations that occur across tools, but rather the primary lenses by which one tool might be selected over another for a given process.

Data Sources: Data that can be obtained constantly such as mobile network usage or website traffic would be closer to the real-time collection end of the data sources spectrum. An example of a data source that sits closer to the slow-data end of the spectrum would be census data that is painstakingly collected on a mass scale over the course of several years. Each of these data types has a significant use, but for the purposes of this research, real-time data presents the most salient opportunity to explore new understandings of human activity.

Collection Methods: Methods for data collection range from passive to active. Passive collection methods refer to strategies that don't require direct participation, such as an installed bus intelligence system for GPS tracking. The other end of the spectrum describes collection methods that require the direct input of users, subjects, or data collectors, such as a survey.

Analysis Tools: Tools used to analyze data (which includes processing, cleaning-up, and coordination) exist on a range of being more statistically or spatially oriented. A geospatial program such as ArcMap has far stronger capabilities for processing data on spatial dimensions, whereas programs such as Stata or R have far stronger capabilities for statistical data processing.

Visualization Tools: The statistical-spatial spectrum also applies to visualization tools. Some tools are proficient at creating outputs that are more statistical in nature (graphs, charts, and diagrams), while others have clear proficiencies for the creation of locational and spatial representations (thematic maps, aerials, perspectives).[6]

Platforms: Platform choice plays a significant role in determining the accessibility and usability of data. The *static-dynamic spectrum* of platforms refers to the degree to which the output visualization can be updated or adapted based on real-time feeds of data. Static platforms, such as a report, provide snapshots of a phenomenon but need to be reproduced when a change occurs. Dynamic platforms are continuing to emerge with the proliferation of web-based programming environments that involve scripting and can pull in data feeds as they are updated. The added benefit of dynamic platforms includes an increased degree of interactivity such as filtering, time-series, animation, overlays, scaling, and mouse-overs.

This framework essentially provides the backdrop development of a workflow that takes data, converts it into base information through processing and visualization, and then creates new knowledge uses through deployment on various platforms. In general, the workflow favors real-time, active collection of data, analyses and visualizations that incorporate spatial and statistical attributes, and platforms that allow for dynamic and interactive representations.

6

IT IS WORTH NOTING THAT SOME TOOLS ALLOW FOR THE INTEGRATION OF BOTH ANALYSIS AND VISUALIZATION, BUT TYPICALLY IT IS THE SEQUENCING OF THESE TOOLS BASED ON THEIR SPECIFIC USES THAT ALLOW FOR THE STRONGEST OUTPUTS.

CHAPTER 2

READING THE CITY: NEW DIMENSIONS OF DATA

To see a world in a grain of sand,
And a heaven in a wild flower;
Hold infinity in the palm of your hand,
And eternity in an hour.

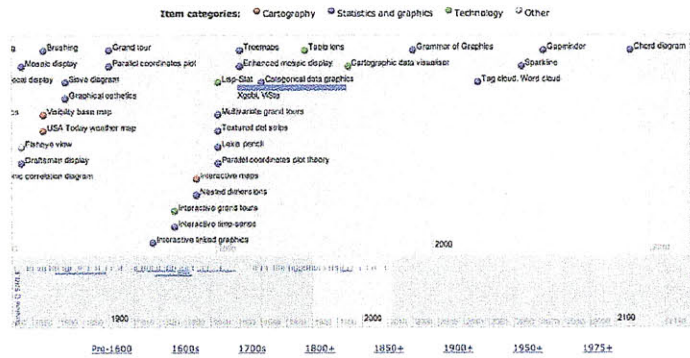
William Blake

2.0

A BRIEF HISTORY OF VISUALIZATION: SHIFTING PERSPECTIVES

Strategies of graphic representation and mapping have existed for centuries, born out of efforts to navigate the seas and skies, to document nature, and to understand numbers. Critical cartographers, geographers, environmental scientists, and art historians have all documented and catalogued milestones in the history of visualization. There are several key benchmarks in visualization strategies that have shifted how mankind is able to perceive the world. To frame the present state of visual representation, one must also recognize the transformations that have led to a new class of programming languages and Web-based tools.

Many historical accounts of Western representation begin in the 15th century, when Brunelleschi's development of linear perspective allowed three-dimensionality to be represented in painting and drawing, approximating reality through projections based on the way the human



MILESTONES IN THE HISTORY OF THEMATIC CARTOGRAPHY, STATISTICAL GRAPHICS, AND DATA VISUALIZATION, AN INTERACTIVE, ILLUSTRATED CHRONOLOGY OF INNOVATIONS BY MICHAEL FRIENDLY AND DANIEL J. DENIS

FRIENDLY AND DENIS'S CATALOGUE PRESENTS A RICH HISTORY OF (PREDOMINANTLY WESTERN) DATA VISUALIZATION INNOVATIONS. HOWEVER, LITTLE HAS BEEN DOCUMENTED IN THE PAST DECADE ABOUT THE RISE OF BIG DATA AND DYNAMIC VISUALIZATIONS.

eye perceives the world (Kwartler 2008). In the following century, Leonardo da Vinci's map of Iamola presented an astounding new vantage: his drawing detailed the city from above, a technique referred to as *ichnographia*.[7] The plan-view representation shifted the ability to see the city from an individual perspective to seeing its entirety from the heavens (Bosselman 1998). The earliest beginnings of visual thinking can be seen in the 17th century, ushered in by increasingly precise measurement of time, distance, and space due to developments in astronomy, surveying, and navigation. Graphic strategies were employed as analytical tools for geometric and probability theory and to represent some of the first uses of demographic statistics. New graphic forms in the 18th century enabled mapmakers to show more than just locational information: contours permitted three-dimensional readings of form on two-dimensional media. Thematic mapping increased as strategies for collecting empirical economic and political data became more systematic. Additionally, new technologies for reproduction such as color printing and lithography emerged that would facilitate the distribution of visualizations (Friendly 2006).

The use of maps as devices for conveying statistical data and generating exploratory perceptions of the city began in the middle of the 19th century. While usage of statistical graphics and thematic maps as analytical tools for the city continued to increase, the end of the 19th century also saw the first uses of photography as a narrative tool for conveying the emotion and experience of urban places. The work of Jacob Riis is one of the most famous examples this medium of exploratory perception. In his book *How the Other Half Lives*, Riis "used photography to (re)present what he perceived to be a social crisis" (Robin 2011, 88), spurring the Victorian urban reform movement

7

THE TERM STEMS FROM THE GREEK WORD *IKHNOS*, MEANING TO 'TRACE' OR 'TRACK.'

by revealing the conditions of slum and tenement districts in New York City.

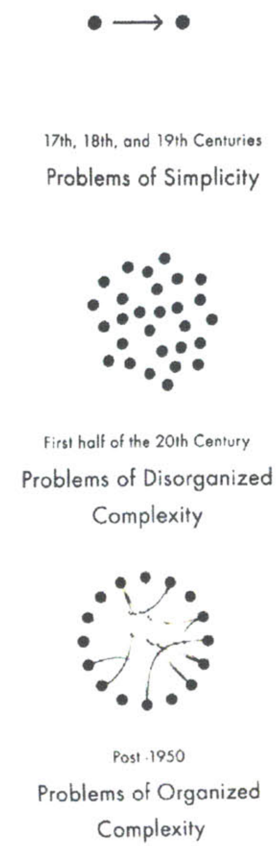
Visual historians refer to the first half of the 20th century as a 'dark age' for information visualization, with few developments or new technologies (Friendly 2006). However, in the field of planning, representations of the city became an object of display. General Motor's Futurama Pavilion at the1939 World's Fair in New York enraptured crowds with a 4-acre physical model of a shimmering city of the future:

> It was an experience never imagined before. A journey into artificial reality where sounds, visions, and three-dimensional models told a story better than words ever could... In front of us a whole world lit up, as if we were flying over it, the most fantastic sight I had ever seen, an entire city of the future... (Ben-Joseph 2005, 151)

As a planning tool, this physical simulation fully engulfed viewers in the experience of an envisioned reality.

Developments in visualization in the latter half of the 20th century were driven by advances in computing technologies and the proliferation of the personal computer; the establishment of exploratory data analysis as a field of statistics; and the commercialization of tools and software enhancing the collection, input, and display of information (Friendly 2006). These factors drastically shifted the scales and speeds at which visualization could occur. For planning, this led to the development of several of the major digital tools considered core competencies in the field today: computer-aided drafting (CAD) as a drawing, modeling, and simulation tool and geographic information systems (GIS) for spatial analysis and representation (Ben-Joseph 2005).

Significant developments in the 21st century that have altered the methods and role of visualization are the globally connected societies of the Internet era, infostructures embedded in the systems of the built environment, and the ubiquity of the mobile phone. These factors have increased the scale and availability of digital data, presenting an extraordinary resource for planners.



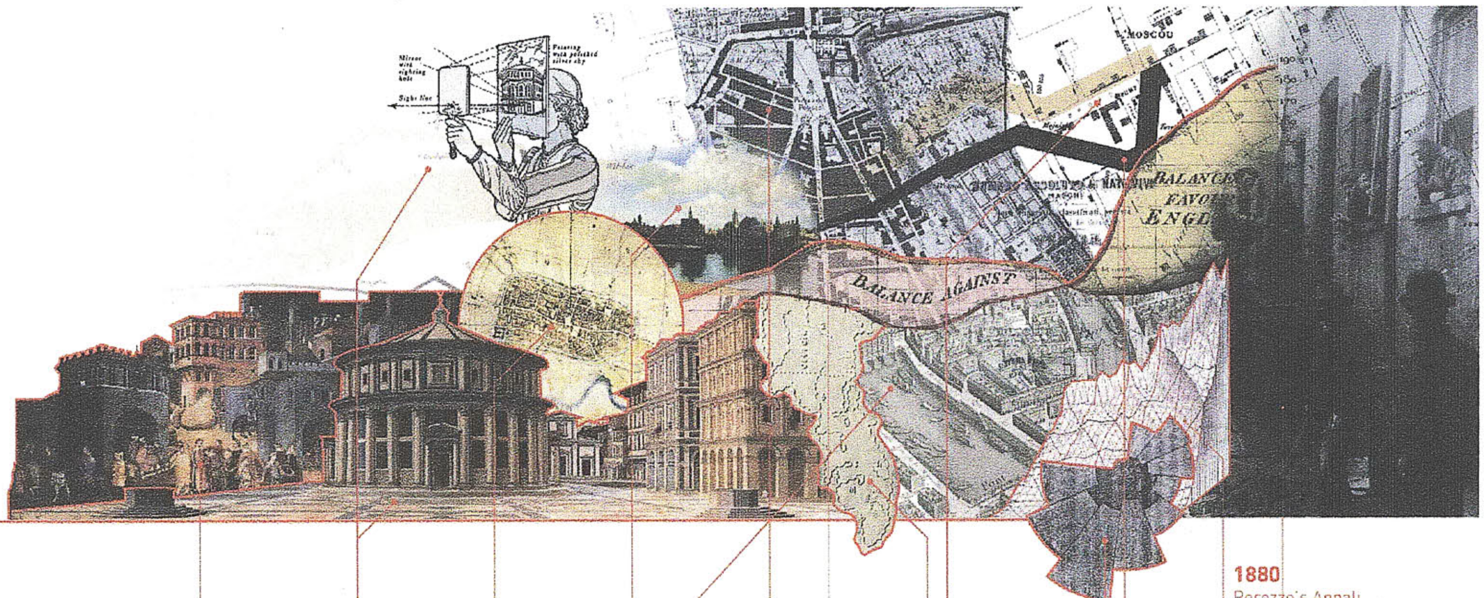
THEORETICAL SHIFTS IN THE COMPOSITION OF PROBLEMS, FROM *VISUAL COMPLEXITY* BY MANUEL LIMA

2.0.1 A CHRONOLOGY OF SHIFTING PERSPECTIVES

NOTE, THIS CHRONOLOGY PREDOMINANTLY CONSISTS OF EUROCENTRIC AND AMERICAN INFLUENCES ON REPRESENTATION

PERIOD
EXAMPLES
MEDIA / TOOLS

THE PERSPECTIVE CITY | THE CITY FROM ABOVE | THE NATURALISTIC CITY | THE STATISTICAL CITY | THE EXPLORATORY CITY



1338-1340 "Effects of Good Government on City Life" by Lorenzetti

1500 Linear perspective by Brunelleschi

1502 Iamola Map by Leonardo da Vinci

1660 "View of Delft" by Jan Vermeer

1739 "Plan de Paris" by Turgot & Beretz

1748 Map of Rome by Giambattista Nolli

1786 Playfair's "Balance of Trade"

1837 "Atlas for the Blind" by S. G. Howe

1854 Broad St. Pump Cholera Epidemic map by John Snow

1858 Florence Nightingale's Coxcomb diagrams

1869 Minard's March on Moscow

1880 Perezzo's Annali di Statistica

1890 Jacob Riis's "How the Other Half Lives"

PAINTING

ICHNOGRAPHIA

CAMERA OBSCURA

THEMATIC MAPPING

ABSTRACT GRAPHS

LITHOGRAPHY & COLOR PRINTING

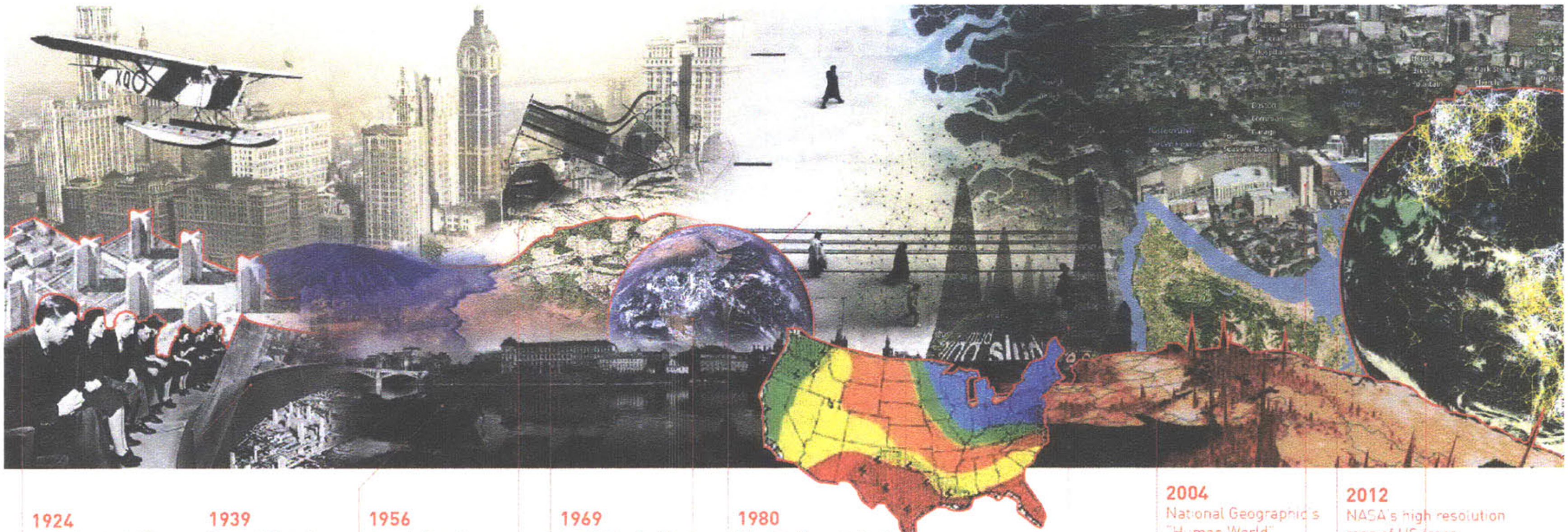
STATISTICAL GRAPHICS

ATLASES THAT DEPICT MULTIPLE LAYERS OF DATA

PHOTOGRAPHY

KODAK PANORAMA CAMERA

THE CITY IN MOTION | THE MODEL CITY | THE INFORMATION CITY | THE SIMULATED CITY | THE SCENARIO CITY | THE VIRTUAL CITY | THE NETWORKED CITY | THE REAL-TIME CITY | THE OPEN-SOURCE CITY



1924 Le Corbusier's "City of To-morrow"

1935 Sherman Fairchild commercializes aerial surveying

1939 General Motor's "Futurama" Exhibit

1956 Joseph Sudek's "Praha Panoramia"

1964 Kevin Lynch's "Image of the City"

1969 Ian McHarg's "Design with Nature"

1972 Blue Marble satellite photo of Earth

1980 Whyte's "Social Life of Small Urban Spaces"

1982 USA Today color weather map

1990s Aerial of Sundarbans

2001 MVRDV's Datescapes

2004 National Geographic's "Human World"

2004 OpenStreetMaps

2011 Nokia Ovi 3D Maps

2012 NASA's high resolution map of US trees

2012 f8 Conference brand by Ben Barry

AXON DRAWINGS

PHYSICAL MODELING

PANORAMIC PHOTOGRAPHY

"MANUAL" GIS (ACETATE)

DIAGRAMMATIC NOTATION OF NON-STATIC VISUAL LANGUAGE

GIS (INITIAL DEVELOPMENTS: EX. SYMAP)

SATELLITE PHOTOGRAPHY

FILM / TIME-LAPSE PHOTOGRAPHY

COMPUTER AIDED DESIGN

AUTOCAD

PYTHON

CAD 3D MODELING

GPS

JAVASCRIPT (STABLE 2011)

SCENARIO PLANNING TOOLS

CSS

ARCMAP (V8.0)

LUMINOUS TABLE (TUI)

AUGMENTED REALITY / VIRTUAL REALITY

ILLUMINATING CLAY (TUI)

COMMUNITYVIZ (COMMERCIAL RELEASE 1)

PROCESSING

SVG

CANVAS

GOOGLE MAPS (FEB)

GOOGLE EARTH (JUNE)

ADOBE CREATIVE SUITE

SECOND LIFE

QGIS

HTML5 (LAST CALL)

GOOGLE CHART API

GGOBI

HTTP://NEOCARTOGRAPHY.ICACI.ORG/

Friendly and Denis, who have catalogued an extensive record of cartographic, statistical, and technological influences on the development of visualization, recognize that few overviews exist of the most recent advancements in data visualization, particularly because they have "occurred at an accelerated pace, and across a wider range of disciplines" (Friendly 2006, 31). These most recent developments are shifting human perception of the world into a new period of complex dimensionality reflective of a networked world that is being represented by parties outside the realm of existing cartographers. A new generation of *neocartographers*,[8] map makers whose experience stems from outside traditional mapping backgrounds, are making use of open data and open source mapping tools for representing the built and natural environments.

2.1

THE NEW DIMENSIONALITY OF DATA

Until now, our primary efforts to represent the city have focused on capturing its built form in its entirety, including its underlying physical infrastructures. We are just now beginning to represent the whole of humanity, understood through its activities, exchanges, habits, and choices. Mitchell framed this as a transition in viewing the world as "structured by boundaries and enclosures to a world increasingly dominated, at every scale, by connections, networks, and flows" (Mitchell 2003, 5). These are new dimensions of data, as evidenced by networks, real-time feeds, and the linking of multiple layers of information from various sources, with each datum time-stamped and spatially referenced.

The dimensional scale of data has increased in terms of both the amount of data that can be collected and processed as well as the speed and immediacy in which this can happen thanks to a now-global wireless infrastructure. On a temporal scale, data are no longer static, fixed values, but "moving target[s]...that adjust to new values every second, hour, or week" (Fry 2007, 3).

Another new dimension of data is its increasing complexity resulting from connectivity in networks. These complex networks contain a larger number of interconnected and interdependent variables—what American scientist Warren Weaver referred to as "problems of organized complexity" (Lima 2011, 45). Multiple variables about systems, exchanges, and behavioral patterns can now be merged or linked.

Materiality refers to a specific type of connectivity: the linking of the virtual and physical spaces and the end of the "trial separation of bits and atoms" (Mitchell 2003, 3). The proliferation of wireless networks, sensors, and transmitters that are embedded in the built environment and its systems increasingly tie events and actions in the physical and digital realms, "radically refashion[ing] the relationships of individuals to their constructed environments and to one another" (Mitchell 2003, 2).

Tools for visualization have been adapting to these new dimensions of data, integrating new degrees of interactivity that increase the efficiency and effectiveness of complex data representations.

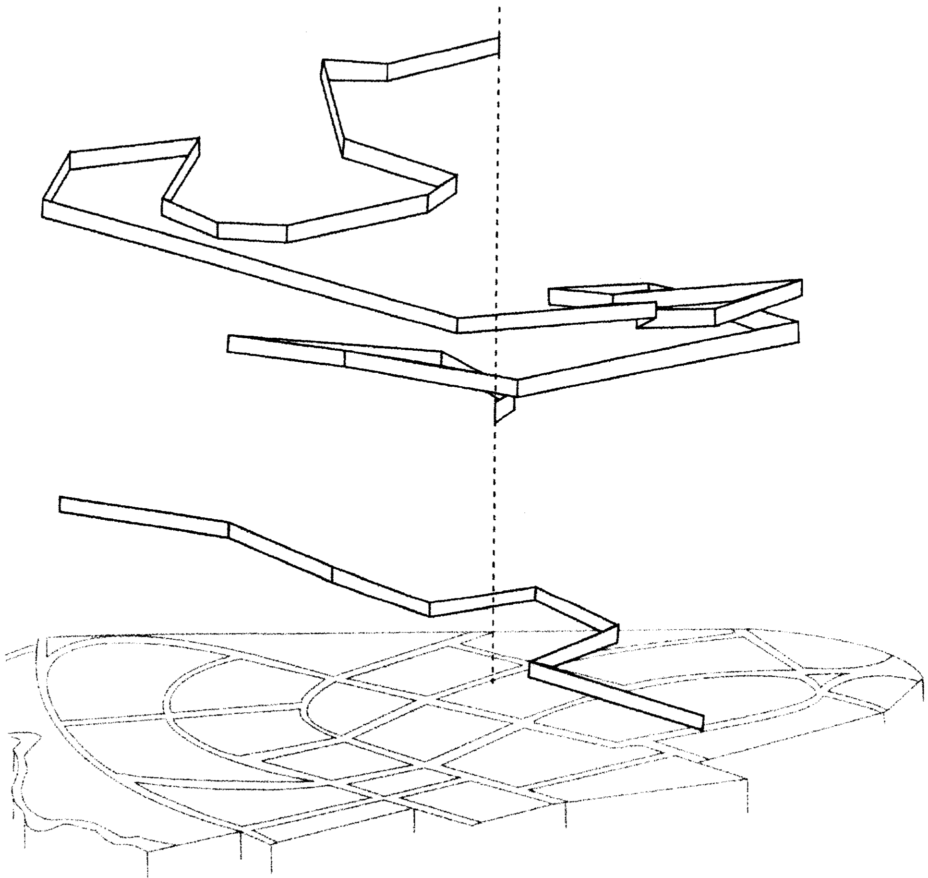
2.2

THE CONVERGENCE OF SPATIAL & TEMPORAL DATA

Perhaps one of the most significant aspects of data collected through mobile phones is that every datum will always be correlated to a point in space and time. This allows for two dimensions of convergence; even if two different types of data are collected, they can be correlated according to coordinates and time-stamps.

This has particular significance for the visualization and outputs of survey data. Typical paper survey methods allow for the recording of both of these dimensions; however, this can become tedious when survey counts are significant. Even Web-based surveys, posted online or sourced through email, typically only contain time-stamps or user-input geographies. The use of mobiles as an interface and tool for conducting surveys enables every entry to automatically log spatial and temporal data.

As planners, we can move beyond solely representing



LESTER & SCOTT'S PAPER ROUTES IN BOYLAN HEIGHTS
FROM *EVERYTHING SINGS* BY DENNIS WOOD

THE TEMPORAL DIMENSION OF THE PAPER ROUTES IS MADE EXPLICIT THROUGH THE USE OF A SPACE-TIME RIBBON, WHERE SPACE IS OUTLINED OBLIQUELY BY THE NEIGHBORHOOD STREETS, WHILE THE ROUTES UNFOLD OVER TIME BY MOVING IN THE VERTICAL DIRECTION.

qualitative measures from survey data as charts or diagrams, but actually relate the results to conditions over time and space. When this is incorporated into analysis of survey data, we can further inquire how the built environment factors into the conditions represented. Ultimately, we can begin to map patterns of human activity, behavior, or preference on a more granular level and with greater accuracy.

For example, Dennis Wood's mapping of paper routes in Boylan Heights (left) explores the static representation of a sequence of moments by correlating the time dimension to spatial location. While quite beautiful in its simplicity, Wood's representation of this sequence is limited to what can be represented for a single day (or even a few hours of the day) at a scale (one neighborhood) that will fit on the medium (a two-dimensional printed page) for a few actors in the system (Lester and Scott). For this particular subject, a more dynamic visualization may not be necessary. However, as planners begin to capture larger scales of activity of far more complex systems, the value of dynamic platforms becomes more evident.

A famous parable written by Jorge Luis Borges describes the pursuit of perfection in mapping. In the story, a group of cartographers attempts to iteratively represent reality to increasing accuracy. By the end of the parable, they attempt representing the world at 1:1 scale, essentially creating a map equal in size to the world itself. Recent technology has brought reality closer to this allegory. While a traditional map is limited by the constraints of physical space as it is restricted to two dimensions on paper of a limited size, digital platforms increase our capacity for representational "thoroughness and even vastness" (Solnit, 1). The potential representative area of digitally-based maps is, in theory, infinite. One can create a map that scrolls infinitely in any direction and thus has no relative boundaries, eliminating constraints on the scope or scale of area that can be represented. Additionally, such tile-ability of maps on digital platforms allows users to view the same data at different zoom levels.

With regard to time, a map on paper can at best approximate conditions at one or a few moments in time. By the time a map is created using traditional cartographic methods, the conditions that map represents have already changed. Mobiles dramatically reduce the period between real-time action and the content of a map as a reflection of that given point in time. As a constant stream of representative data, mobiles enable new modes of maps that are dynamic rather than static, closing the gap between a map and the reality of its subject.

2.3

RETHINKING A BIG DATA PLOT: NEW PROGRAMMING ENVIRONMENTS

The new tools and platforms for visualization that are rapidly developing alongside the rise of big data and infostructures have been heavily influenced by a few major shifts:

- Exponential increases in computer processing speed and capacity, allowing computationally intensive methods and access to massive data problems (Friendly 2006, 31);

- The global proliferation of the web as a primary medium for distributing and engaging information;

- The open development of thousands of Application Programming Interfaces (API) [see Figure 2.3.1], that "encourage and entice developers to do something with all the available data" on the web (Yau 2011, xv);

- Increasing access to open data sources and a rising interest in the stories that data are able to tell, and thus a demand for the tools to create those narratives.

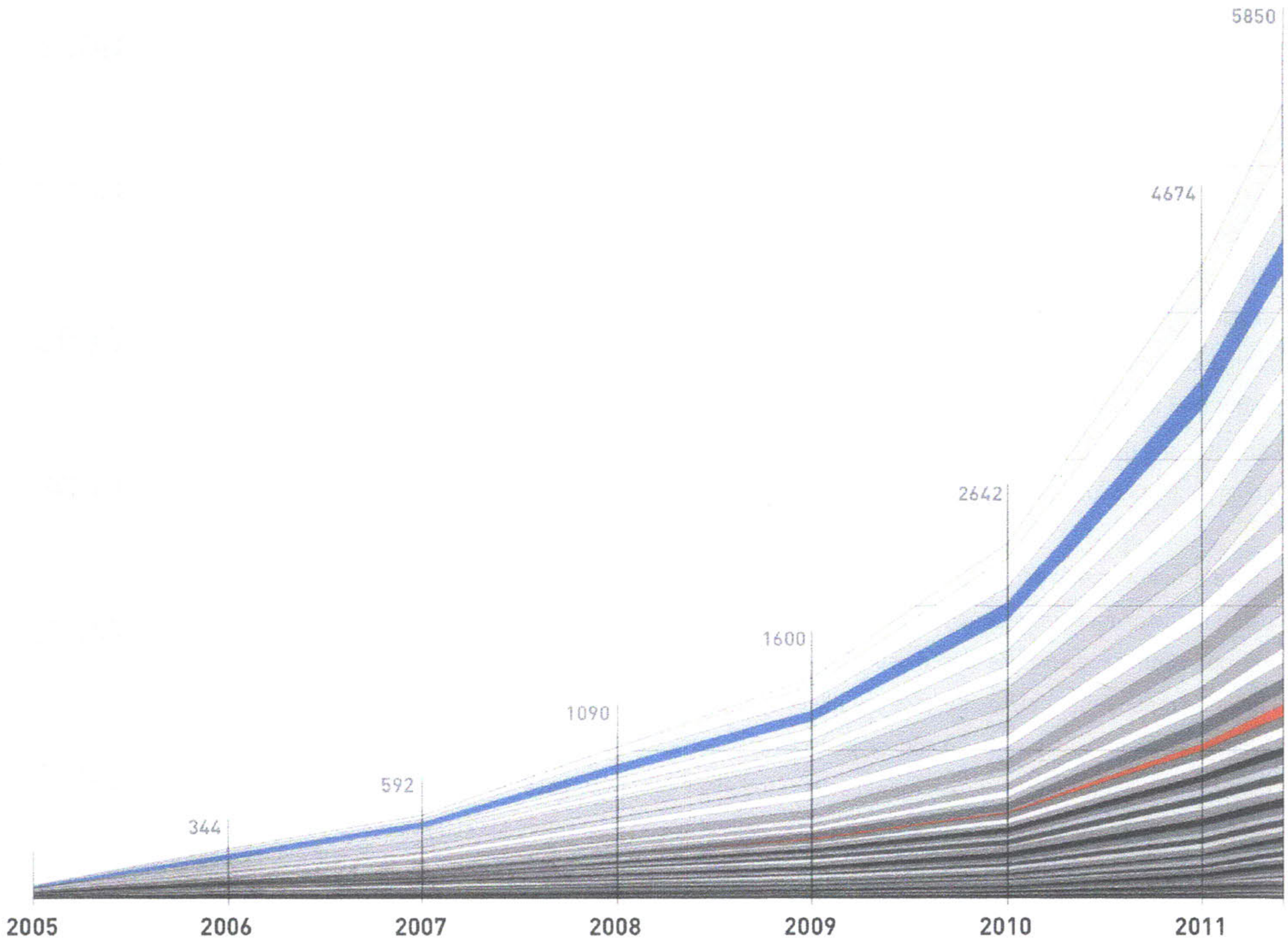
Given these conditions, programs have been developed using the native languages of the Web: Java, C++, Actionscript, and others. This thesis will further illustrate how these tools are being deployed, demonstrating potential applications for planning practice by looking at what interactions and understandings their use enables.

New programming environments continue to improve the ability to generate visualizations that incorporate spatial and temporal dimensions. While proprietary software such as ArcMap can perform advanced calculations for very discrete needs in spatial analysis, the program makes feeble attempts to incorporate time-series animation and interactivity. There is a disconnect between the complex tools of analysis and the strategies used to convey the information gained.

While the following list of programming languages for visualization is by no means comprehensive, it effectively displays a broad-brush view of the field of new tools that have proliferated over the last several years:

- Web-based rendering of information: HTML(5), Canvas, CSS, SVG
- Web-based Google Maps and Charts API
- Flash and Actionscript
- Python
- Javascript and associated libraries: jQuery, D3, PolyMaps, Protovis, Processing.js
- Processing
- PHP
- QGIS
- R

2.3.1 THE PROLIFERATION OF APPLICATION PROGRAMMING INTERFACES (API)



NUMBER OF APIS BY CATEGORY SINCE 2005.

DATA SOURCE: HTTP://WWW.PROGRAMMABLEWEB.COM/APIS/DIRECTORY/

9

THIS TAXONOMY IS PRIMARILY OUTLINED BY JEFFERY HEER AND BEN SHNEIDERMAN, COMPUTER SCIENCE PROFESSORS AT STANFORD AND BERKELEY, RESPECTIVELY.

Open source programming environments such as HTML5, JavaScript, Canvas, and Processing are opening the floodgates of possibility in creating interactive visual prototypes. Not only do these tools enable the translation of data into visual formats, but they also enable degrees of real-time updating, interactivity, and scalability. These programming environments operate in the space between click-and-drag design software such as Adobe Illustrator or Inkscape that have limited data crunching capabilities, statistical and data manipulation software such as Excel and R that are inversely limited in highly customized visual outputs, and geospatial software such as ArcGIS that struggle to incorporate interactivity into their outputs.

There are downsides and upsides in beginning to operate using these programming environments. Because they are open source, their access and use is free. However, this also means that help guides are not always readily available or consolidated. Open source programs do tend to generate vast amounts of user-generated solutions, which can be found through a quick Internet search.

These programming environments provide a high degree of customizability and interactivity in their outputs. Their value is embodied in a few primary methods that these programming environments enable through interactive visualizations[9]:

Select: With static visualizations, necessary information must be highlighted solely using visual techniques of hierarchy, such as highlighting with a dominant color the items of most importance or reducing the transparency of subdominant items. The functionality of selecting items within a dynamic visualization becomes apparent when dealing with large datasets or data with multiple dimensions viewed simultaneously. Using common forms of selection, such as mouse hover, click, region selection, or area cursors, users can more easily filter or highlight to focus on relevant components of a visualization (Heer 2012, 7).

Navigate: As data visualizations become more complex, the ability to guide viewers using familiar techniques through various scales of data will be a significant

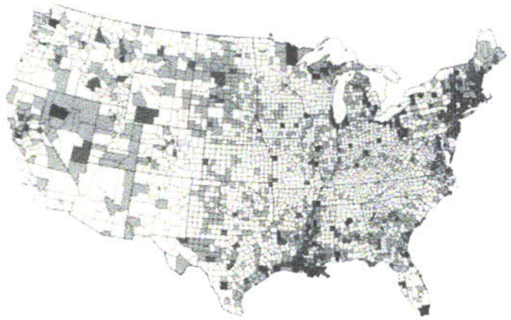
Comparisons

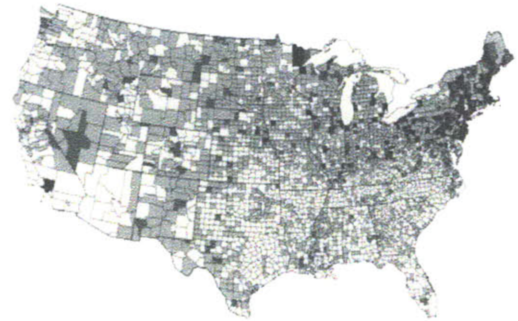
Comparisons are difficult between different groups.

Mental effort is spent locating information rather than comparing, analyzing, etc.

There are 6 of these maps across 3 pages

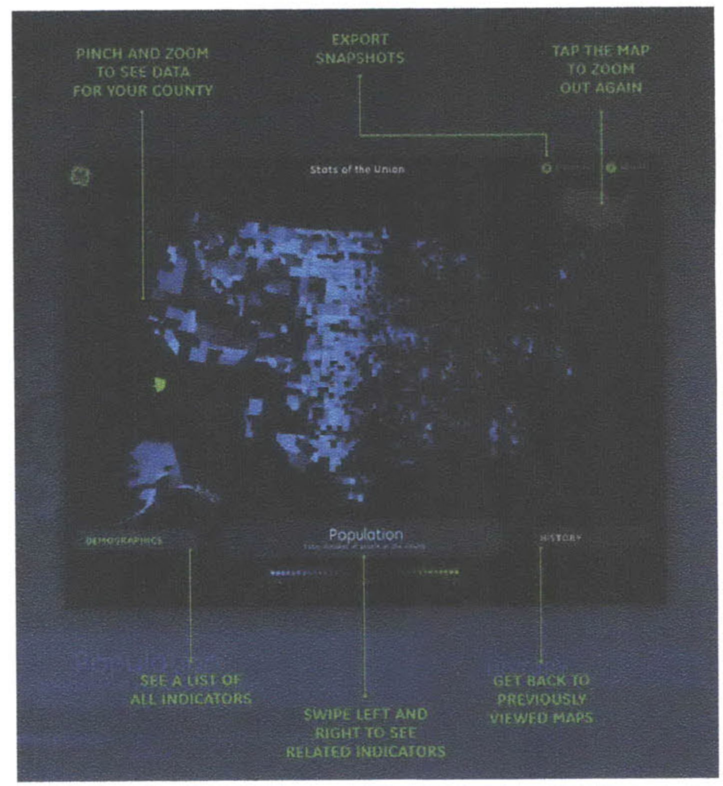
Can we increase data density to enable comparisons?





LEFT: CLOROPLETH MAPS OF DIFFERENT HEALTH METRICS FROM "THE VISUAL DISPLAY OF QUANTITATIVE INFORMATION" BY EDWARD TUFTE

BELOW: SINGLE-SCREEN INTEFACE "STATS OF THE UNION" IPAD APPLICATION BY FATHOM



functionality in dynamic visualizations. There are various forms of guiding users through a visualization, summarized in the following mantras:

- "Overview first, zoom and filter, then details-on-demand" (Shneiderman 2006), highlighting the ability to navigate from large scale to exploring specific components.

- "Search, show context, expand on demand" (van Ham 2009), the inverse of the previous navigation method that starts with a specific component oriented to the remainder of the data, which can be seen in overview as needed.

Coordinate: Simultaneously coordinating multiple views of data in an interactive format allows for different perspectives, comparisons, and observations across multiple variables or categories. Coordinated views can also be useful in displaying the same data using different projections or different visualization types. The technique of brushing or linking facilitates the interactive exploration of multiple views, allowing users to highlight a data component in one view and see the corresponding data in another (Heer 2012).

Organize: This feature of dynamic visualizations refers primarily to the layout and configuration of various elements in the interface of a visualization. The organization of an interactive visual should clearly define the hierarchy between different components and indicate which views or windows can be added or removed as needed.

Record: This functionality maintains activity logs in the use of dynamic visualizations. Recording interactions enables users to navigate back and forth through different sequences or chronologies, or reveal hierarchies of information (Heer 2012). This can be used for analytical purposes to gauge the relevance of components of a visualization; Google Analytics, for example, allows for the recording of which parts of a web-based platform are used most and by which types of users.

Annotate: The ability for users to add details or notes provides a means of "recording, organizing, and communicating insights gained" while interacting with a dynamic visualization (Heer 2012, 17). Annotations can be graphic or textual, and can themselves become data points. A common example of annotation is creating 'My places' on Google Maps by dropping markers or starring places to create personal references or custom maps. The sites in Figure 2.3.2 were created to annotate findings during fieldwork; each marker was also labeled with a QR code that allowed application users to quickly mark which site they were working on.

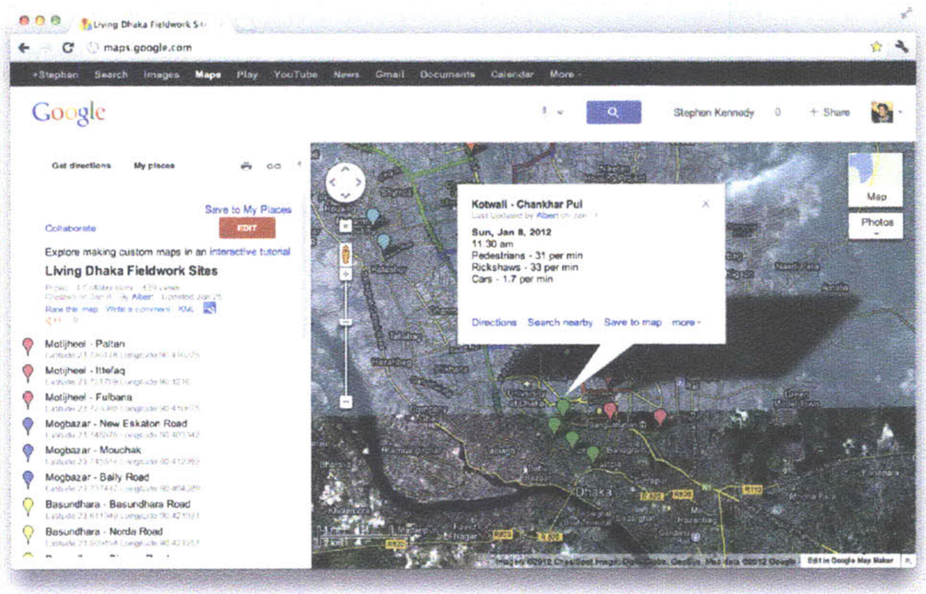
Share: This feature refers to the social aspect of a dynamic visualization, or the ability to transfer use and disseminate knowledge by exporting, publishing, or embedding on different platforms. This enables new degrees of collaboration, particularly when collaborators are working asynchronously or distributed across many places (Heer 2012). The same "My places" custom map in Figure 2.3.2 was shared with multiple fieldwork volunteers who annotated the map in real time on tablets.

2.4

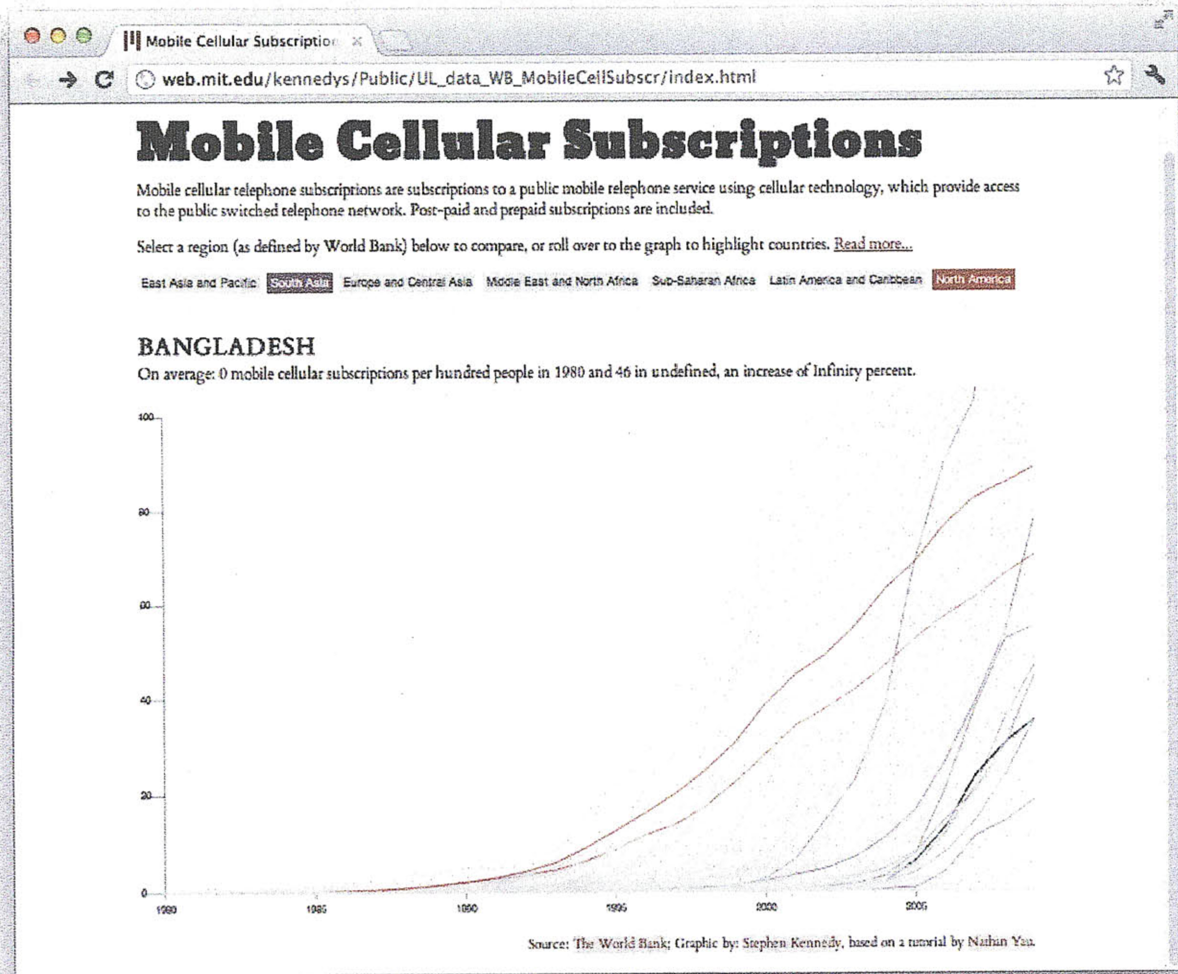
EXPERIMENTAL TESTS OF INTERACTIVITY

The following samples demonstrate interactive visual prototypes built using new programming environments. These were developed for this thesis using open source tutorials and guides released by programmers as resources for the general public.

2.3.2 (BELOW) A CUSTOM MAP CREATED IN GOOGLE MAPS THAT MARKS FIELDWORK SITES AND ANNOTATED BUS ROUTES FOR LIVING DHAKA. THE MARKERS WERE GENERATED IN THE OFFICE AND THEN ANNOTATED DURING FIELDWORK USING A TABLET



2.4.1 MOBILE CELLULAR SUBSCRIPTIONS



TEMPORAL

CONDITIONAL

VISUALIZATION TYPE

DYNAMIC DATA DISPLAY

AUTHOR

STEPHEN KENNEDY, BASED ON TUTORIAL BY FLOWINGDATA.COM

DATA SOURCE

THE WORLD BANK DEVELOPMENT INDICATORS

CONTEXT

GLOBAL

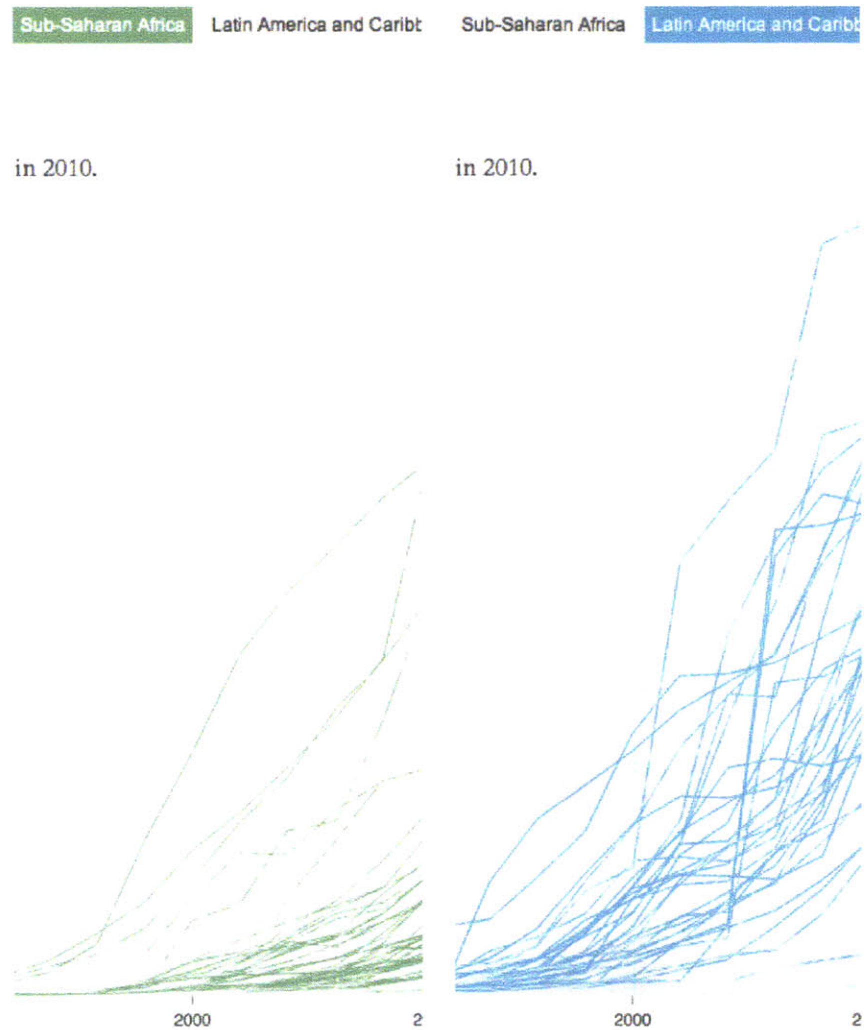
SCALE

NATIONAL

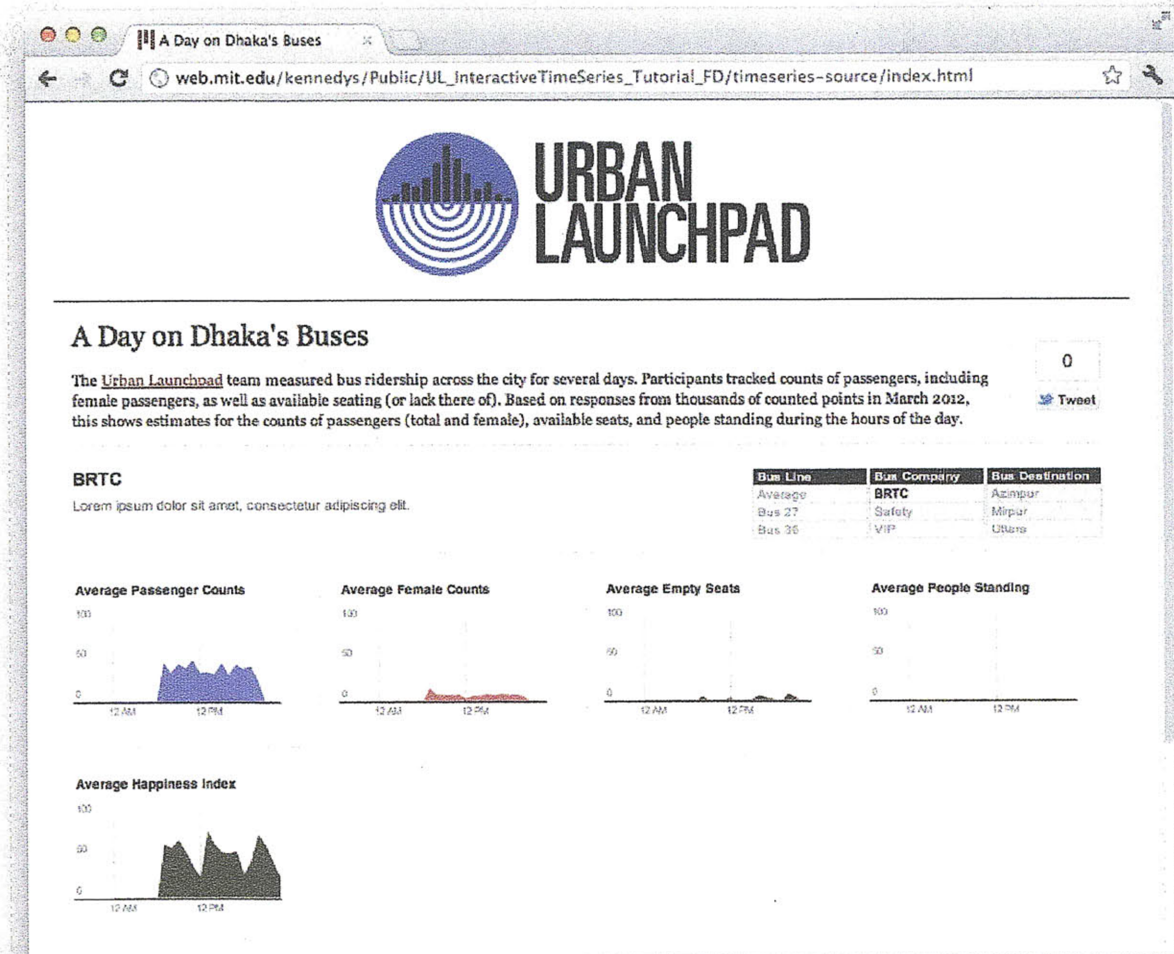
MOBILE CELLULAR SUBSCRIPTIONS

This visualization presents a method for representing global development indicators from the World Bank as an interactive time series. This dashboard was built using a JavaScript library called D3.js (Data-Driven-Documents), jQuery, Python, HTML, and CSS. Each of these serves a specific role in enabling an interactive platform for the data. By combining these programming environments, several objectives can be achieved that traditional statistical representations would not be able to do:

- **Select:** The mouse-over ability to simultaneously access macro-scale trending (the combined trajectory of all countries) and micro-scale details (the trajectory of an individual nation);
- **Filter:** The ability to filter for regional groupings of the data (either a single region at a time, or several regions for comparison, differentiated by color);
- **Annotate:** The ability to auto-generate text descriptions using components of the data set.



2.4.2 A DAY ON DHAKA'S BUSES



TEMPORAL

CONDITIONAL

BEHAVIORAL

EXPERIENTIAL

VISUALIZATION TYPE

DYNAMIC DATA DISPLAY

AUTHOR

STEPHEN KENNEDY,
BASED ON TUTORIAL BY
FLOWINGDATA.COM

DATA SOURCE

FLOCKSOURCED BUS DATA

CONTEXT

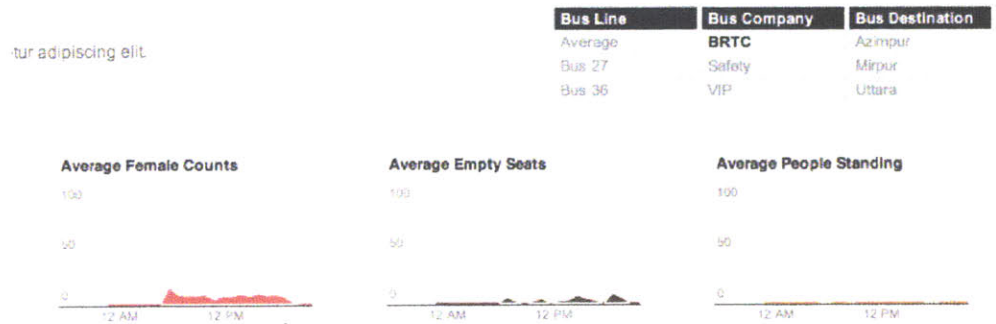
DHAKA, BANGLADESH

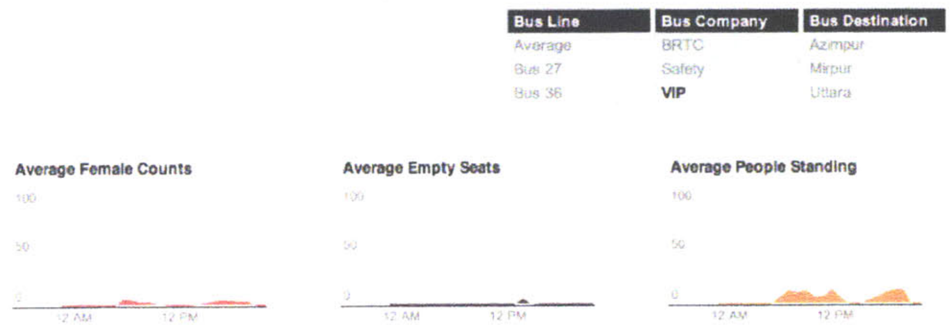
SCALE

URBAN

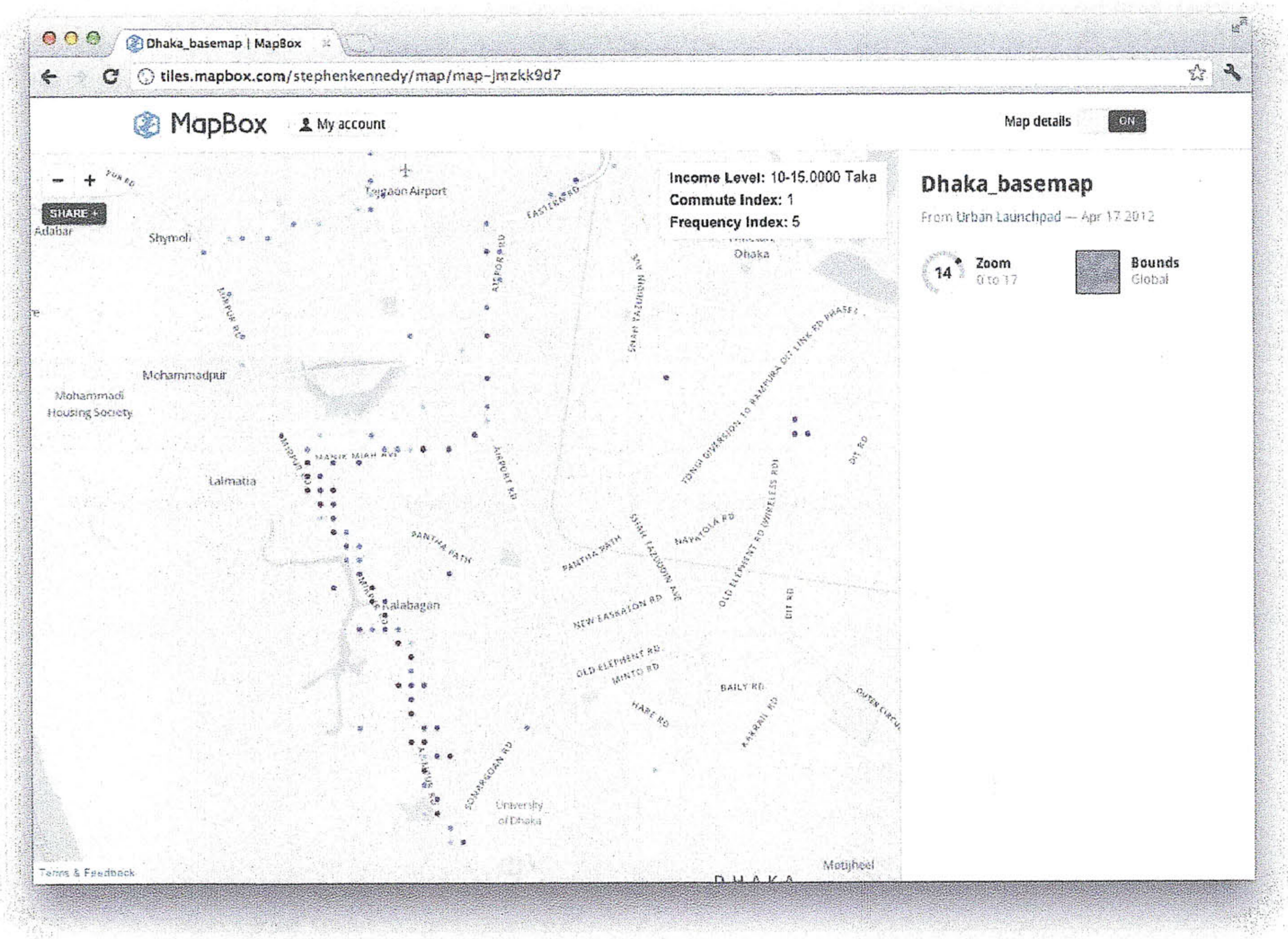
This visualization is similar in background structure to the previous one, built with D3.js, jQuery, Python, HTML, and CSS. The added feature in this representation, which is a type of small multiples visualization, is the animation of data between selected categorical filters. Even though the graph typology is quite simple, the basic animation provides a novelty that invites users to interact with the various categories. Again, by combining these programming environments, several objective interactions can be achieved that traditional statistical representations would not be able to do:

- **Filter:** The ability to filter based on identifiers;
- **Navigate:** The ability to use animation to show distinctions between filtered identifiers;
- **Annotate:** The ability to auto-generate text descriptions using components of the data set.





2.4.3 BUS HAPPINESS PLOTS IN DHAKA



SPATIAL

COMPOSITIONAL

EXPERIENTIAL

VISUALIZATION TYPE

LIVING MAP

AUTHOR

STEPHEN KENNEDY

DATA SOURCE

FLOCKSOURCED BUS DATA

CONTEXT

DHAKA, BANGLADESH

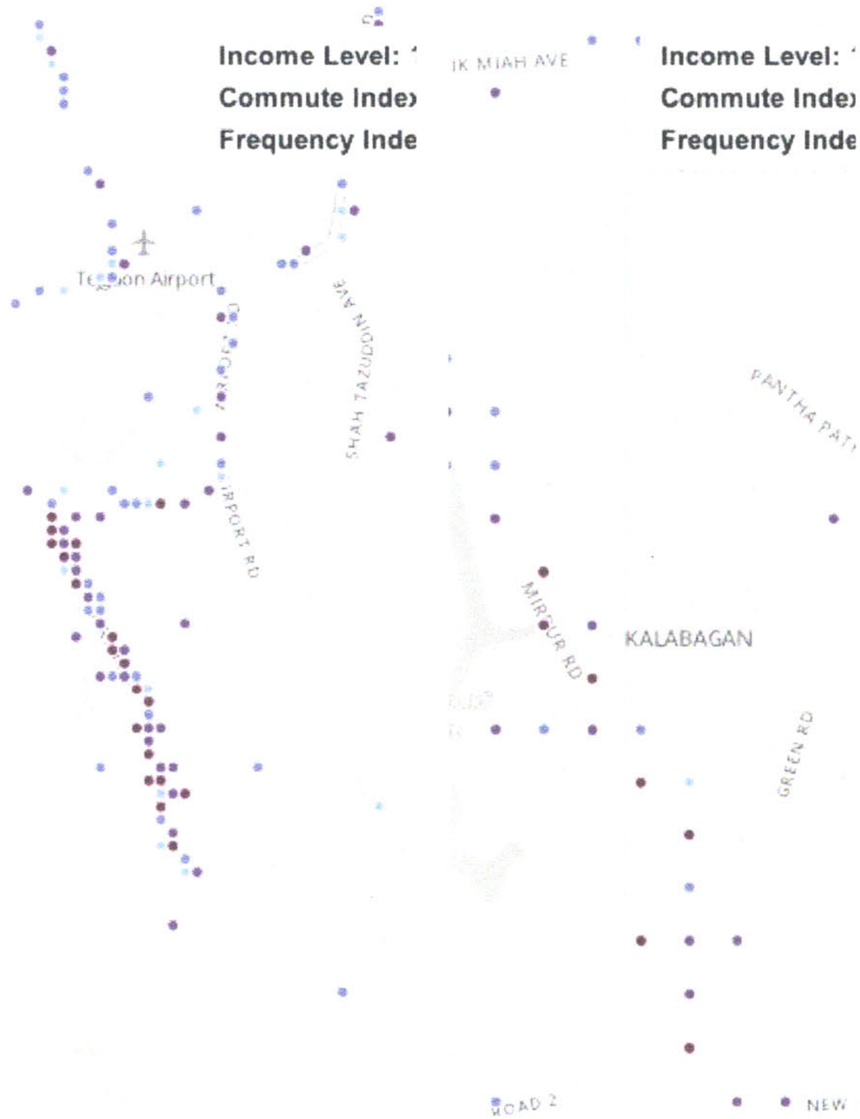
SCALE

URBAN

BUS HAPPINESS PLOTS IN DHAKA

This visualization uses a web-cartography program called TileMill for building interactive, customizable maps using spatial data. This represents a simple test of what is possible using this program and the data collected using the flocksourcing. As long as data has an associated latitude and longitude, it can be integrated as a layer in TileMill. While this program is not able to do heavy computation possible in a geospatial analysis program such as ArcMap, it does provide several features that enable interactive geospatial data visualizations:

- **Organize:** Highly customizable layering of base maps (available from the OpenStreetsMaps repository, Natural Earth, as well as any geo-referenced shapefile);
- **Navigate:** Scalability of information through tiled layers of slippy-map interface;
- **Select:** Mouse-over details pulled from additional associated metrics for each data point;
- **Share:** Fully embeddable on web platforms.



CHAPTER 3

REPRESENTING THE CITY: NEW PRACTICES IN VISUALIZATION

All visualizations share a common "DNA"—a set of mappings between data properties and visual attributes such as position, size, shape, and color—and customized species of visualization might always be constructed by varying these encodings.

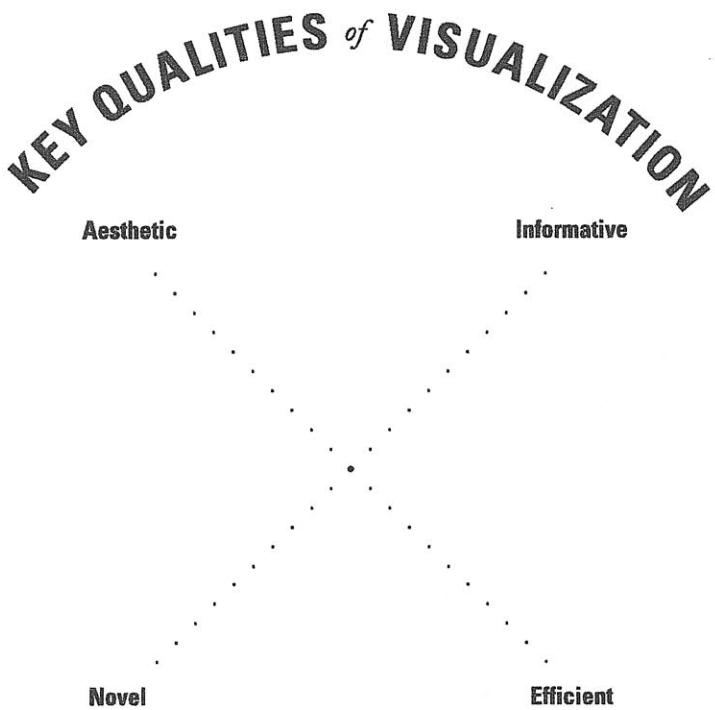
Jeffrey Heer, Michael Bostock, and Vadim Ogievetsky, in "The Visualization Zoo"

Visualizing data is a creative act: one must select appropriate information, apply transformations or manipulations, construct an argument, and present it in a digestible format. The primary transformation of data occurs using "visual encodings to map data values to graphical features such as position, size, shape, and color" (Heer 2010, 59). An effective visualization provides a new level of understanding rather than simply converting data into a graphic format. *Beautiful Visualization* outlines four key qualities of an effective visualization: aesthetic, informative, efficient, and novel (Illinsky 2010). Each quality reveals new insights into the conditions that data represent. These qualities can be used to characterize the effectiveness of visualizations as instruments for conveying information and demonstrate the potential value of visualizations for planning purposes.

3.0

THE KEY QUALITIES OF VISUALIZATION

The **Aesthetic Quality** of visualization refers to the appropriate use of graphic conventions to guide viewers through



a visual. Universal techniques for graphic construction—shape, color, proximity, layout, etc.—are the elements used to communicate the meaning behind data by reveling and highlighting relationships and patterns. These universal techniques represent one of the designer's primary leverage points: aesthetics help convey general intentions and increase the overall utility of the visualization, as well as putting it in context with elements familiar to the audience. This contextualization should also be considered for further research, particularly when the designer comes from a different cultural context than the intended audience of a visualization.

The **Informative Quality** is the degree to which a visual provides "access to information so that the user may gain knowledge" (Illinsky 2010). This takes into account two aspects of visualization: the intended message that addresses the audience's "specific knowledge needs" and the context within which a visual will be used. The latter refers to whether the visualization is meant to facilitate communication of existing knowledge to other parties, or intended as a tool for further examination to reveal new knowledge.

The **Efficient Quality** of visualization is the ability to provide access to information in the most straightforward way possible. This includes editing out unnecessary data (reduction of noise) or the use of layers of information that are revealed only when relevant to the knowledge needs of individual users (Illinsky 2010). The efficiency of a design is influenced by the use of graphic conventions related to hierarchy and directionality. This quality is enhanced by recent progress in the development of interactive platforms for visualization.

The **Novel Quality** elevates visualization from a purely accessible representation of data to a representation meant to provoke interest and result in a previously unattained level of understanding. This is a difficult balance to strike, as a design whose intention is only to be novel may lack true utility for an audience. When representations generate excitement by effectively creating understanding from data, "their novelty is a byproduct of effectively revealing some new insight about the world" (Illinsky 2010).

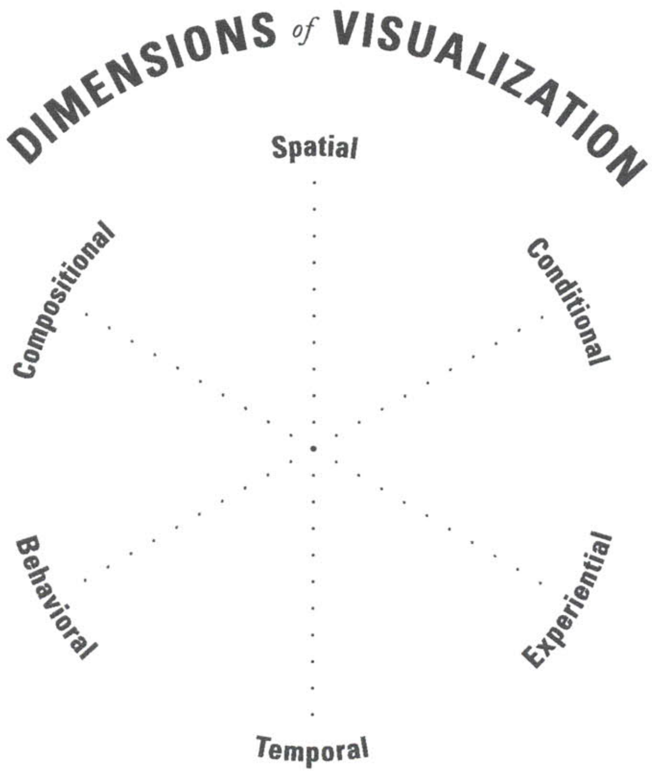
3.1

DIMENSIONS OF DATA VISUALIZATIONS

Visualizations utilize representational strategies that enable the communication of new dimensions of big data. In many cases, a visualization incorporates several dimensions simultaneously. While these dimensions are not new in and of themselves, recently developed programming languages allow them to be linked and overlaid into dynamic visualizations. Ultimately, the combination of these dimensions enables a higher-level understanding to arise from data, particularly when multiple data sets are combined or layered.

Visualizations that make use of the **Spatial Dimension** typically present the orientation, proximity, directionality, overlap, or gaps of data points. Most often, spatial visualizations are possible using coordinates or overlaying data on a map or diagrammatic abstraction of a place.

Visualizations include the **Temporal Dimension** when data is represented relative to a particular scale and interval



of time or in a sequence that illustrates the temporal relationship between data points. Temporal dimensionality can be explored when data is not presented for a single period, but instead illustrates changes or patterns through a series of snapshots over time.

Visualizations that incorporate the **Compositional Dimension** illustrate the constituent elements, make-up, configuration, structure, or framework of the data. An example is using icons for data points that illustrate what each data point might represent, rather than simply an abstract shape. Visualizations employing a **Conditional Dimension** move beyond the simple composition of the data subject and display its quality, grade, strength, or intensity.

Two final dimensions indicate more humanistic elements of a data set. Visualizations with a **Behavioral Dimension** demonstrate patterns through data that articulate activity, choice, conduct, or response of the subject. Visualizations with an **Experiential Dimension** incorporate opinion, preference, opposition, or attitude, which are most often tied to survey data or polling.

3.2

ANALYZING STRATEGIES FOR VISUALIZATION

This framework of qualities and dimensions of visualization is used to analyze several case studies of visualization techniques. The cases are drawn from recent developments in processing and visualizing complex data on human activity. In particular, selected cases utilize strategies for showing time-series, spatialized data, or a combination of the two.

While these cases represent just a portion of the field of recently developed representation strategies, they illustrate several key typologies of dynamic visualizations. While some are blended together in various applications, each employs different authorial intentions and serves distinct purposes for its audience.

Living Maps are community-generated visualizations. They enable local knowledge to be embedded in formal representations of urban environments, through strategies of crowd-sourcing information. They also increase in utility through customization, whereby a publicly accessible map can be supplemented based on a user's distinct needs.

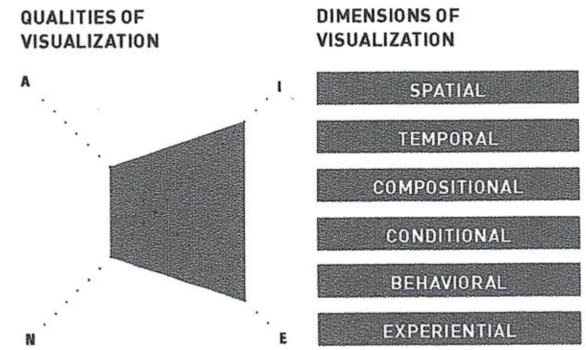
Several of the visualizations presented above, such as the subway maps, are **User-Service Products**; they serve as visual trip planners to improve the navigability of complex systems. Features include live displays of disruptions to systems, search capabilities for filtering between relevant routes or stations, and the relation of the system to the built environment (how subway routes relate to streets, for example).

Dynamic Data Displays are most often forms of data journalism, communicating topical information related to current events. These examples are infographics in the most traditional sense, meant to communicate data patterns primarily through graphic conventions.

Mobility Tracings are mappings of activity over time. They relate individuals navigating a system to additional metrics, such as speed, intensity, and frequency. These visualizations often present information about a particular event by integrating several view modes, filters, and multiple scales for understanding the story. This creates narratives that are legible in different forms.

Interactive Illustrations, while not explored as extensively in this thesis, are dynamic visualizations that illustrate visionary projects. They allow for navigation between overall concepts and specific proposals. The provide opportunities for input from users, who can view plans or proposals from multiple points of view.

Assessment criteria include:

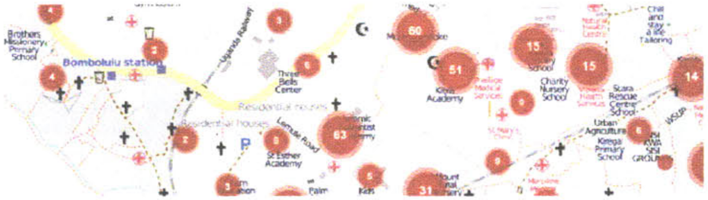


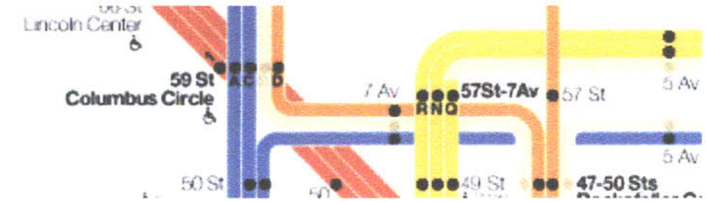
A AESTHETIC QUALITY

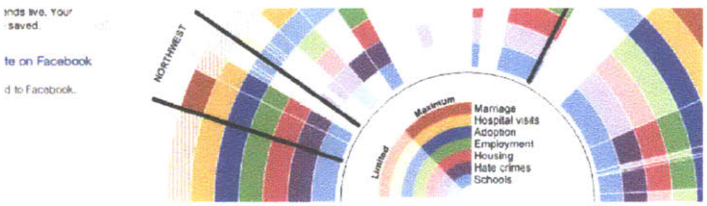
I INFORMATIVE QUALITY

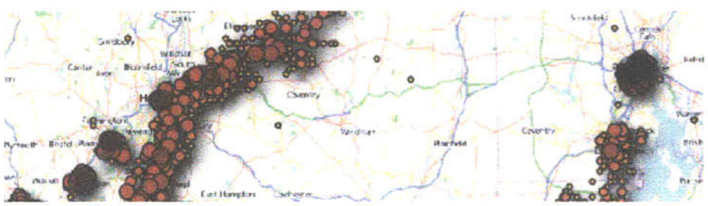
E EFFICIENT QUALITY

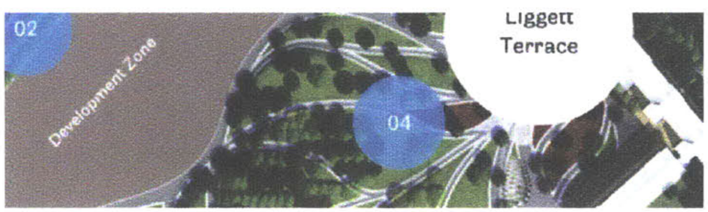
N NOVEL QUALITY











LIVING MAPS:

3.2.1

3.2.2

3.2.3

USER-SERVICE PRODUCTS:

3.2.4

3.2.5

DYNAMIC DATA DISPLAYS:

3.2.6

3.2.7

MOBILITY TRACINGS:

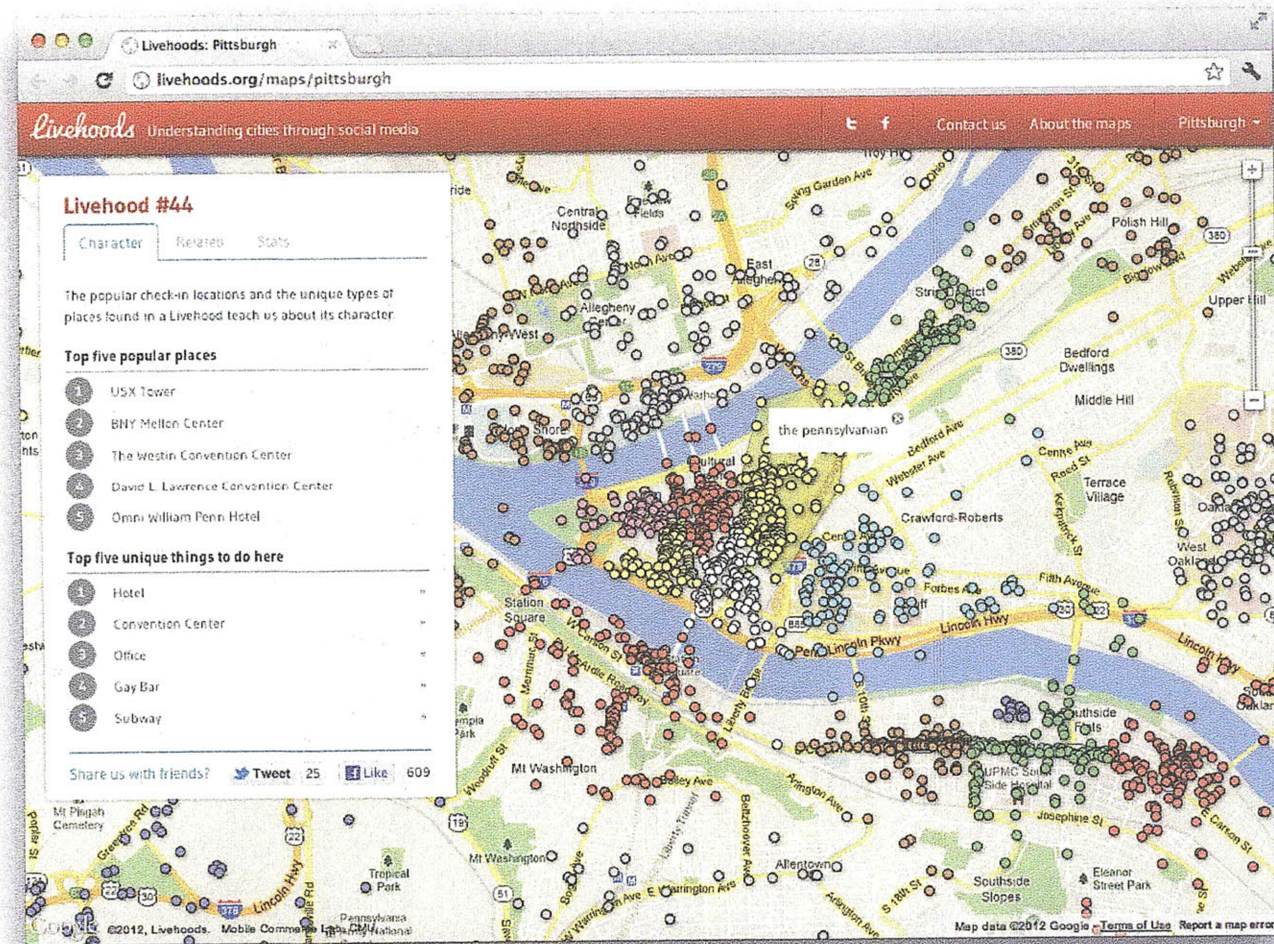
3.2.8

3.2.9

INTERACTIVE ILLUSTRATIONS:

3.2.10

3.2.1 LIVEHOODS



SPATIAL

COMPOSITIONAL

BEHAVIORAL

EXPERIENTIAL

VISUALIZATION TYPE

SOCIAL-MEDIA BASED MAP

AUTHOR

MOBILE COMMERCE LAB, CARNEGIE MELLON UNIVERSITY

CONTEXT

NEW YORK / SAN FRANCISCO / PITTSBURG

SCALE

URBAN / NEIGHBORHOOD

URL

LIVEHOODS.ORG

DATE

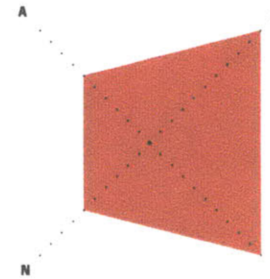
2012

Livehoods is an exploration of the use of machine learning to recalibrate definitions of neighborhood spaces based on the perception and activity of people themselves. The project explores how social dynamics formalize the spatial areas of the city just as effectively, if not more so, than institutionally imposed boundaries. Using around 18-million check-ins from location-based online networks such as Twitter and foursquare from a 7-month period in 2011, the authors applied a spatial clustering mechanism that generates distinct geographic areas of the city that reflect "the character of life in these areas" (Cranshaw 2012, 1).

The authors make use of interactive mapping strategies to effectively convey multiple scales of information regarding the resulting Livehoods generated through their method. As a navigational strategy, users first obtain an overview of clustering demonstrated through color groupings of the spatially plotted data points. Selection capabilities allow for further investigation of the compositional elements of each cluster; clicking one datum reveals the boundaries of the Livehood, as well as additional compositional dimensions such as related areas or locations categorized by type. Behavioral elements revealed through the visualization include weekly and hourly pulse points; experiential dimensions are revealed through the most popular sites within the Livehood based on quantity of related check-ins.

The potential of these redefined Livehoods is in the dynamic nature of their definition; the clusters can shift and adapt based on real-time feeds as communities' patterns of behavior and preferences change over time. The data is based on human activity, and thus becomes reflective of the "activity levels and characteristics in those neighborhoods as well" (Livehoods 2012). As planners continue to re-conceptualize how urban spaces are characterized by the way people actually use them as much as the institutional definitions, these types of hidden organizational structures of the city will become increasingly important to understand. As a visualization, a new platform for defining urban spaces based on behavior is now possible.

QUALITIES OF VISUALIZATION



DATA SOURCE

SOCIAL MEDIA (FOURSQUARE, TWITTER)

COLLECTION METHOD

SOCIAL MEDIA SCRAPING

ANALYSIS TOOLS

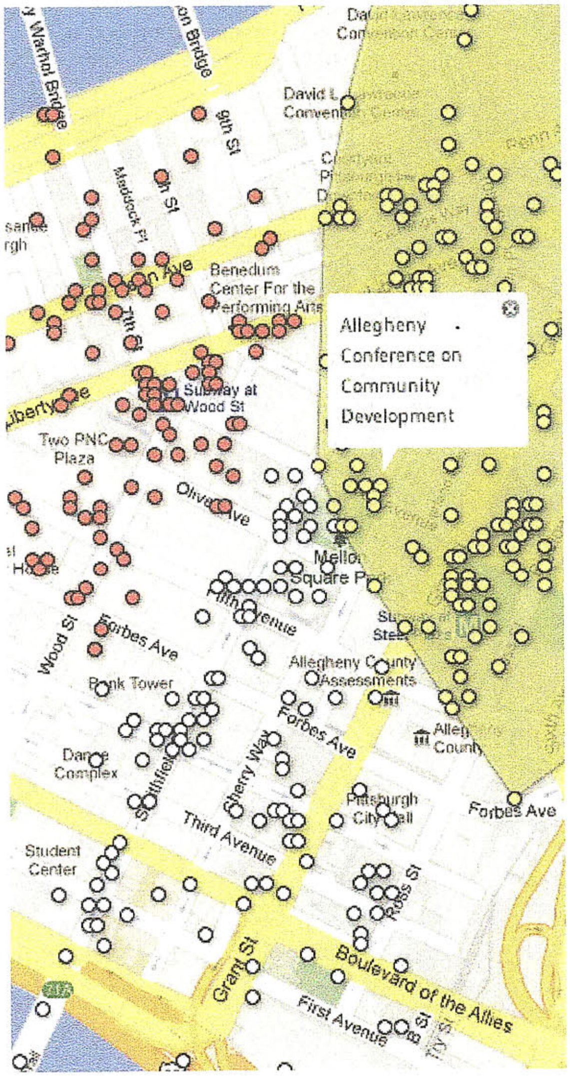
MACHINE-LEARNING CLUSTERING ALGORITHMS

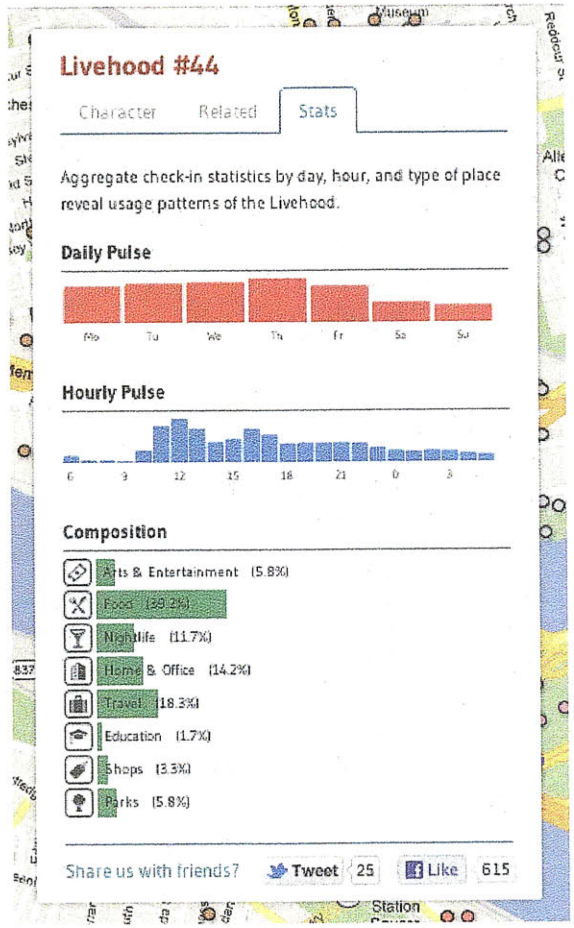
VISUALIZATION TOOLS

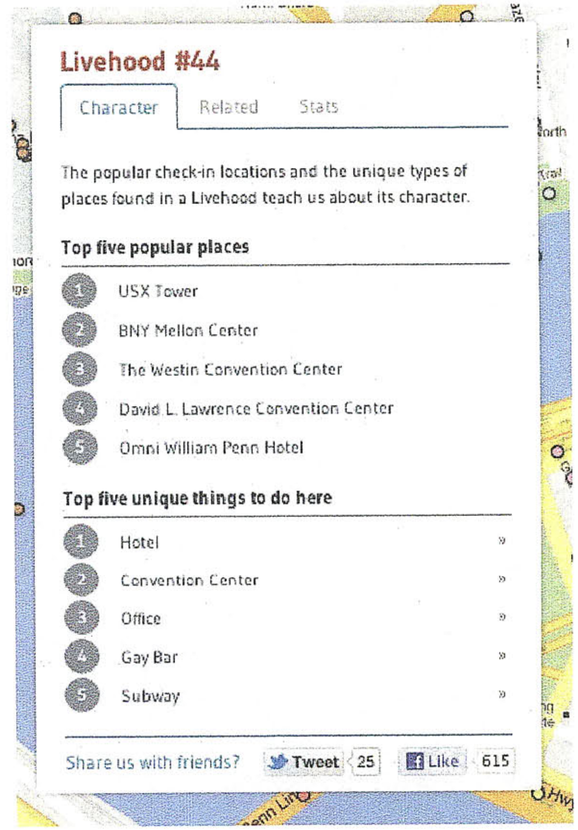
GOOGLE MAPS API

PLATFORM

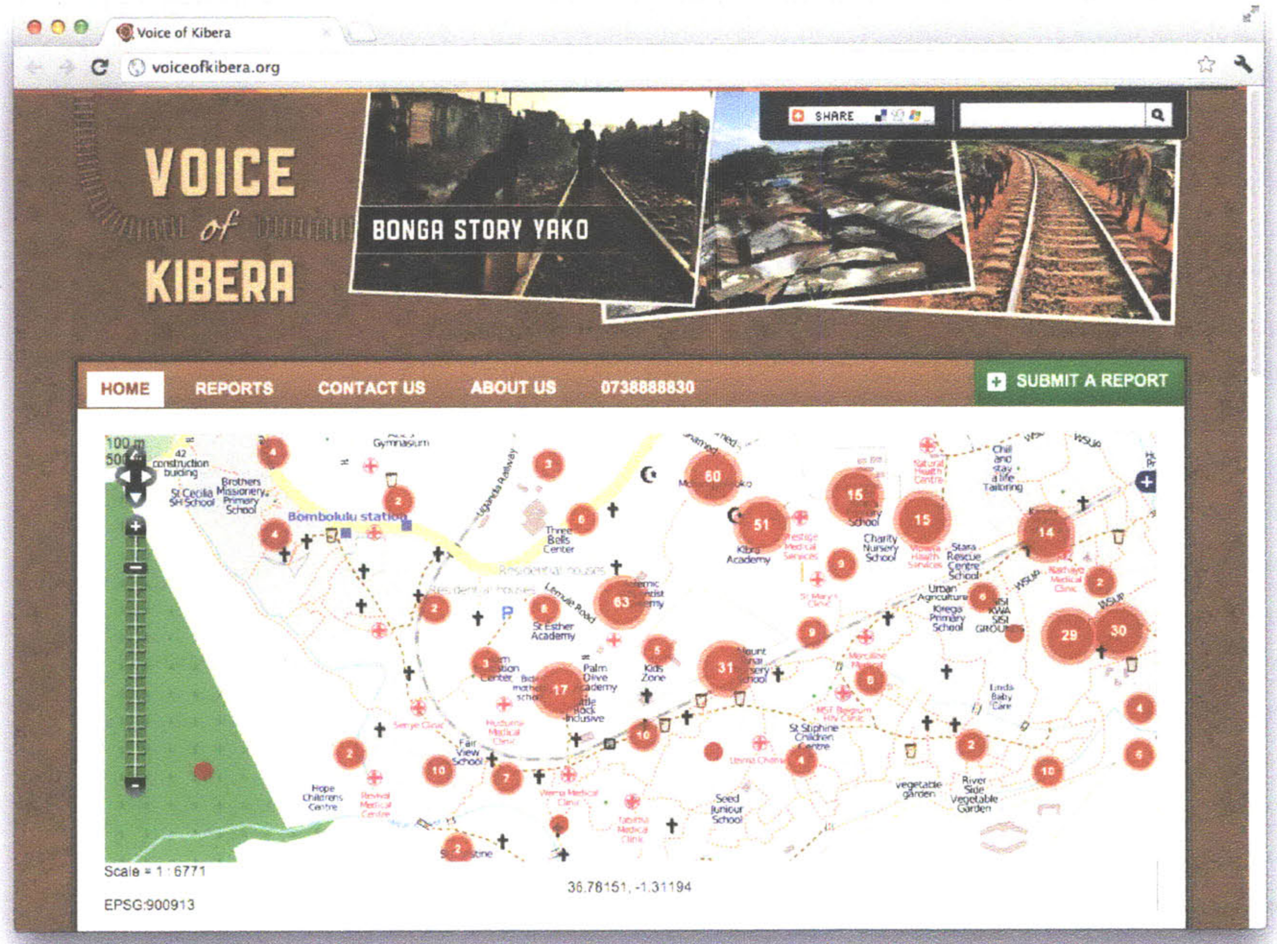
INTERACTIVE WEB-BASED SLIPPY MAP


Allegheny Conference on Community Development
Benedum Center For the Performing Arts
Subway at Wood St
Two PNC Plaza
Liberty Ave
Oliver Ave
Mellon Square Park
Fifth Avenue
Forbes Ave
Wood St
Allegheny County Assessments
Pittsburgh City Hall
Third Avenue
Cherry Way
Smithfield St
Grant St
Boulevard of the Allies
First Avenue
Ross St
Student Center
Dance Complex
Forbes Ave
9th St
8th St
7th St
Andy Warhol Bridge
David L. Lawrence Convention Center


Livehood #44
Character
Related
Stats
Aggregate check-in statistics by day, hour, and type of place reveal usage patterns of the Livehood.
Daily Pulse
Mo
Tu
We
Th
Fr
Sa
Su
Hourly Pulse
6
9
12
15
18
21
0
3
Composition
Arts & Entertainment (5.8%)
Food (39.2%)
Nightlife (11.7%)
Home & Office (14.2%)
Travel (18.3%)
Education (1.7%)
Shops (3.3%)
Parks (5.8%)
Share us with friends?
Tweet 25
Like 615


Livehood #44
Character
Related
Stats
The popular check-in locations and the unique types of places found in a Livehood teach us about its character.
Top five popular places
1 USX Tower
2 BNY Mellon Center
3 The Westin Convention Center
4 David L. Lawrence Convention Center
5 Omni William Penn Hotel
Top five unique things to do here
1 Hotel
2 Convention Center
3 Office
4 Gay Bar
5 Subway
Share us with friends?
Tweet 25
Like 615

3.2.2 MAPKIBERA



SPATIAL

COMPOSITIONAL

CONDITIONAL

BEHAVIORAL

EXPERIENTIAL

VISUALIZATION TYPE

COMMUNITY DEVELOPED MAP

AUTHOR

YOUNG KIBERANS & GROUNDTRUTH INITIATIVE

CONTEXT

KIBERA, NAIROBI, KENYA

SCALE

NEIGHBORHOOD

URL

WWW.MAPKIBERA.ORG

DATE

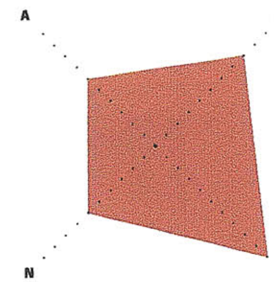
2009

Informal settlements like Kibera, one of Africa's largest slums, have constantly presented one of the greatest representational challenges to the field of planning. For most slums throughout the world, little documentation exists to formally represent the built environment, which is often irregular in nature to surrounding context. However, base maps and drawings still prove integral in the processes of community development and provide the underlay for data gathered for assessing the conditions of a neighborhood. These types of places are often so physically dense that even aerial photography provides little help in assessing spatial forms and patterns.

Through the Map Kibera project, community members themselves spearheaded the generation of the first online, free, public map of the 550-acre neighborhood. Over the course of three weeks, volunteers used the OpenStreetMap java platform to catalogue the dense network of community assets. The resulting interactive web map works on several dimensions. Spatially, it provides a plan view of the community. The composition of the neighborhood is revealed through the location of community assets, highlighting access to schools, clinics, churches, and other significant features. The experiential dimension is overlaid through a partner project called Voice of Kibera, that generates spatially-plotted mini-news stories supplied in real-time by community members using short message service (SMS) on their mobile phones. This process also generates a behavioral dimension by demonstrating key areas of newsworthy interest in the community.

A significant aspect of this project is the knowledge transfer between mapping experts and local community. Grassroots map-making is a self-enabling effort that allows citizens to more effectively plan for development, allocate resource flows, and advocate for changes in their own communities. This is an example of how the "[c]ontrol of information, now more than ever before, determines who enters the conversation about policy-making and access to resources" (Hagen 2010, 42).

QUALITIES OF VISUALIZATION



DATA SOURCE

COMMUNITY-GENERATED DATA

COLLECTION METHOD

FIELDWORK

ANALYSIS TOOLS

-

VISUALIZATION TOOLS

OPENSTREETMAP

PLATFORM

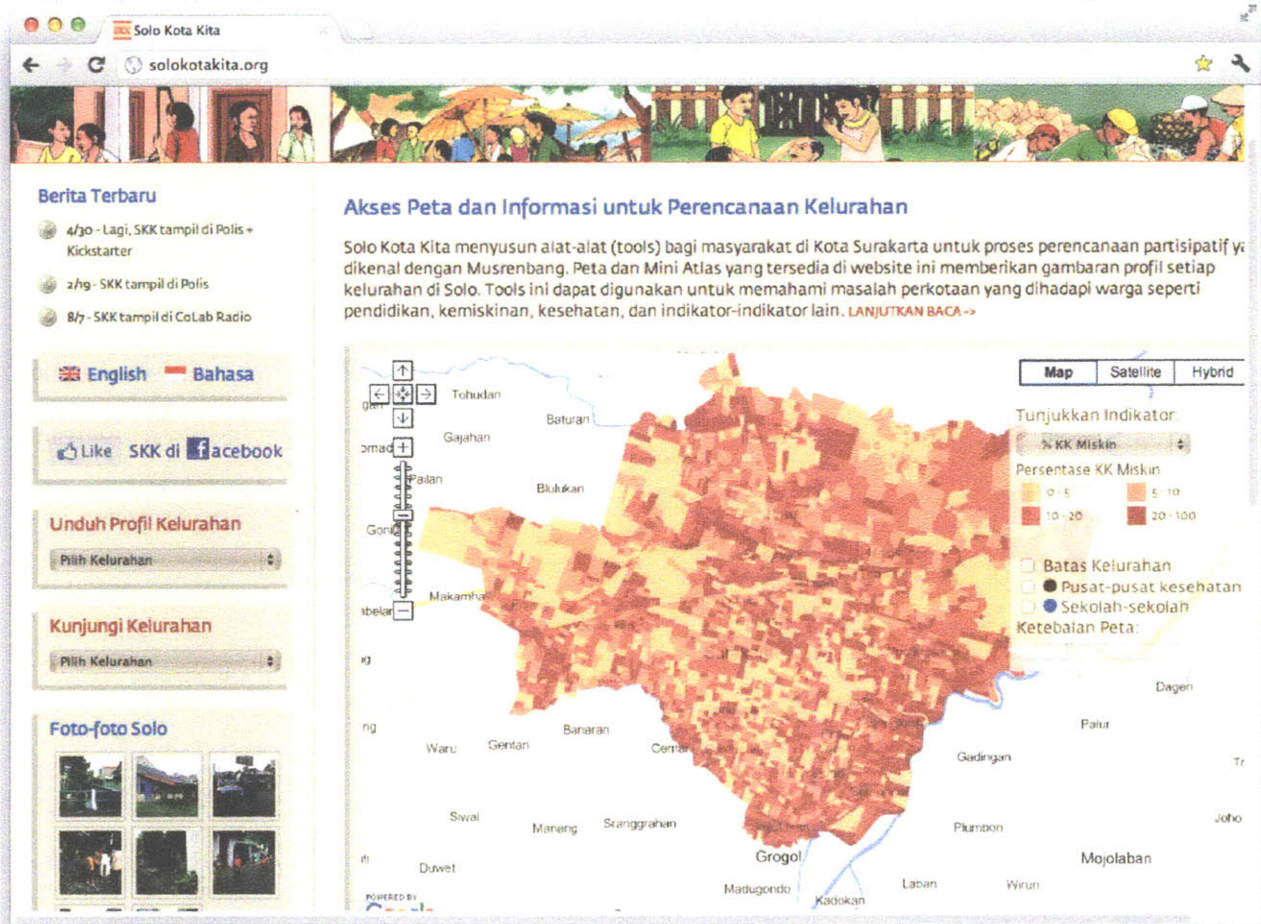
INTERACTIVE WEB-BASED SLIPPY MAP

3.2.3 NEIGHBORHOOD MINI ATLASES

SPATIAL

COMPOSITIONAL

CONDITIONAL



VISUALIZATION TYPE

ORGANIZATIONALLY AGGREGATED MAP

AUTHOR

SOLO KOTA KITA

CONTEXT

SOLO, INDONESIA

SCALE

URBAN / NEIGHBORHOOD

URL

SOLOKOTAKITA.ORG

DATE

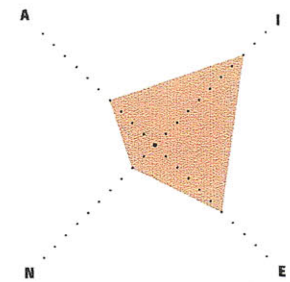
2010

Solo Kota Kita's community mapping project uses a decentralized approach of volunteer data collection and web-based visualization. The process involved questionnaires used to survey leaders of 2,7000 neighborhood sub-units in Solo, Indonesia, in Central Java. Tabular survey data was connected to neighborhood maps using the open-source spatial analysis tool Quantum GIS (QGIS) and aggregated the findings into a graphic tool known as a mini atlas.

While also spatial and compositional, the visual is primarily conditional in dimension, essentially a dynamic chloropleth map of different neighborhood indicators. Each neighborhood is characterized by several metrics, including density, land tenure, poverty, and access to schools, various types of water and sanitation resources, open space, and medical facilities. The dynamic filtration of the map allows communities and local planners to efficiently view these metrics in tandem and draw out correlations.

The distributed date collection process ensures that each neighborhood is documented to the same relative degree. Neighborhoods that may not have as much social or political capacity are able to advocate for resources if they can demonstrate gaps or opportunities in terms formalized through the visual mini atlases. The visual has been designed for use as a tool in the municipal budgeting process known as the musrenbang (Schultz 2010). As community leaders gather for this annual process, each of the atlases becomes a tool through which to evaluate the conditions and needs of each neighborhood.

QUALITIES OF VISUALIZATION



DATA SOURCE

COMMUNITY-GENERATED DATA, NEIGHBORHOOD DATABASES

COLLECTION METHOD

FIELDWORK

ANALYSIS TOOLS

QGIS

VISUALIZATION TOOLS

GOOGLE MAPS API

PLATFORM

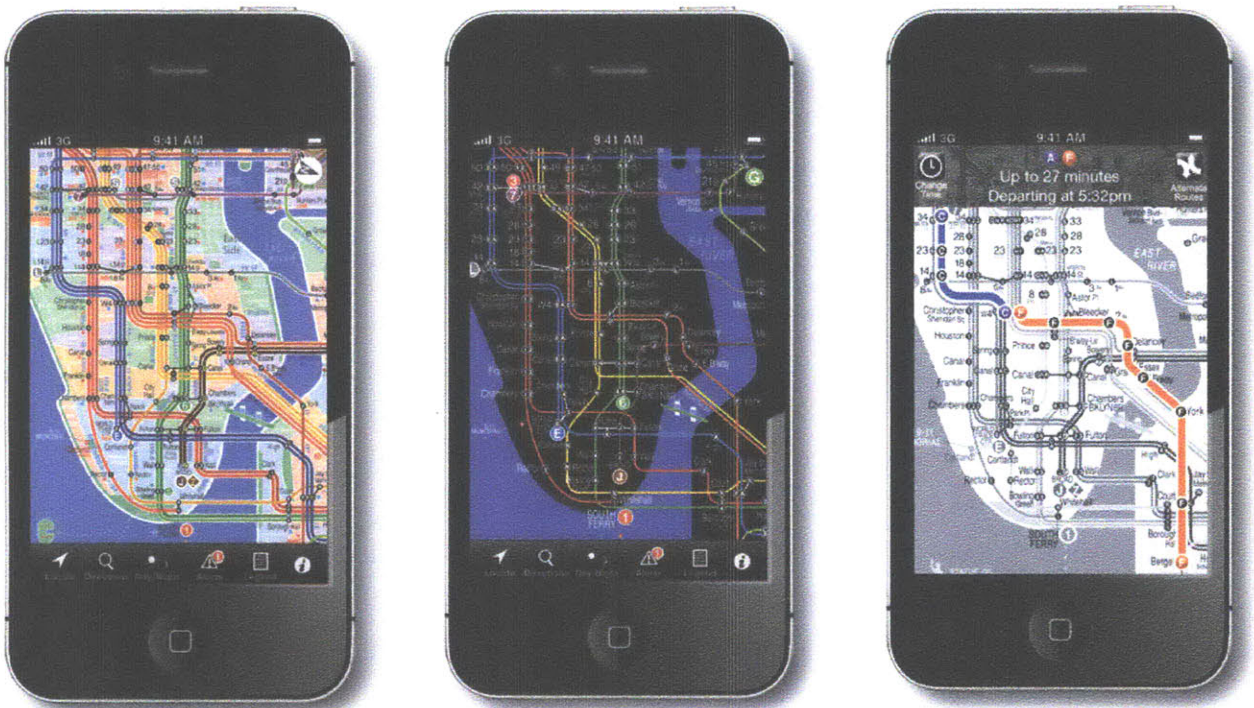
INTERACTIVE WEB-BASED SLIPPY MAP

3.2.4 KICKMAP

SPATIAL

TEMPORAL

COMPOSITIONAL



Day / Evening Map
26 lines

Late-Night / Early Morning Map
19 lines

Step-by-Step
Directions on the Map

VISUALIZATION TYPE

USER-SERVICE TRAVEL PLANNER

AUTHOR

KICK DESIGN

CONTEXT

NEW YORK CITY

SCALE

URBAN

URL

WWW.KICKMAP.COM

DATE

2010

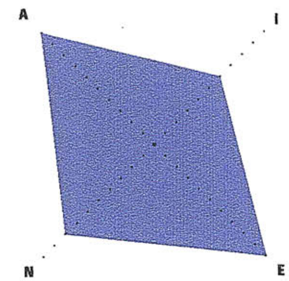
Subway maps can be considered one of the most iconic visualizations, essentially becoming their own classic typology of representation, stemming from Harry Beck's diagrammatic rendition of the London Underground based on the conventions of drawing electrical circuit boards (Illinsky 2010). The most effective subway maps are essentially a balance between distilling down to only the most relevant information for commuters and providing an accurate spatial depiction of an urban-scale system. From a commuter perspective, the complexity of the subway map can become a barrier to the use of the system. Even for those extremely familiar with the New York City subway, the day-to-day changes and disruptions become a hinderance, primarily through the difficulties of communicating this form of information in real time.

The Kick Map is an attempt to hybridize several versions of the New York City Subway by combining both diagrammatic and topographic conventions for representing the spatial composition system (Illinsky 2010).

Scalability of the map is a major feature that influences its mobility. Designed for use at multiple platforms, the map reads at the macro-scale of viewing the system as a whole for comparing various lines and trajectories, as well as the micro-scale of details relating individual stops to surrounding context. The temporal dimension is introduced through a simple functionality separation: the map switches view to only showcase relevant lines and stops usable during late night or early morning.

For planners, the primary lessons from the Kick Map relate to graphic conventions that negotiate a system, the urban fabric it exists in, and the people who have to navigate it. The ability to differentiate and filter for information that is relevant to the individual aids in their ability to navigate through a complex system. Rather than presenting overloaded or complex visualizations of information to the public, dynamic visualizations would allow the public to seek out what is relevant to them, providing a degree of orientation that facilitates further engagement.

QUALITIES OF VISUALIZATION



DATA SOURCE

PREVIOUS MAP RENDITIONS

COLLECTION METHOD

ADJUSTMENTS BASED ON FIELDWORK

ANALYSIS TOOLS

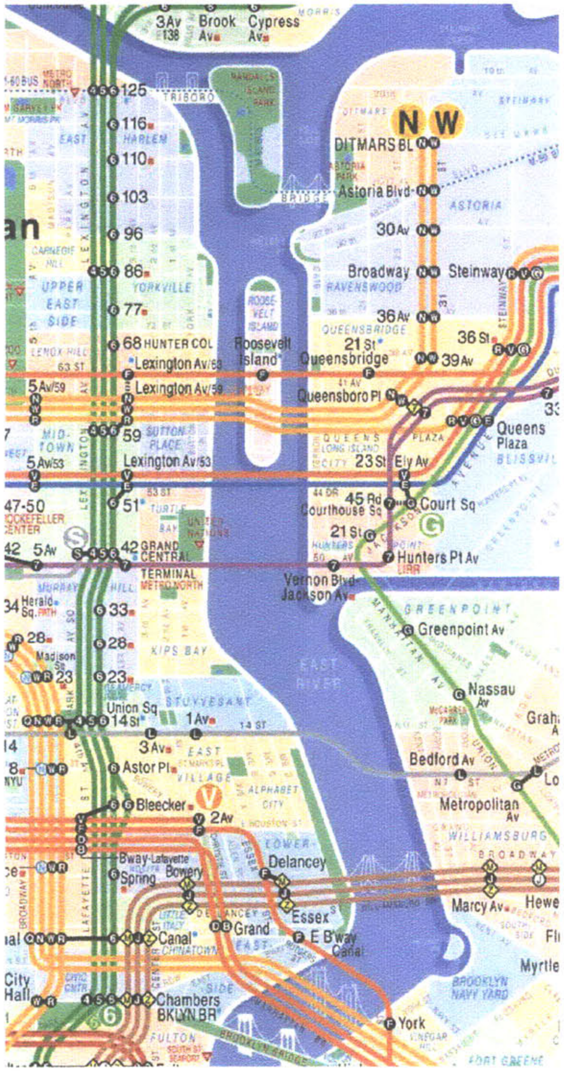
-

VISUALIZATION TOOLS

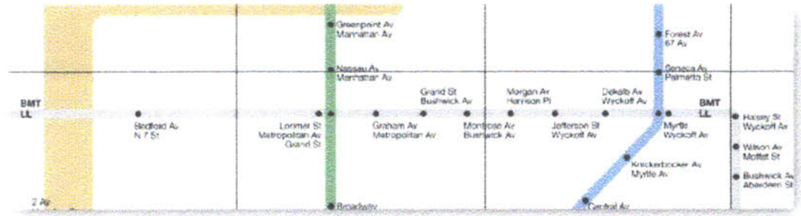
ILLUSTRATOR / IOS

PLATFORMS

WEB & MOBILE



A



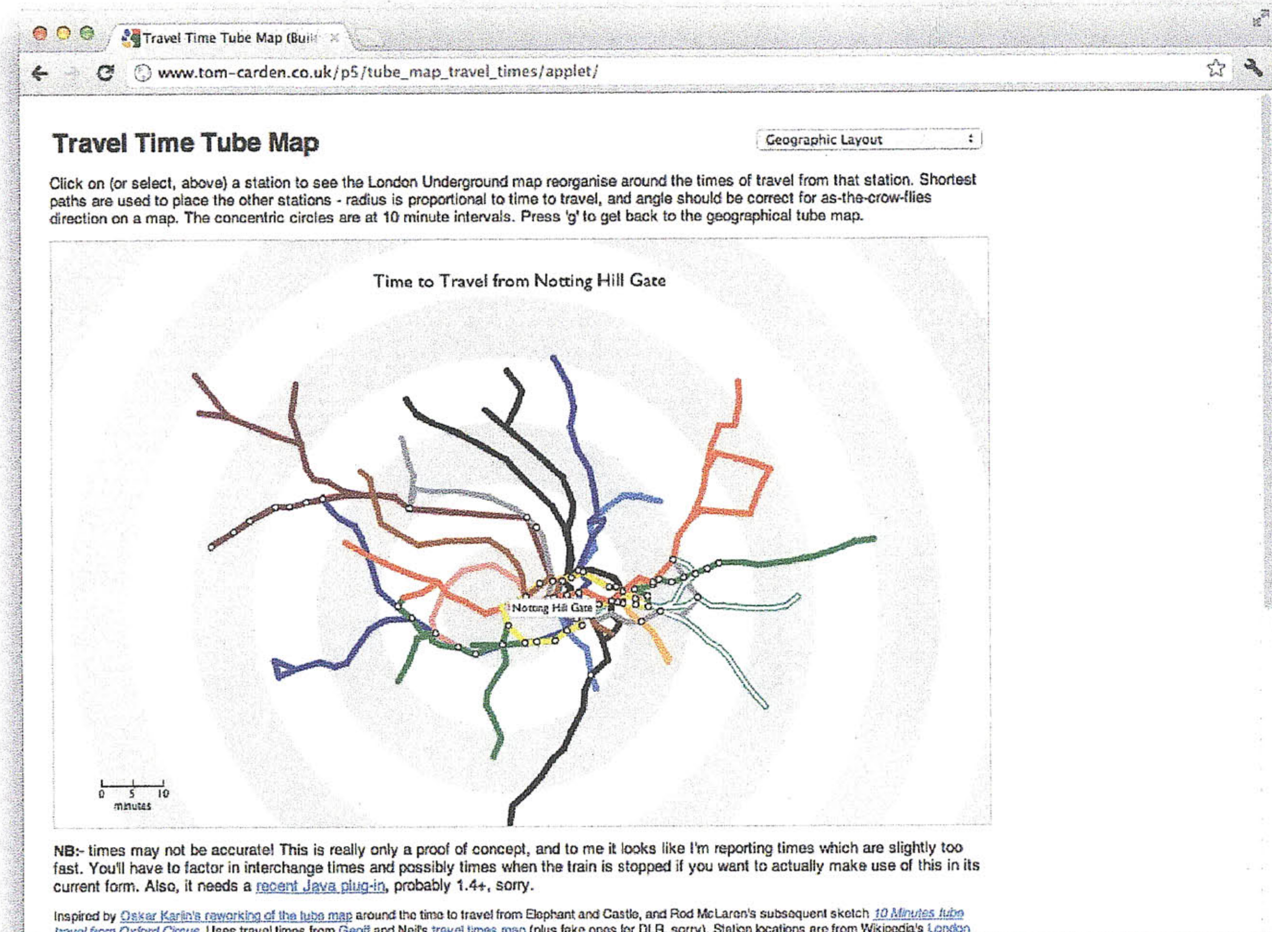
B

C

FAR LEFT: SHOWCASES THE USE OF MULTIPLE LINES IN A COLOR GRADIENT ILLUSTRATE DIFFERENT LINES THAT USE THE SAME TRACK.

LEFT: ILLUSTRATES THE HYBRIDIZATION UTILIZED BY THE KICK MAP [B], WHICH FEATURES BOTH DIAGRAMMATIC ASPECTS USED IN THE VIGNELLI VERSION [A] AND TOPOGRAPHICAL STRATEGIES USED BY TAURAC-HERTZ [C].

3.2.5 TRAVEL TIME TUBE MAP



SPATIAL

TEMPORAL

COMPOSITIONAL

EXPERIENTIAL

VISUALIZATION TYPE

USER-SERVICE TRAVEL PLANNER

AUTHOR

TOM CARDEN

CONTEXT

LONDON

SCALE

URBAN

URL

WWW.TOM-CARDEN.CO.UK/P5/TUBE_MAP_TRAVEL_TIMES/APPLET/

DATE

2005

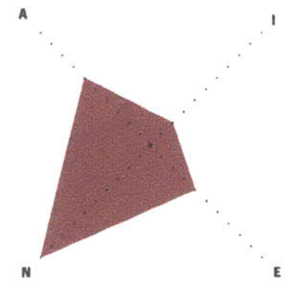
One of the most difficult aspects to represent through visual strategies is the relativity of time, particularly in static images. The traditional London Tube Map primarily uses the spatial and compositional dimensions to communicate the relationship of lines in the system and the sequential relativity of stations. The Travel Time Tube Map utilizes a different approach: while still maintaining the overall composition of the system, the map dynamically generates relativity between stations and lines based on travel time.

The dynamic aspect of this visualization begins with the fact that the user can re-orient the entire system to whatever station is selected. A graphic representation of relative commutes for each station can quickly be generated. This provides not one static view from which to understand the system, but a perspective reorientation for every point in the system.

As a way-finding device, this visualization could certainly be improved in terms of scale and search-ability. Relative travel time could be displayed for each major station, ordered by magnitude. Additionally, different graphic conventions could enhance the readability of stations along the lines.

For planning purposes, having dynamic reorientations of complex systems provides a humanistic degree of perspective. For example, stakeholders in a participatory planning process can select what they consider the central feature in a system and analyze how changes impact their direct needs.

QUALITIES OF VISUALIZATION



DATA SOURCE

TUBE TRAVEL TIMES

COLLECTION METHOD

SOURCED FROM GEOFF.CO.UK

ANALYSIS TOOLS

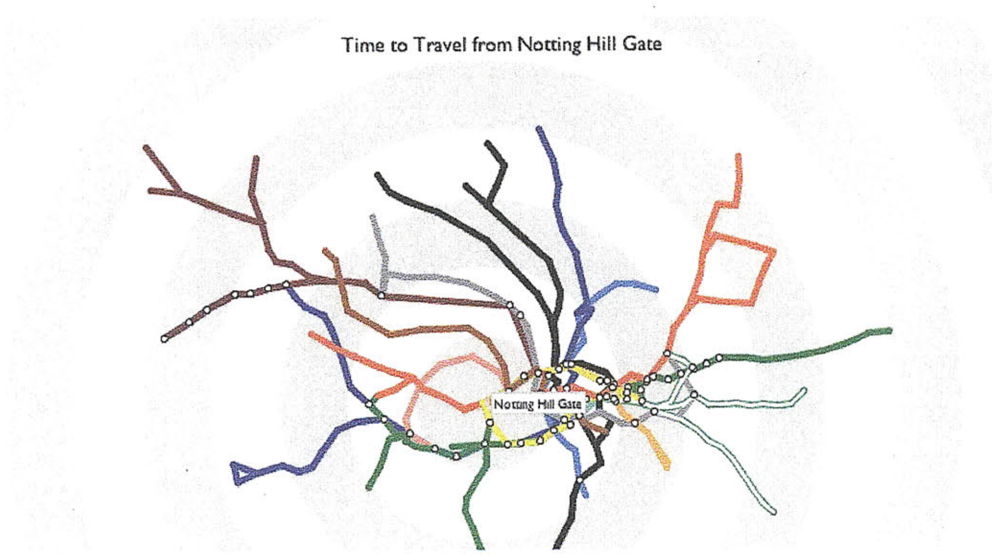
-

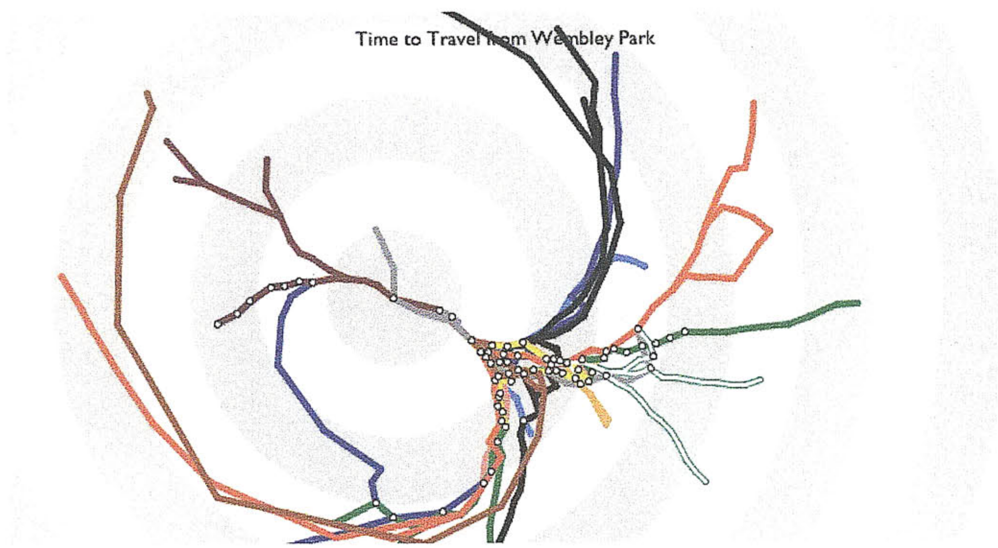
VISUALIZATION TOOLS

PROCESSING

PLATFORMS

WEB

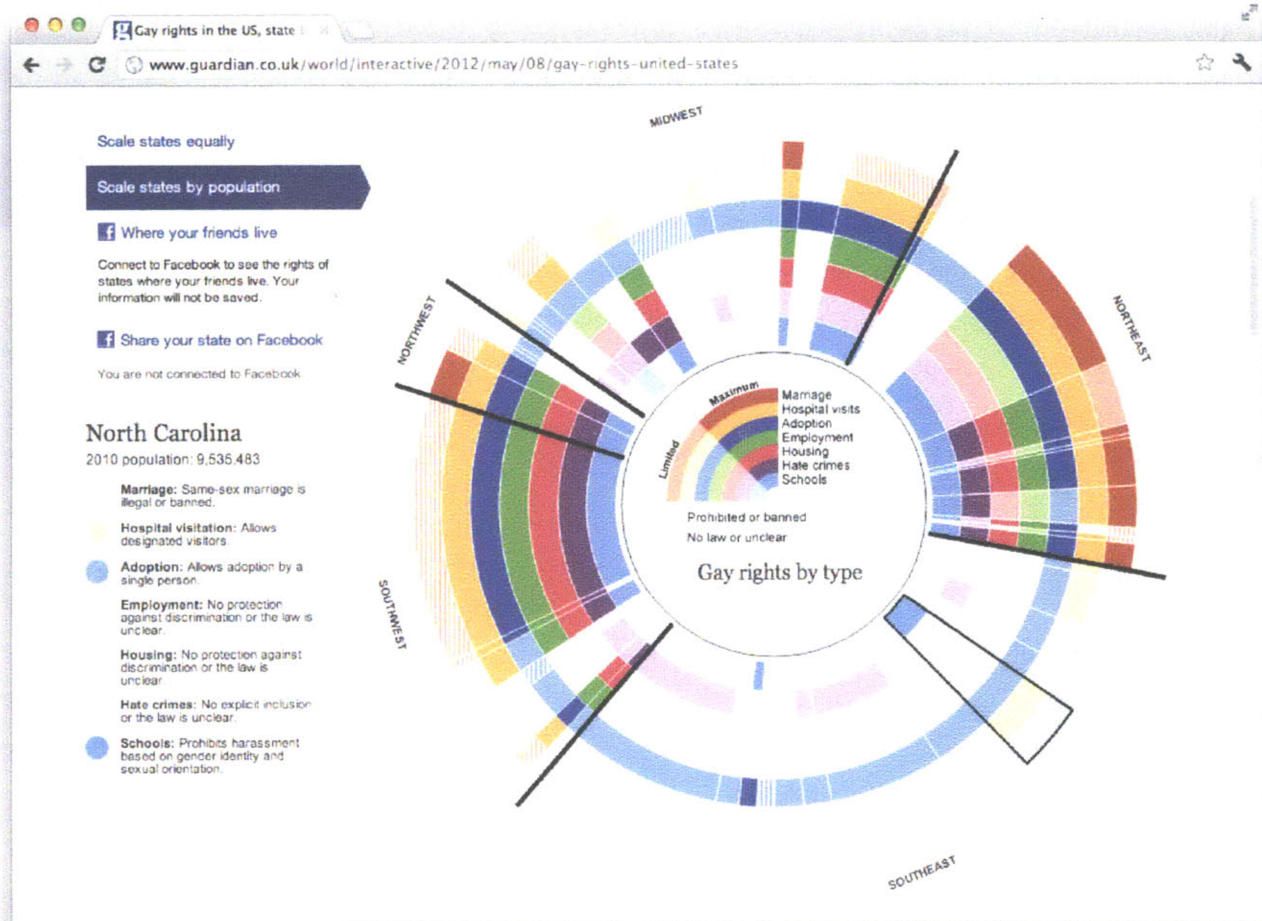




LEFT: ILLUSTRATES THE DYNAMIC ADJUSTMENT OF THE SYSTEM BASED ON WHICH POINT IS SELECTED.

TRAVEL TIME TO OTHER PARTS OF THE SYSTEM, AS ILLUSTRATED BY THE RELATIVE LENGTHS OF THE LINE, DRASTICALLY INCREASES WHEN SELECTING A STATION NEAR THE END OF A LINE OR THE EDGE OF THE SYSTEM, SUCH A WEMBLEY PARK.

3.2.6 GAY RIGHTS IN THE UNITED STATES



SPATIAL

COMPOSITIONAL

CONDITIONAL

VISUALIZATION TYPE

DATA JOURNALISM: INTER-ACTIVE GRAPHIC / ASPATIAL

AUTHOR

GUARDIAN IN AMERICA INTERACTIVE TEAM

CONTEXT

UNITED STATES

SCALE

STATE

URL

WWW.GUARDIAN.CO.UK/WORLD/INTERACTIVE/2012/MAY/08/GAY-RIGHTS-UNITED-STATES

DATE

2012

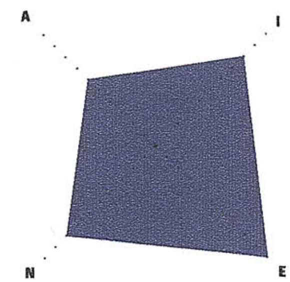
This visualization is a display of gay rights in all fifty states. Primary issues radiate in concentric circles, increasing in color intensity based on the degree of rights available in each state. A lack of color indicates no laws exist, while hatch lines indicate prohibitive laws.

The arrays efficiently indicate the polarization of gay rights to certain regions of the country. A quick glance infers that the majority of states in the northeast support a full range of gay rights, as do a few of the west coast states, while little rights exist at all in much of the midwest and the entirety of the southeast.

This graphic takes advantage of filtered interactivity by allowing for a normalized scaling of each state's pie wedge based on population rather than solely scaling each state equally. This filtering reveals a more striking story regarding the larger segment of the US population in the southeast who live without equal rights legislation for gays.

The visualization not only efficiently displays the distribution of rights, but also begins to allude to the types of rights that act as precursors to having the full range of rights, culminating in true marriage equality. For example, the majority of states that currently support hospital visitation, adoption, employment anti-discrimination laws already allow domestic partnerships or civil unions. Here, the information the visualization moves beyond declarative knowledge and becomes communicative, indicating the implications of providing some rights.

QUALITIES OF VISUALIZATION



DATA SOURCE

STATE LEGISLATION (SLOW DATA)

COLLECTION METHOD

MANUAL RESEARCH

ANALYSIS TOOLS

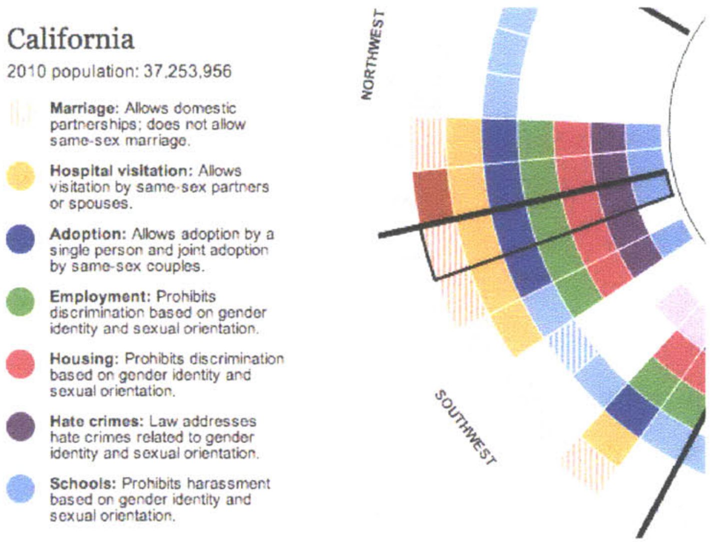
-

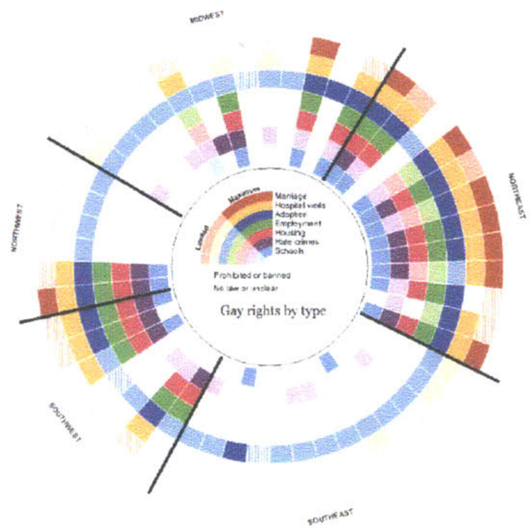
VISUALIZATION TOOLS

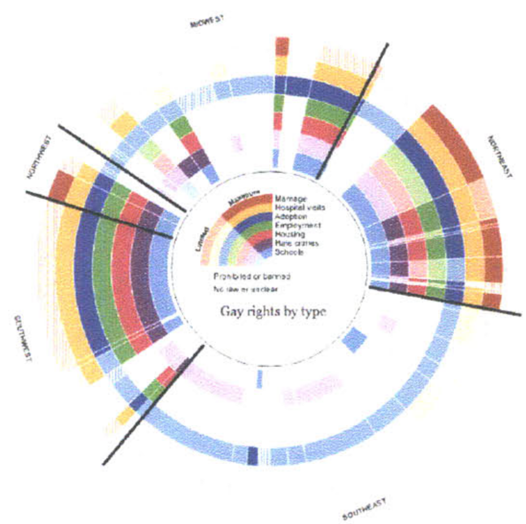
JAVASCRIPT

PLATFORMS

WEB





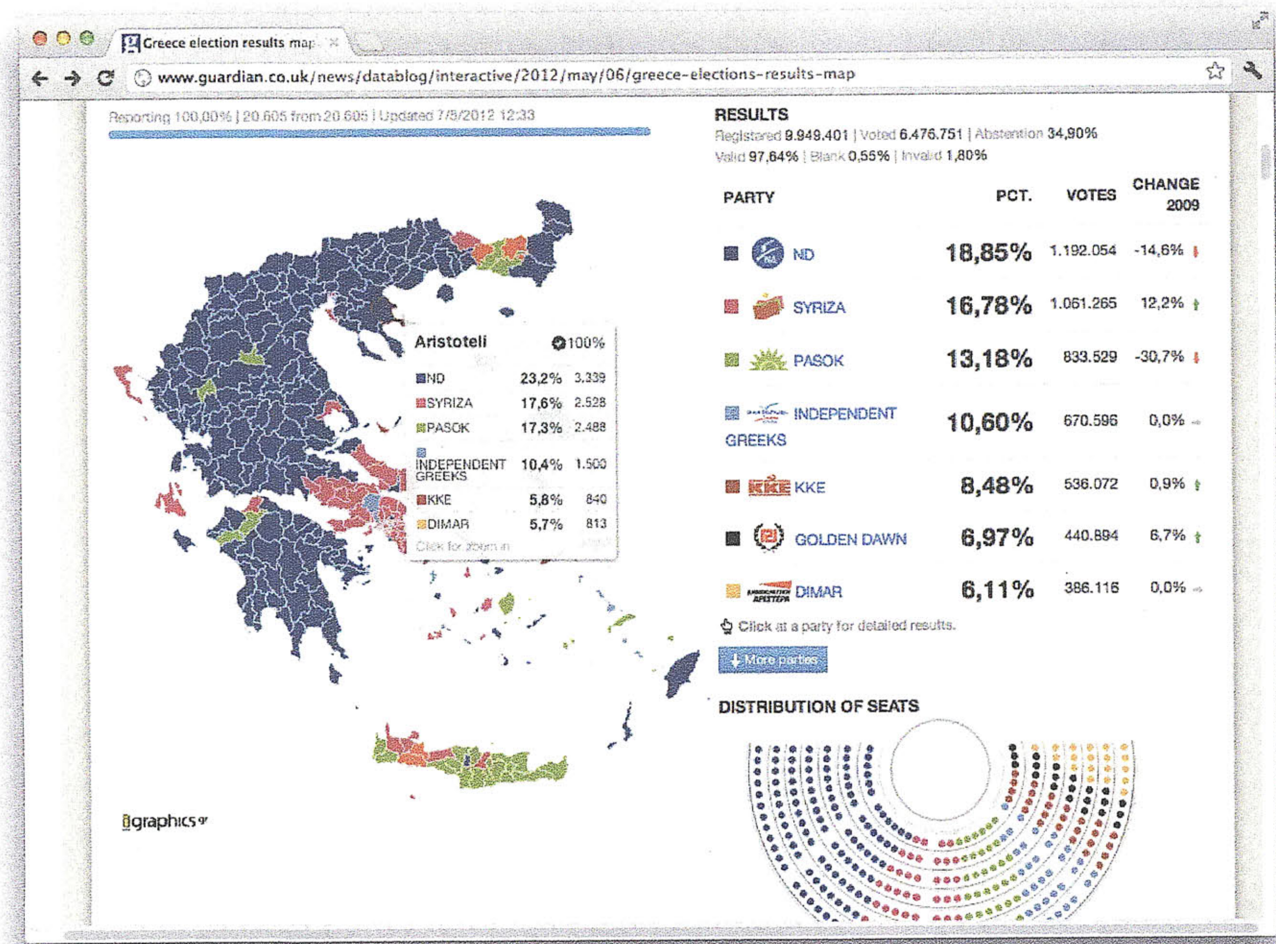


TOP FAR LEFT: DETAILS SHOWN WHEN MOUSEOVER ON EACH STATE IN THE PIE CHART

BOTTOM FAR LEFT: DISAGGREGATED SMALL MUTLIPLES OF EACH CATEGORY OF RIGHTS

LEFT: STATES EQUALLY REPRESENTED (TOP) VERSUS SCALED ACCORDING TO POPULATION (BOTTOM)

3.2.7 GREECE ELECTIONS RESULTS MAP



SPATIAL

BEHAVIORAL

VISUALIZATION TYPE

EVENT TRACKING / RESULTS

AUTHOR

IGRAPHICS.GR

(PUBLISHED BY THE GUARDIAN)

CONTEXT

GREECE

SCALES

NATIONAL / REGIONAL / MUNICIPAL

URL

WWW.GUARDIAN.CO.UK/NEWS/DATABLOG/INTERACTIVE/2012/MAY/06/GREECE-ELECTIONS-RESULTS-MAP

DATE

2012

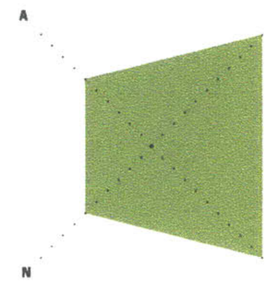
The Greece Elections Results map provides a combined spatial and statistical display of the 2012 parliamentary election, updated in real-time as votes were received. Unlike the Gay Rights visualization, this not only displayed comparative metrics on the parties involved in the election, but also correlated the results to their spatial distribution.

Users are able to understand the election results from several perspectives simultaneously, similar in format to a dashboard. The visualization has a high degree of efficiency because there three modes simultaneously displayed in one screen. The amount of information in the visualization is densified by designating a specific portion to dynamically update, maintaining spatial context whether viewing the winning party for each constituency or filtering for a single party.

As a dynamic data display, the Greece Election Results map efficiently provides information on the election at multiple scales, accessible by several different navigational modes. Navigating using the national map allows for the macro-scale comparison of which constituencies favored which parties. Users can also mouse-over each constituency to reveal details about the voting percentages per party. This macro-scale view can also be adjusted to display the results using a different spatial definition, reconfiguring the map to municipal boundaries. Additionally, a query function enables users to search for specific municipalities.

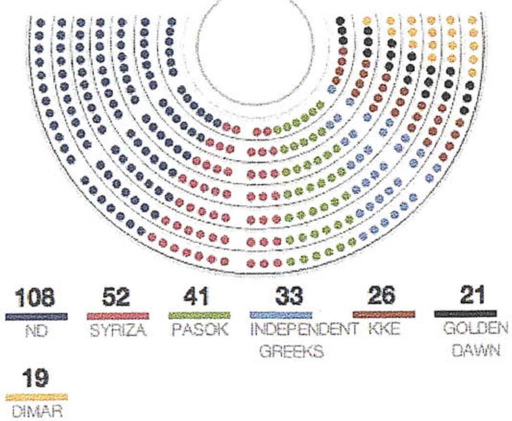
Users can also navigate through the information by clicking on a party from the right-hand list, ordered by percentage of votes. Selecting a party reconfigures the map to reveal an intensity map of support in every constituency, rather than just color coding with the most dominant party. This degree of interactivity further illustrates the primary impact of the election: the drastic shift away from the dominance of a two-party system as a result of recent financial disparity for the country.

QUALITIES OF VISUALIZATION



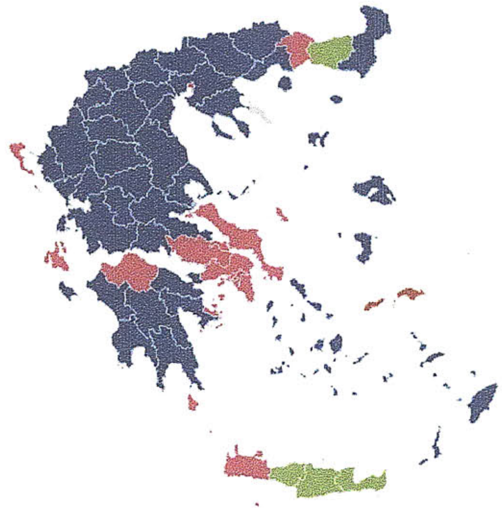
DATA SOURCE
ELECTION RESULTS
COLLECTION METHOD
REAL-TIME DATA FEED
ANALYSIS TOOLS
JQUERY / PIWIK
VISUALIZATION TOOLS
JAVASCRIPT
PLATFORMS
WEB

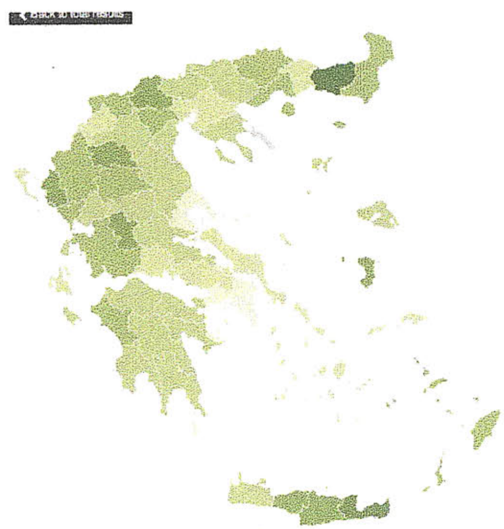
DISTRIBUTION OF SEATS



THE BATTLE FOR THE ENTRANCE

The parties near the threshold of 3% for entry into parliament



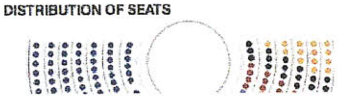


PARTY	PCT.	VOTES
ND	18,85%	1.192.05
SYRIZA	16,78%	1.061.26
PASOK	13,18%	833.52
INDEPENDENT GREEKS	10,60%	670.59
KKE	8,48%	536.07
GOLDEN DAWN	6,97%	440.89
DIMAR	6,11%	386.11

Click at a party for detailed results.

More parties

DISTRIBUTION OF SEATS



CONSTITUENCY	PCT.	SEATS	VOTES	CI
A' Athinon	9,71%	1*	28.309	
Axaias	14,11%	1*	26.590	
Aitoloakarnanias	16,95%	1*	24.865	
A' Peiraios	8,61%	0	10.602	
Argolidos	13,90%	1*	8.744	
Arkadias	16,09%	1*	10.822	
Artas	14,41%	1*	7.596	
A' Thessalonikis	10,44%	1*	36.356	
B' Athinon	9,07%	4****	92.913	
B' Peiraios	8,16%	1*	14.745	
B' Thessalonikis	11,23%	1*	23.142	
Dramas	17,75%	1*	11.944	
Dodekanisou	16,99%	1*	17.887	
Evoias	12,80%	1*	17.526	
Evrou	18,55%	1*	17.679	

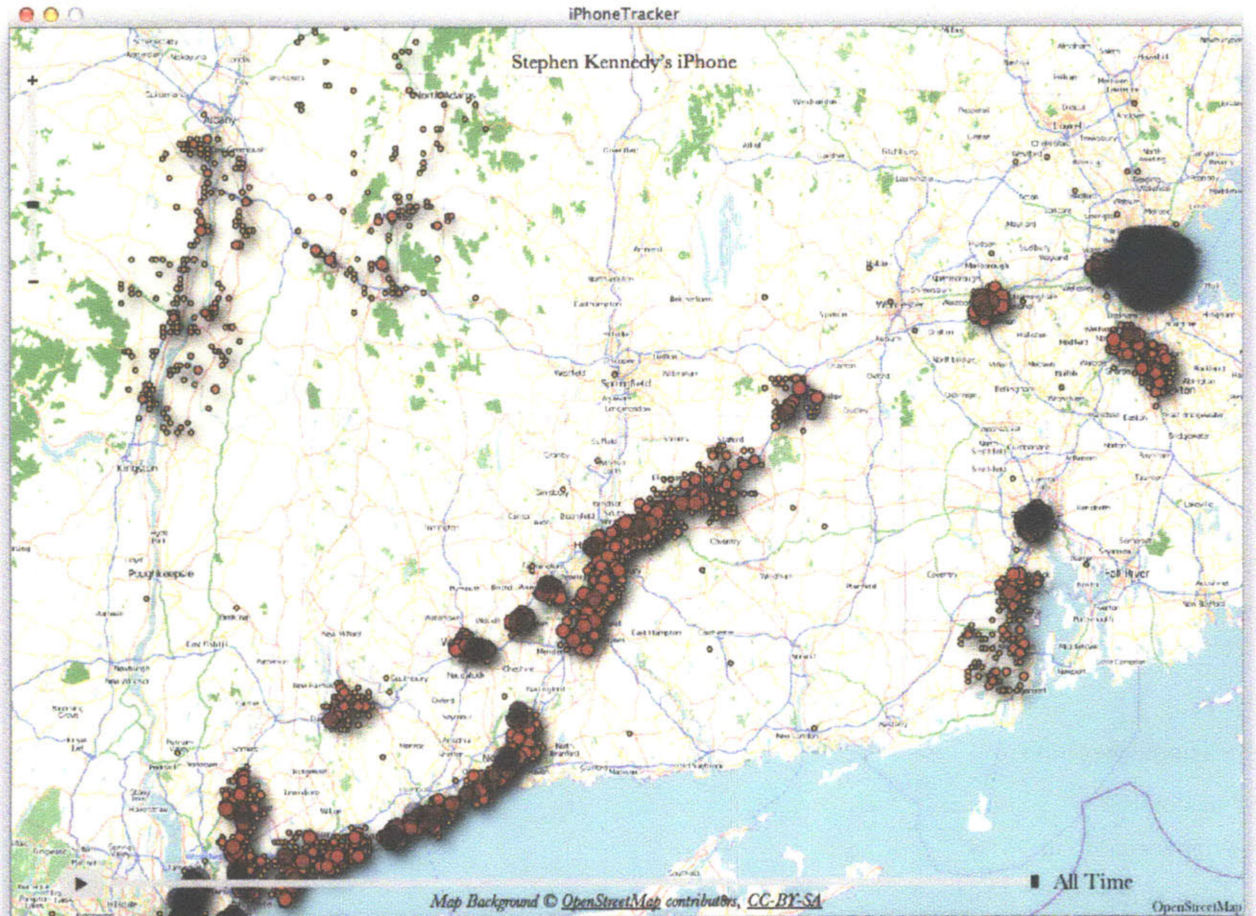
FAR LEFT: SHOWS AN ABSTRACTED VIEW OF THE PARLIAMENT RESULTS, INDICATING THE OVERALL DISTRIBUTION OF SEATS COLOR-CODED BY POLITICAL PARTY.

LEFT: ILLUSTRATE THE IMPACT OF FILTERING FOR A SINGLE PARTY. WHILE PASOK APPEARS ON THE OVERALL MAP TO HAVE ONLY BEEN THE DOMINANT PARTY IN FOUR CONSTIUENCIES, A HEATMAP VERSION WITH COLOR INTENSITY CORRELATED TO PERCENTAGE OF VOTES REVEALS THAT THE PARTY STILL MAINTAINED RELATIVE STRENGTH IN MANY CONSTUENCIES IN THE NORTHWESTERN PART OF GREECE.

3.2.8 IPHONE TRACKER

SPATIAL

TEMPORAL



VISUALIZATION TYPE

PERSONAL MAPPING / TRACKING

AUTHOR

PETE WARDEN

CONTEXT

GLOBAL

SCALE

GLOBAL / REGIONAL / URBAN / NEIGHBORHOOD

URL

PETEWARDEN.GITHUB.COM/IPHONETRACKER/

DATE

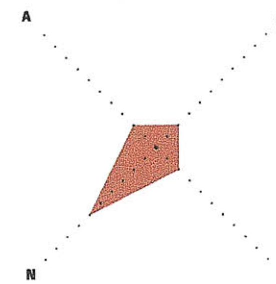
2011

iPhone Tracker presents an interesting combination of temporal and spatial data. Essentially, it showcases the intensity of use of the iPhone over various locations and times. A redundant visual technique is used to highlight the magnitude of use in a given area by scaling and color-coding objects based on the number of collected data points in a location.

The animation provides a series of snapshots that effectively show a difference between extended time spent in a particular location versus travel traces between cities. However, the distinction is only relative, as a clear key indicating the quantity of traces is not provided. As the animation ends, an 'All Time' representation of the iPhone GPS logs gives an overall view of locations for the recorded time.

While this dynamic visualization plots tracings over time without much effort required by the user, the degree of interactivity is still quite limited. The generated map is simply a set of tracings, indicating where a user has spent more or less time. There is the potential to overlap and integrate more information to the plotted tracings, particularly with data from the mobile device that is paired spatially and temporally.

QUALITIES OF VISUALIZATION



DATA SOURCE

IPHONE GPS LOGS

COLLECTION METHOD

DATA PULLED FROM IPHONE BACKUPS ON PERSONAL COMPUTER

ANALYSIS TOOLS

PYTHON

VISUALIZATION TOOLS

OPENHEATMAP JQUERY PLUGIN / OPENSTREETMAP / CSS

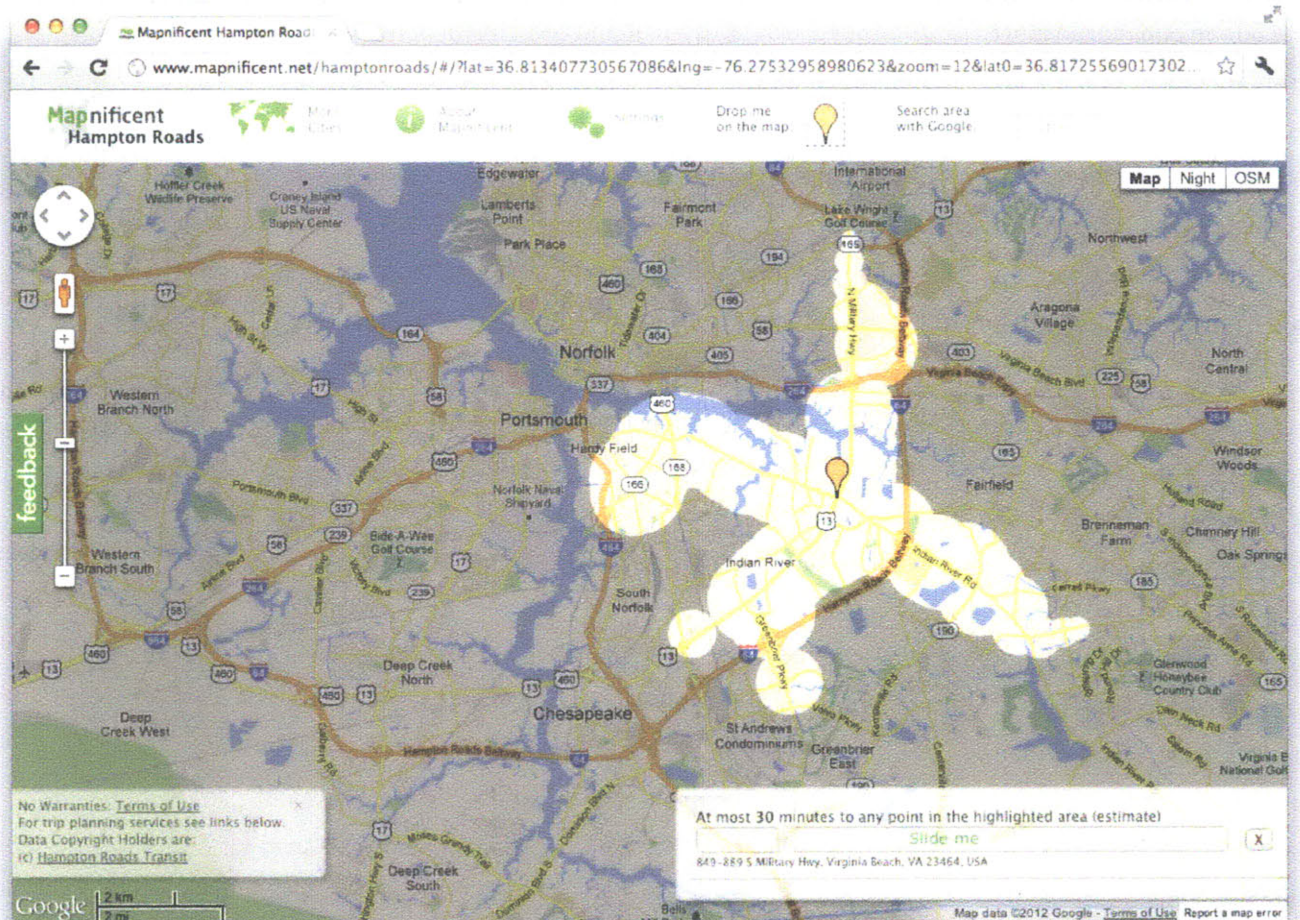
PLATFORMS

DESKTOP PROGRAM (NON-WEB)

3.2.9 MAPNIFICENT

SPATIAL

TEMPORAL



VISUALIZATION TYPE

USER-SERVICE TRAVEL PLANNER

AUTHOR

STEFON WERHMEYER

CONTEXT

GLOBAL

SCALE

URBAN, NEIGHBORHOOD

URL

WWW.MAPNIFICENT.NET

DATE

2010

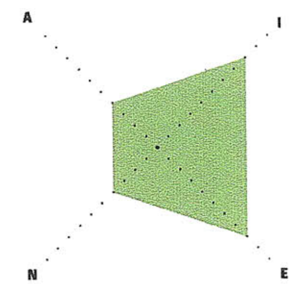
Mapnificent is a JavaScript-based visualization that calculates the area of a city reachable in a given time. The buffers are calculated using data on the public transport systems pulled from General Transit Feed Specification (GTFS) Data Exchange, which hosts open-source city transit schedules and their geographic information. Buffers are visualized over the Google Maps API using an HTML5 Canvas overlay. The overlay acts as a mask, dimming the areas not reachable from a point dropped on the map.

While not necessarily effective as a tool for trip planning, Mapnificent visual analyses of reach integrated with the search function of Google Maps. For example, one can place a marker on the map, adjust the time scale to reflect a desired maximum travel time, and search for restaurants. The Canvas overlay simply reveals which results are reachable by brightening those areas of the map; outside the search radius are obscured with a darker tinting. The results are redundantly encoded by color, with features within the travel time designated by red markers while non-reachable points are marked in gray. The capability of computationally searching for features provides a distinct spatial and conditional dimensions that relies on existing real world locations and venues. All information about destinations found normally using Google Maps search functionality is still available.

Another additional feature is the ability to plot multiple points on the map, attempting to determine areas that multiple users can reach. The results, however, could be improved by differentiating the area reachable by all plotted points with the areas reachable by each point individually. This could be achieved through the use of color coded visual overlays or a scaling of tinting.

While this dynamic visualization is not extremely novel in output, it demonstrates the potentials of generating vector overlays on fully searchable map platforms like Google Maps. The open-source nature of these tools will encourage future integration of generating analysis using real-time information available on the Web.

QUALITIES OF VISUALIZATION



DATA SOURCE

GTFS DATA EXCHANGE

COLLECTION METHOD

SLOW-DATA EXTRACTION

ANALYSIS TOOLS

JAVASCRIPT

VISUALIZATION TOOLS

HTML5 CANVAS / GOOGLE MAPS API

PLATFORMS

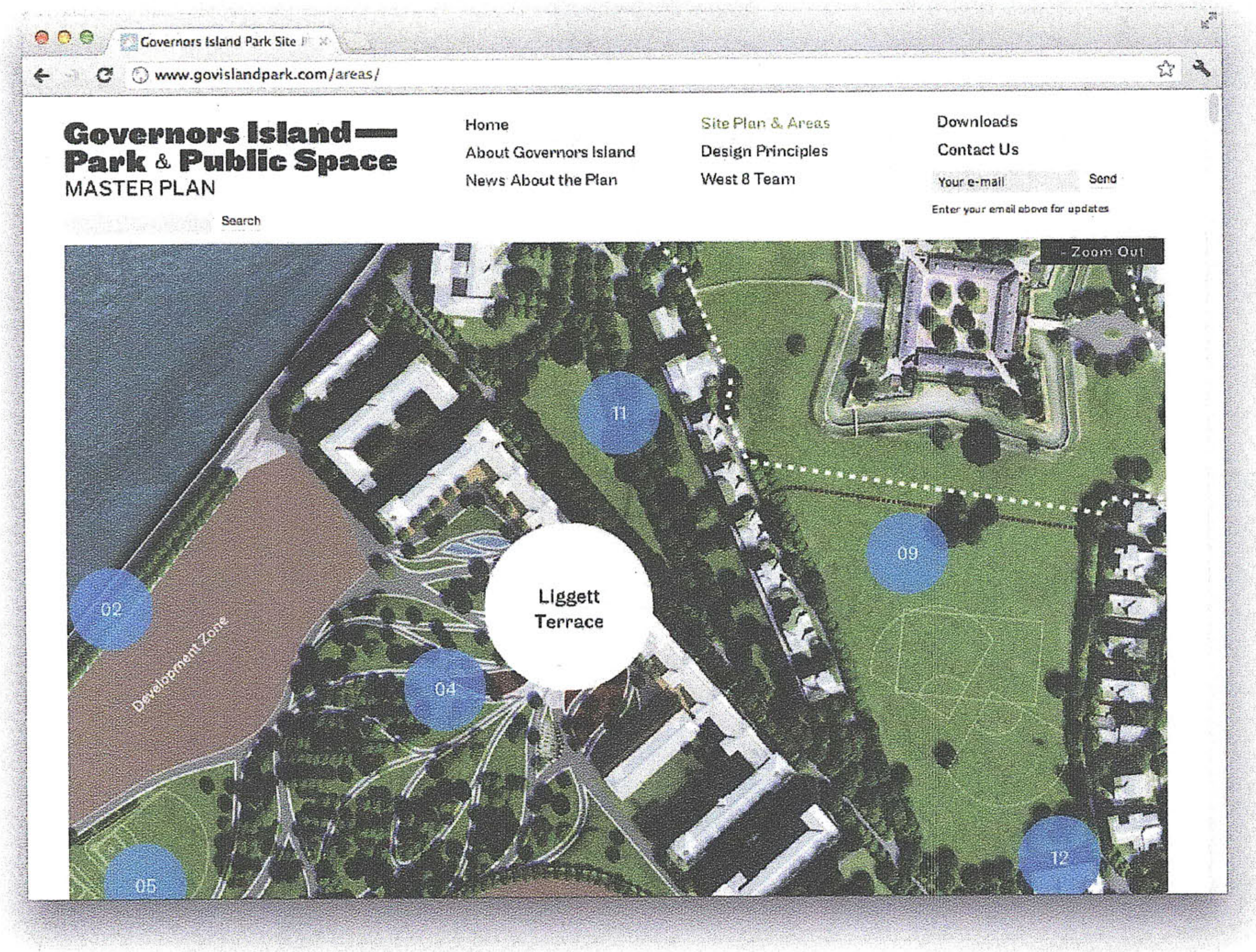
WEB

TOP LEFT: A USER IN JERSEY CITY IS PLOTTED WITH 30-MINUTE TRAVEL TIME AREAS HIGHLIGHTED AND REACHABLE COFFEE SHOPS PLOTTED WITH RED MARKERS.

BOTTOM LEFT: ADDING A SECOND PLOTTED POINT IN THE EAST VILLAGE ON MANHATTAN, ADDS THE AREA REACHABLE FROM THAT POINT IN 15 MINUTES.

TO IMPROVE THE UTILITY OF THESE RESULTS, THE DESTINATIONS REACHABLE BY BOTH POINTS WITH THEIR RELATIVE TIME BUFFERS COULD BE SHOWN AT 100% BRIGHTNESS, THE AREA REACHABLE BY EACH POINT RESPECTIVELY SHOWN AT 75% BRIGHTNESS, WHILE THE UNREACHABLE AREAS COULD BE OBSCURED BY A 50% BRIGHTNESS OVERLAY.

3.2.10 GOVERNORS ISLAND MASTERPLAN



SPATIAL

COMPOSITIONAL

CONDITIONAL

EXPERIENTIAL

VISUALIZATION TYPE

INTERACTIVE MASTERPLAN

AUTHOR

WEST8 & MAVEN INTERACTIVE

CONTEXT

NEW YORK CITY

SCALE

NEIGHBORHOOD

URL

WWW.GOVISLANDPARK.COM

DATE

2010

The Governor's Island Master Plan website features an interactive illustration of the West 8 vision of the park and public space. Users experience a highly aesthetic overview of the proposal, and are able to click through sections to experience more information and additional imagery of site details. They are also able to directly respond to the plan via comments (below, right).

The plan features some of the functionality available in other Web-based mapping interfaces such as the ability to zoom in and out. The plan automatically re-centers as users navigate with their cursor in any direction. Animated bubbles reveal the names of specific site features, inviting users to click through and experience each site in a sequence of their choosing.

While these interactive features are engaging and add a degree of novelty to understanding the plan, the use of interactive conventions is still quite limited. The degree of visual quality projects to future potentials for developing high resolution digital plans. Sections could be updated to illustrate projects currently underway, areas unplanned but ripe for community input, and the metrics of completed projects available for public evaluation. By enabling information to be embedded and updatable in the visual artifact of the plan itself, the master plan becomes a living proposal adapted to current community needs.

Comments (103)

Comments –

Please plan for ample public restrooms and reasonably priced food offerings that are family oriented.
By Rich Rotondo on April 14, 2010 11:52 am

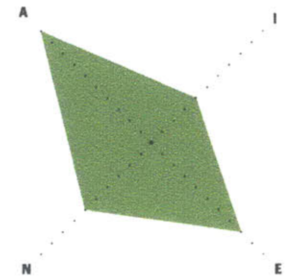
The design is great, but it is the Manhattan problem, an island where you can't touch the water. Where do I beach the kayak?
By Peter Brown on April 14, 2010 5:22 pm

Nice stuff. But a glaring omission: What are the "Development" areas? Will this be residential, commercial, what? They are huge portions of the island, and it feels as if you're sugar-coating a possible playground for the rich.
By tom Bloom on April 20, 2010 5:45 am

The plans for the Southern tip are absolutely fantastic! I recall, As a teenager in the early 1940s, there was nothing beyond the parade grounds other than an area previously used as an incinerator. At the time a far cry from the very beautiful Northern end.
By Wm. Fraser on April 26, 2010 9:08 am

The designs seem to perpetuate the notion that the public likes nothing more than vast expanses of lawn, endless uniform paths, railings and seating, and trendy design elements. The 'hammock grove' idea is cute, but I'd say doomed to fail..not sure why, exactly, but it seems creepy – like the movie, "Cocoon"...Maybe also because it's too much like organized relaxation. Ditto for the huge lawns. Sheep Meadow works because the East and West side crowds come from close by...not an hour by train and boat. For all the Gov. Is. design effort there's not enough to make people want to come all the way here. Needs more of an incentive than pretty scenery and landscaping, and passive pastimes. The whole 'project' seems to have been imposed, ala Robt. Moses (thought of more as a control freak than an Olmstead-type visionary) – and not allowed to evolve naturally over time.. Maybe if there were a slew of diverse attractions – a maritime museum, aquarium, an estuarium,

QUALITIES OF VISUALIZATION



DATA SOURCE

-

COLLECTION METHOD

-

ANALYSIS TOOLS

-

VISUALIZATION TOOLS

FLASH / WORDPRESS / PHOTOSHOP / XML / HTML / JAVASCRIPT

PLATFORMS

WEB

CHAPTER 4

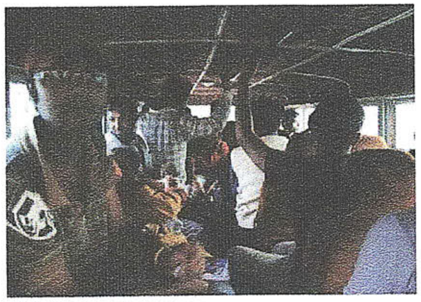
OVERLAYING THE CITY: A MINUTE IN DHAKA

I don't want to be your icon of poverty
or a sponge for your guilt.
My identity is for me to build, in my own image.
You're welcome to walk beside me,
but don't stand in front to give me a helping hand.
You're blocking the sun.

Shahidul Alam, a former chemist who became a photographer because he was tired of seeing images of the developing world through the lens of Western photographers

This research uses Dhaka, Bangladesh as a case for the use of cell phones and Web-based visualization. Dhaka exemplifies a complex context where these technologies are not yet ubiquitous, but where the use of big data may provide the greatest opportunities for change. With increasingly limited resources, every planning decision about the allocation of these assets becomes more significant. Information becomes equally important under such tight constraints because it leads to actionable knowledge on which to base those decisions. To assess the changing nature of data collection and visualization as components of planning discourse, the author undertook an observer role in a research project in Dhaka in January of 2012. Coordinated by the local non-profit Kewkradong organization with the cooperation of Urban Launchpad, the project focused on mobile technology strategies for data collection in the resource-constrained environments of the developing world.

The goal of these observations was to assess the increasingly synchronized process of collecting and disseminating data. Initiated and carried out by



CROWDED BUS RIDES DOCUMENTED BY THE KEWKRADONG BANGLADESH TEAM

Kewkradong Bangladesh, cell phones were equipped with applications to determine what type of data could be collected on Dhaka's transit systems. Kewkradong deployed the application using a method called flocksourcing, a process of data collection using guided volunteers. Using the mobile applications on over 240 bus rides and performing more than 1,000 onboard surveys of commuters, the flocksourcing team amassed data on over 10,000 bus location points along several primary routes in Dhaka. Upon receiving the datasets from Kewkradong, the author determined how to process and present the information to various audiences given available technology.

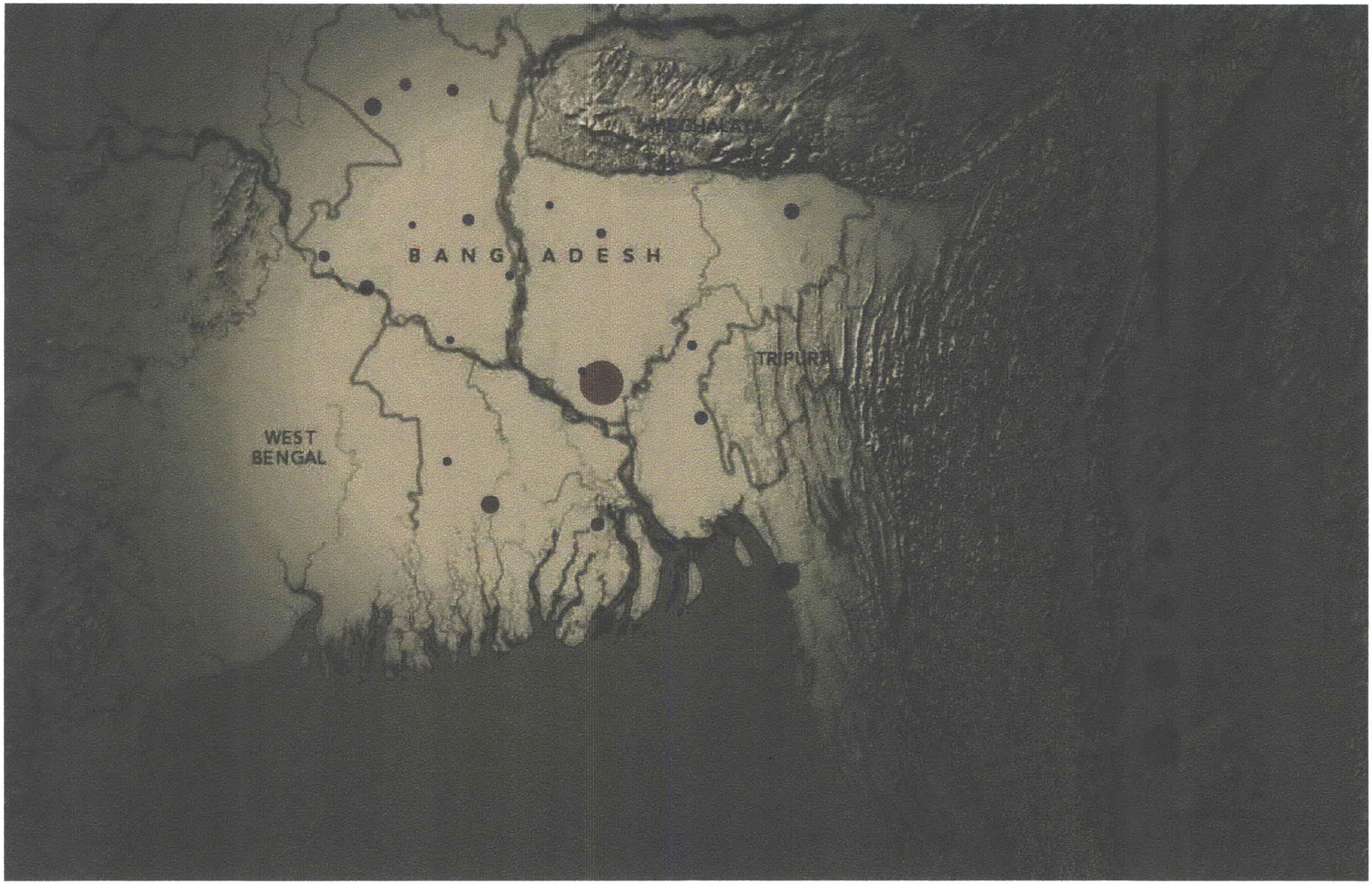
4.0

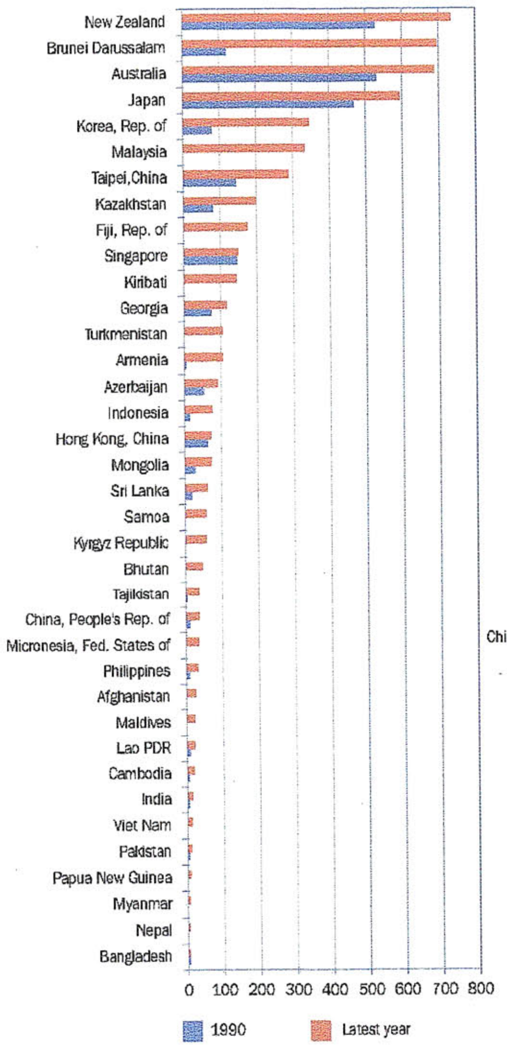
CASE CONTEXT

According to the United Nations Environmental Programme, Dhaka, the capital of Bangladesh, is expected to become the world's second largest city within the next five years. One of the world's densest and fastest growing megacities, Dhaka's population is projected to top 23 million by 2015. Not only does it face the predicaments associated with rapid urbanization, but also tops the list of the World Wildlife Fund's as the one city most vulnerable to the short- and long-term impacts of climate change. The city is thus particularly susceptible to natural disasters such as earthquakes and storm surges, as well as sea-level rise. Due to a lack of resources and the overwhelming magnitude of its urbanization, Dhaka severely needs adaptive solutions to address its citizens' needs and improve their quality of life.

Even though Dhaka is located in central Bangladesh, over 150 km inland from the Bay of Bengal, the entire city sits near sea level. Its position in the lower reaches of the Ganges River delta makes it highly susceptible to flooding during the region's rainy season. For many of the city's laborers, these waters disrupt their daily journey to work. For those living on the margin of poverty, a disrupted day of work can have substantial long-term effects on quality of life.

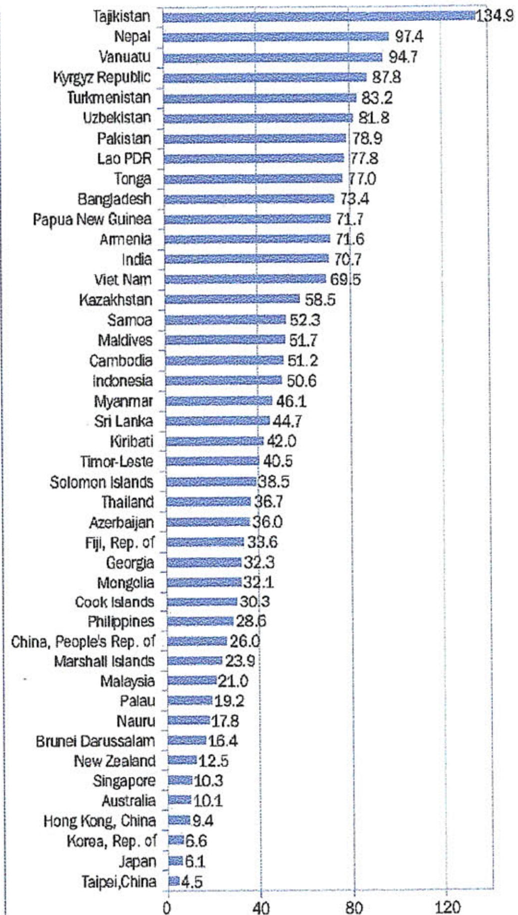
4.0.1 TOP 20 URBAN AREAS IN BANGLADESH





MOTOR VEHICLES PER 1,000 POPULATION, 1990 AND 2008 OR LATEST YEAR

[KEY INDICATORS 2011, 240]



AVERAGE ANNUAL PERCENTAGE GROWTH IN CELLULAR PHONE SUBSCRIPTIONS, 2000 TO 2010

[KEY INDICATORS 2011, 244]

4.0.1

DHAKA'S TECHNOLOGICAL CONTEXT

Cell phones have recently escalated as a gateway technology for many developing nations, allowing individuals and organizations to leapfrog beyond current resource constraints to enhance communication, education, transactions, and information sharing. According to reports released by the United Nations in 2011, mobile penetration in the developing world has exceeded fifty-percent (Measuring, 1). In Bangladesh, private sector actors have helped bridge the digital divide. Most notably is Grameenphone, a telecommunications company whose goal is to provide universal mobile phone access in Bangladesh. Grameenphone's founder, Iqbal Quadir, believes that the 'telephone is a weapon against poverty' when leveraged as a tool for productivity. Adding one new telephone to a family has an impact ten times higher in countries on the lower end of the GNP per capita spectrum than in highly developed nations (Quadir, 2005). With this impact potential in mind, Grameenphone and other telecommunications providers have helped elevate

Bangladesh into the top ten Asian and Pacific cellphone markets over the last decade, alongside many other South and Central Asian nations (Key Indicators 2011, 244).

4.0.2

DHAKA'S TRANSPORTATION CONTEXT

Dhaka's current transport development path is distinctive from South and Southeast Asian megacities of comparable scale. Several mobility models exist in the region, ranging from traffic-saturated motorcycle cities such as Ho Chi Minh; traffic-saturated bus cities like Bangkok, Jakarta, and Manila; and infrastructure-saturated transit cities such as Hong Kong, Seoul, and Singapore (Hickman 2011, 16). With increasing urbanization and population growth, Dhaka sits at the precipice of becoming debilitated by its saturated roads. The city already faces severe problems related to traffic: congestion, health impacts due to air pollution, social exclusion for various modes, and unsafe conditions for drivers, passengers, and pedestrians alike.

As the nation continues to urbanize, the city boundary has expanded to include new settlements in order to provide services and infrastructure for the influx of rural migrants. New neighborhoods to the north have increased the city's footprint and the demand for its limited road space, leading to dramatic increases in travel times across the city. Dhaka's car ownership rate, however, currently sits at 1%, one of the lowest in the region (Key Indicators 2011, 240). The city has not sprawled as drastically as other comparable South and Southeast Asian megacities. Dhaka's urban footprint is still relatively small, allowing pedestrian and cycle rickshaw to dominate personal transportation, though they currently offer a fairly poor-quality experience.

The city is facing unprecedentedly rapid growth, extreme environmental vulnerability, which presents a timely opportunity to ensure that sustainable transit can succeed and bring the city out of the auto-dominated urban expansion. Fortunately, overall mode share in the city still favors pedestrians, buses, and paratransit. The city's planning strategies, however, are not particularly supportive of these modes. According to the Asian

4.0.2 DHAKA

POPULATION ESTIMATE (2012)

15,414,000

METRO AREA (KM²)

347

DENSITY (PEOPLE / KM²)

44,420

DATA SOURCE:
DEMOGRAPHIA WORLD URBAN AREAS: 8TH ANNUAL EDITION (2012.04)

POPULATION METHOD

UNITED NATIONS AGGLOMERATION ESTIMATE.

LAND AREA SOURCE

MAP OR SATELLITE PHOTOGRAPH ANALYSIS

MAP: OPENSTREETMAPS

4.0.3 JAKARTA

POPULATION ESTIMATE (2012)

26,063,000

METRO AREA (KM²)

2,784

DENSITY (PEOPLE / KM²)

9,361

DATA SOURCE:
DEMOGRAPHIA WORLD URBAN AREAS: 8TH ANNUAL EDITION (2012.04)

POPULATION METHOD

LOWER ORDER JURISDICTIONS, INCLUDING REDUCTION FOR RURAL AREAS.

LAND AREA SOURCE

MAP OR SATELLITE PHOTOGRAPH ANALYSIS

MAP: OPENSTREETMAPS

4.0.4 BANGKOK

POPULATION ESTIMATE (2012)

7,151,000

METRO AREA (KM²)

2,202

DENSITY (PEOPLE / KM²)

3,250

DATA SOURCE: DEMOGRAPHIA WORLD URBAN AREAS: 8TH ANNUAL EDITION (2012.04)

POPULATION METHOD

LOWER ORDER JURISDICTIONS, INCLUDING REDUCTION FOR RURAL AREAS.

LAND AREA SOURCE

MAP OR SATELLITE PHOTOGRAPH ANALYSIS

MAP: OPENSTREETMAPS

4.0.5 MANILA

POPULATION ESTIMATE (2012)

21,951,000

METRO AREA (KM²)

1,425

DENSITY (PEOPLE / KM²)

15,404

DATA SOURCE:
DEMOGRAPHIA WORLD URBAN AREAS: 8TH ANNUAL EDITION (2012.04)

POPULATION METHOD

LOWER ORDER JURISDICTIONS, INCLUDING REDUCTION FOR RURAL AREAS.

LAND AREA SOURCE

MAP OR SATELLITE PHOTOGRAPH ANALYSIS

MAP: OPENSTREETMAPS

Development Bank, Dhaka's current US$5billion transportation plan allocates a mere 0.22% for improving pedestrian facilities (Hickman 2011, 47).

4.1

A MINUTE IN DHAKA: VISUAL ANECDOTE OF MULTIMODAL TRANSIT

As an initial test of visualization's role in Dhaka, the Urban Launchpad coordinated an exploratory workshop with university students using a project entitled "A Minute in Dhaka." The author, as an observer, witnessed both the potential and shortcomings of visualization as a strategy for conveying information about urban conditions and planning issues. The project used a mechanism of pairing video footage of traffic and street conditions with average traffic counts by mode in different parts of the city. This pairing is an example of linking metrics and visual stories, and presents an opportunity to assess the value of visual anecdotes.

Stepping onto a main street in Dhaka, one is immediately bombarded by the din of daily life. A sea of rickshaws, buses, cars, bicycles, motorcycles, and CNGs extends in every direction as the city's 18 million residents and their goods move about. As in many developing cities throughout South and Southeast Asia, this chaos is an accepted characteristic of the urban condition. The street, the stage of this orchestra, is also occupied by an enormous number of pedestrians. En route to their daily activities, people make purchases at stalls informally occupying the majority of what would normally be considered a sidewalk. Street crossing happens at any given point without regard to the speed and flow of traffic.

Quantifying a minute in Dhaka would at first seem like an unimaginable task: masses flow from every direction, at varying speeds, disregarding feeble attempts by the devices of an inefficient traffic management system to impose order. In some cases, this 'system' is embodied by an elderly man with a stick prodding rickshaws into one narrow lane or another. While this would seem ineffective to commuters of developed countries constrained by double yellow lines, sidewalks, and red lights, such

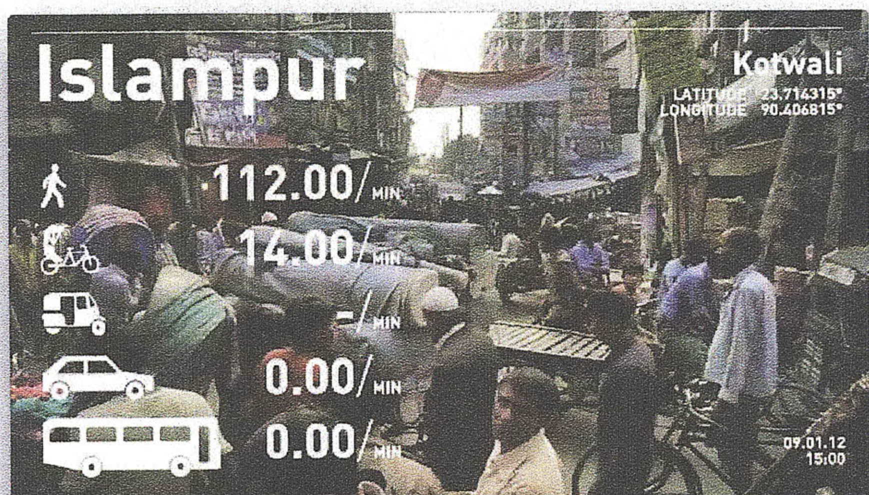
4.1.1 "A MINUTE IN DHAKA" VIDEOS

informal methods can have a surprising impact. At a particularly hectic intersection along Nazimuddin Road in Kotwali, a tangled, ancient neighborhood of Dhaka, one gentleman successfully coordinated the flow of more than 450 rickshaws in 20 minutes through a corridor that hardly accommodates one motorized vehicle. His compensation: the occasional cigarette offered by a passerby.

In addition to the magnitude of traffic that occurs on the streets of Dhaka at any given moment, the multi-modal nature of urban transit makes understanding mobility exponentially more complex. While in the U.S., street capacity and utilization can be measured in numbers of cars, pedestrians, and the occasional cyclist, a traffic engineer attempting to understand Dhaka's streets would have to account for pedestrians, rickshaws, CNGs, cars, taxis, bicycles, motorcycles, buses, and microbuses. Generating snapshots of the quantity of each of these modes is a daunting task.

"A Minute in Dhaka" was an attempt by the Urban Launchpad to link the visual story of a place to quantified metrics. One minute of footage was taken at eighteen intersections selected throughout Dhaka to document traffic conditions. The visual narrative of the videos was paired with counts for five transit modes: walking, rickshaws, CNGs, cars, and buses. The data presented reflect an average number of pedestrians or vehicles per minute over a 20-minute period at each site. By linking quantitative metrics with the visual story told through each video, each set of data became part of an anecdote for its associated site.

The purpose of making this connection was to embed insights directly into a visual artifact and generate



BELOW: VIDEO SCREENSHOT FROM "A MINUTE IN DHAKA"

THE VIDEOS LOOP FOR ONE MINUTE AS A VISUALIZATION OF THE COLLECTED MODAL COUNTS FOR EACH SITE.

discussion about the causes behind certain features of the counts. For example, using only the counts data set, the average car per minute count in Islampur is zero. When paired with the minute video loop, however, it quickly becomes evident that both the physical capacity of the road and the scope of goods being moved through this part of the city by couriers and rickshaws simply could not accommodate personal cars. Viewed on their own, the counts for Mirpur 1 might mislead one to think that the comparatively high pedestrian count indicates the presence of a decent infrastructure to support this mode. However, the video loop quickly reveals that pedestrians at the site simply navigate as a crowd between traffic moving in every direction. By linking video stories and metrics, this visualization puts simple data into context and increases knowledge about the conditions of each site.

4.2

IDENTIFYING DATA VISUALIZATION POTENTIALS

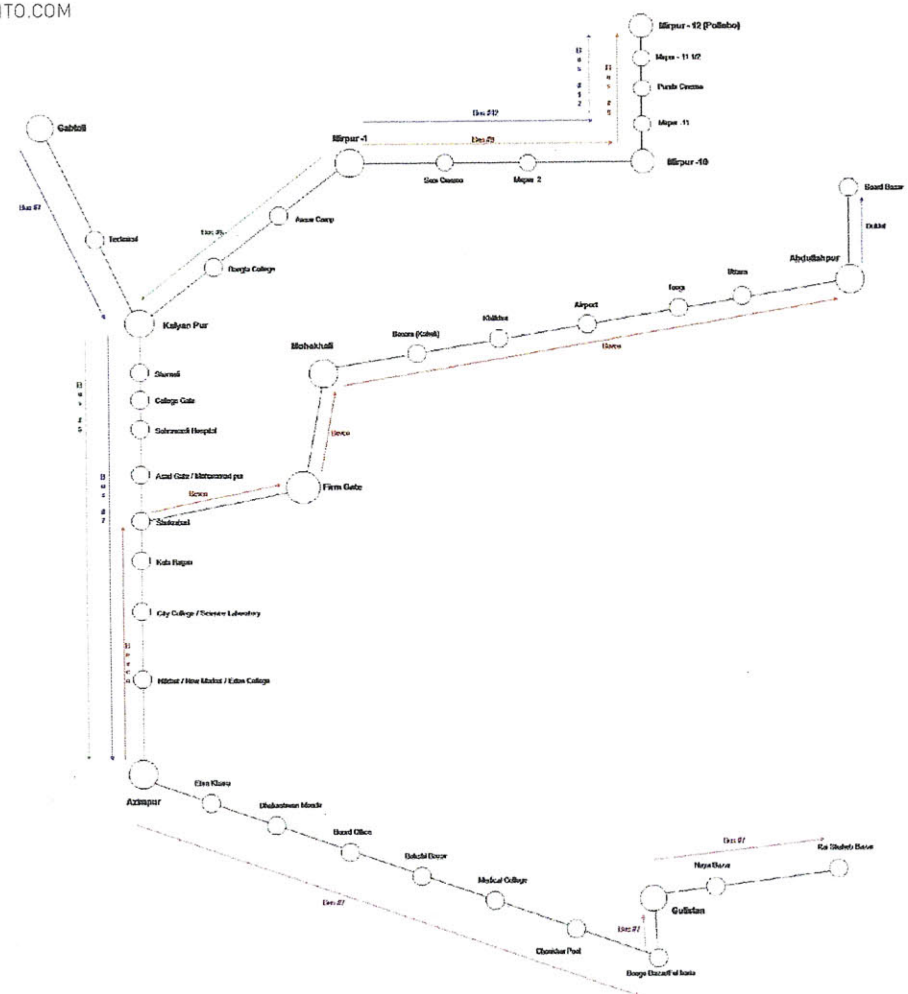
"A Minute in Dhaka" presents one form of accessible data about Dhaka's transport system. It counts for various modes across the city incorporate spatial and temporal dimensions of data. Further data collected through flocksourcing added additional dimensions to the information about Dhaka's bus system.

Dimension	Rides	Surveys
SPATIAL	LATITUDE / LONGITUDE COORDINATES, DESTINATIONS	HOME / WORK LOCATIONS
TEMPORAL	TIME-STAMPS	AVERAGE COMMUTE TIMES
COMPOSITIONAL	GENERALIZED ROUTES, DIRECTIONALITY, SEATING CAPACITY	GENDER, AGE
CONDITIONAL	SPEED, AVAILABILITY OF SEATS	INCOME, PHONE OWNERSHIP
BEHAVIORAL	RIDERSHIP COUNTS, FEMALE RIDERSHIP	WEEKLY RIDERSHIP
EXPERIENTIAL	RIDE TIME	HAPPINESS, COMFORT, SAFETY

Given that thousands of buses operate in Dhaka, it may not be surprising that no true bus map exists of such a chaotic system. Figure 4.2.1 is one of the few instances found of what could be considered a bus routing map of Dhaka. Minimal and for the most part aspatial, the only real relationships it implies is the sequencing of stops that may or may not exist for a few specific routes. A true

4.2.1 EXISTING DHAKA CITY BUS MAP

POSSIBLY THE ONLY
EXISTING CITY BUS MAP ON
MYDIGONTO.COM



bus map for the city exists at this point only in the mental models of residents themselves (a powerful local resource that should not be ignored, particularly given the aims of this thesis). The data presents a sample with which several new representations of the bus network could be created. Each of these visualization products serves different users and purposes, but all could benefit from the increased functionality and accessibility enabled by dynamic mapping strategies. These products might include:

- Local planners or the city transit agency could design a bus route map to gauge the activity levels of the system. Interactive visualization strategies support the ability to overlay the multitude of bus lines to simultaneously allow a view of the entire system and individual lines. While the initial route map may present a tangled network, users could easily navigate the complex bus system by selecting or querying for specific bus numbers, companies, or locations. A route map may prove useful for planning purposes to determine both areas of extreme congestion and areas lacking service. Using spatially and temporally linked survey data, planners could assess the level of service provided. Depending on the availability of data, a visualization of this nature could act as a dynamically updated tool reporting bus service status.

- Another possibility for interactive visualization of transit data is a bus dashboard used by bus companies or the Bangladesh Road Transport Corporation (BRTC) for operations management. With data stored and updated in real-time through Google Fusion tables, a dynamic dashboard could be created that shows current statistics for each of a company's lines. Operators could monitor where buses are at a given moment, where stalls are occurring, or where more buses may need to be deployed on a daily basis.

- A third possibility is a bus user-map for commuters to obtain real-time information feeds on buses. Akin to the KickMap or similar user-service dynamic maps, users could access estimated wait times, trip length, comfort or safety ratings, or perhaps even know if a seat will be available on an upcoming bus. This product could be deployed by the city transit agency in an effort to promote the use of the bus system, by cell phone providers as an added purchasing incentive, or by a bus company seeking a competitive edge through a better informed customer base.

4.3

VISUALIZATION PROTOTYPE: DHAKA BUS DASHBOARD

The following section describes a prototype of a dashboard displaying data on Dhaka's buses. Using principles described in the DIK continuum and the key qualities and dimensions of visualizations, these represent first attempts at overlaying usable knowledge through spatiotemporal representations of the network. While not currently interactive, the prototype is described through the intention of the design and knowledge gathered about current capabilities in Web-programming environments for visualization.

Initial mappings of bus route data generate tracings using the Google Maps API, marking upload points from mobiles. These tracings reveals the general trajectory of the tracked bus lines, but provides little more information beyond what anyone on the streets of Dhaka could tell you about the route of a bus. By applying the additional dimensions of information gathered through the surveys and counts performed on the buses, these initial tracings are transformed into maps that uncover the performance and experience of the bus system. It is not hard to see the most basic needs of Dhaka's 5+ million bus riders: crowding and travel times. Anyone attempting to use the system has a few basic questions:

- When is the bus coming?
- How long will I have to wait?
- Will it be full or will I be able to get a seat?
- Do I have another option?

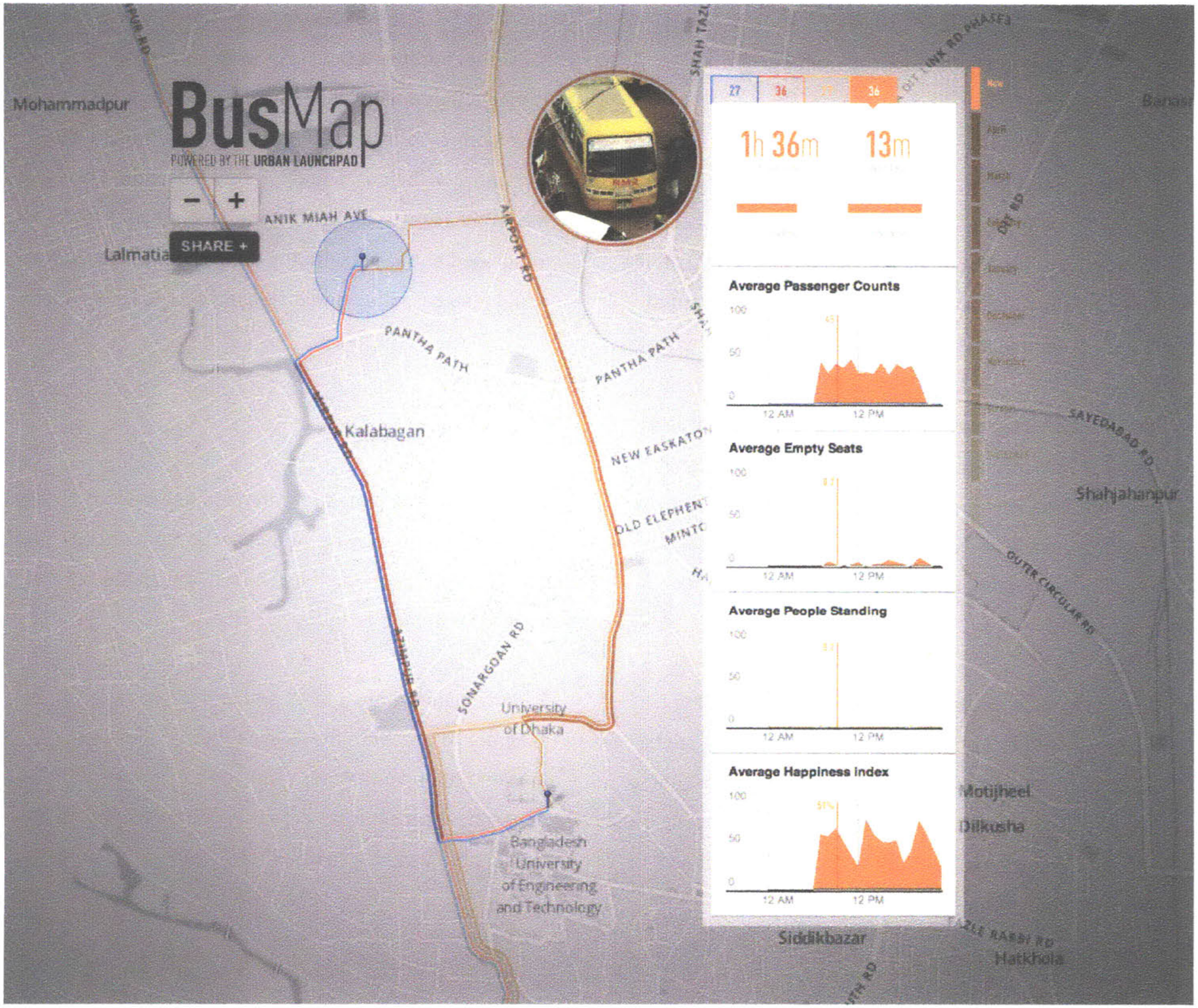
These are the primary drivers underlying the construction of a prototype bus routing map for Dhaka. The primary inputs for this interactive bus map are (1) the start and end location (and directionality interpolated from these inputs) and (2) whether one is traveling on a weekday or weekend. Figure 4.3.1 presents a view of the type of visual representation of Dhaka's bus system that could be created, supplemented by the multi-dimensional metrics of the various bus lines through mobile user-flocksourced data collection.

Overlays of data make maps more useful for both planners and city officials, "uncovering realities previously unseen or unimagined" (Corner 1999, 213) and unfolding potentials for improvement. The additional information that is most valuable to improving the day-to-day experience of using the bus system and how that information is most appropriately and effectively conveyed should be further assessed.

4.3.1

STRUCTURAL DESIGN

The dashboard is intended for use on various Web platforms (computers, tablets, Web-enabled phones) to maximize opportunities to apply interactive techniques



4.3.1

INTERACTIVE BUS MAP PROTOTYPE

to data visualization. The structural anatomy of the dashboard is as follows:

- A slippy-map tiled interface provides the contextual base map of Dhaka, with primary points of interest and the streets. The map enables semantic zooming on the spatial dimension, meaning that features relevant at different spatial scales are revealed dynamically.

- An HTML5 foreground overlay on the map creates a "bifocal view" that highlights the area of focus and lowlights the peripheral areas. This feature improves navigability with a visual hierarchy around a specific context, but maintaining a degree of surrounding context detail.

- D3 / Javascript generates small multiples charts for specific statistics on average ridership, empty seats, and other metrics, which toggle between time-scales (weekday, weekend, holiday, or monthly averages). This allows for coordinated views of the conditional and spatial dimensions of the data.

- jQuery text manipulation via the Document Object Model (DOM) enables specific details about lines to be dynamically displayed like the line name and bus company, or the current estimated travel time or wait time. Bus driver identity information could be integrated and keyed into the data table, which then could also be pulled and displayed via the DOM.

4.3.2

CONTENT DESIGN

The dashboard is designed for intended use by commuters whose daily journey may be significantly impacted by what transportation mode they choose. The design of the dashboard content is as follows:

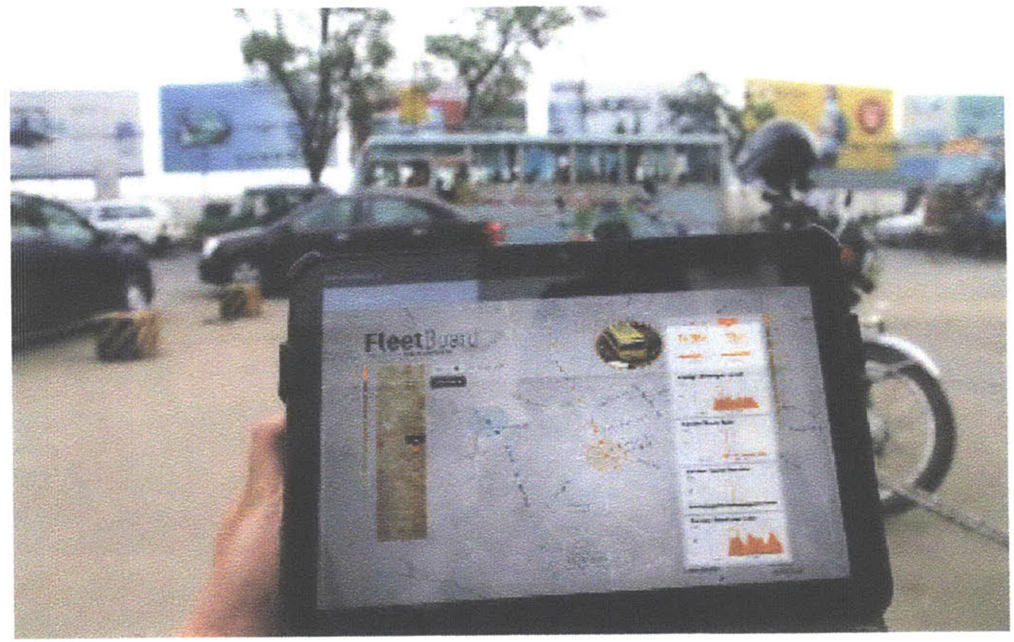
- When a user inputs a start and end location, the dashboard presents the nearest bus routes as the thickest lines on the map. This is an example of the "search, show context, expand on demand" model of navigation (van Ham 2009, 953).

- Narrower lines are drawn along streets to connect the start and end locations to the nearest points on the primary bus routes. While these lines are thinner, they are still fully saturated for visibility. This feature constructs a hierarchy for navigating the route.

- The segment of the bus lines relevant to the particular trip remains fully saturated, while extensions of the bus line before and beyond the extent of the trip become more transparent. This allows the user to understand the broader trajectory of the bus line, but only the most relevant portion is highlighted when a trip is selected.

- Bus lines are color coded according to the bus company. If a company operates multiple lines along the same route, the colors of the additional routes are scaled from the primary hue to denote similarity in company but differentiate the multiple lines.

- A dashboard displaying information on the selected route is overlaid on the primary mapping interface.

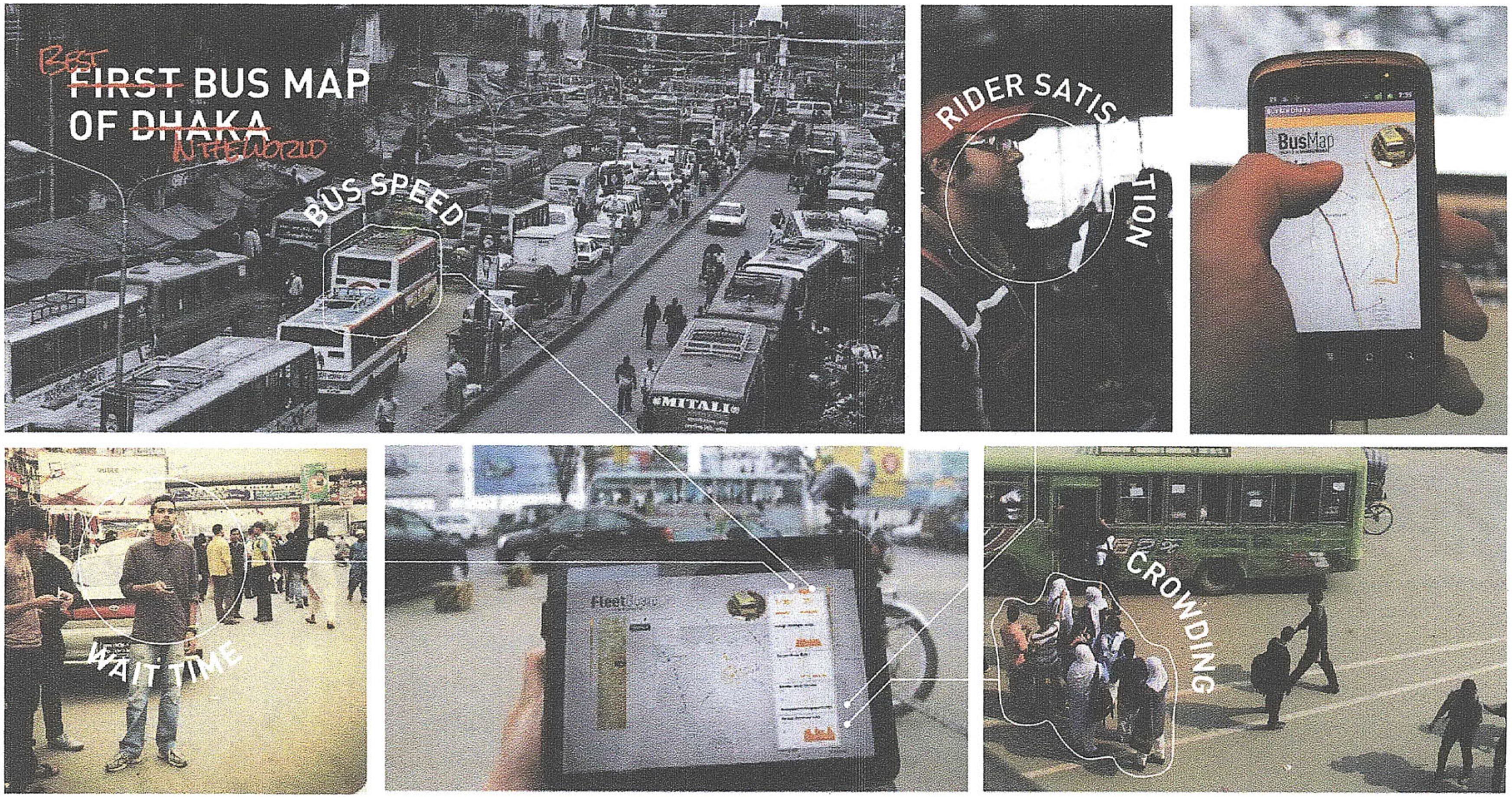


MOCK-UP OF A WEB-BASED BUS ROUTING MAP FOR DHAKA VIEWED ON A TABLET

Toggling through different route options on this dashboard permits users to select the most appropriate route based on the information most relevant to their decision. This interactivity allows a higher degree of efficiency by using panels to maximize the available screen real estate of the interface.

- The dashboard displays typical travel time and wait

4.4.1 THE FIRST BUS MAP OF DHAKA



time for the selected trip, as these will most likely be the primary decision-making factors for most users. This feature increases the utility of the visualization, enabling formative knowledge to make route choices.

- Passenger counts, empty seats, people standing, and a happiness index are also displayed as a time-scaled series, so the user can determine if they are trying to catch the bus at a crowded time and if the bus would be less crowded at a different time. The actual value is also displayed on a line indicating the time of when the search was made.

- An image of the bus that highlights color and style allows users unfamiliar with a particular line to have a reference from which to recognize the bus on the street. While this feature may not be the most structurally informative, it adds a degree of novelty by pairing metrics with a more human view of what the buses look like.

4.4

DEPLOYMENT: THE CHALLENGE OF THE DIGITAL DIVIDE

Web-based displays of information may not be fully accessible in developing contexts such as Dhaka. While municipal agencies and bus companies may be able to afford or already own the requisite technologies to make use of dashboards, Web-enabled mobile phones are still not fully accessible to the public at large. While this digital divide will narrow over time, today it is still worth considering the impact of deploying Web-based tools in a largely analog context.

One aspect of this divide is the degree of digital literacy in a particular context; while data visualizations may be a regular medium of information exchange in one context, the graphic conventions for displaying data may not be digestible in another. While the videos of "A Minute in Dhaka" only provided snapshots of traffic conditions familiar to workshop participants, they initiated a broader dialogue about mobility issues in the city

10
LIGHT EMITTING DIODE (LED) DISPLAY SIGNS THAT ANIMATE INFORMATION THROUGH A SCROLLING ACTION.

overall. Students observed interacting with "A Minute in Dhaka" did not discuss transportation issues in the city based on interpretations of gaps or opportunities that the data might have shown. These users may not have interacted with these modes of interpreting information before. Participating students were easily able to generate suggestions when prompted or guided through discussion, using the visual stories as a backdrop. The visual story paired with the quantitative metrics of mode counts still acted as an anecdote, creating small sparks that catalyze larger discussions.

These interactions lead to further inquiry as to what are the analog modes of these Web-based, interactive prototypes? How can those who do not have access to the technology or lack a particular literacy use them? As expressed by Nabil Hamdi:

> Language and media of expression is key to cultural legibility...Prevalent belief systems will place significant differences on the value of information...Technologies, with all their implied difference in behaviour and process, may not fit the needs, desires, or expectations of people, whatever their practical advantage. On the other hand, modern or 'respectable' imagery, although sometimes unfamiliar, may be more acceptable because it represents progress—what could be in the future, rather than what is now. (2010, 175-176)

Further research into the visual culture of the context is necessary to answer these types of questions. For example, determining what media are dominant in certain communities can demonstrate the potential value or role of Web-based media. In the case of Dhaka, the newspaper still plays a significant role in the dissemination of information. A dynamic dashboard of bus information could be exported as a static image on a daily basis, similar to a weather report, and disseminated via print media. Digital feeds could be displayed through simple LED tickers[10] on buses themselves, announcing delays, destinations, or drop-off points. The local chai wallah with a tablet or smart phone could receive dashboard updates, redistributing information to commuters who inquire about the next arriving bus or which routes are overly congested. Knowledge acquired through visualizations can take advantage of the existing social information distribution network, sparking conversations and interactions that initiate action more effectively than a visual could ever do on its own.

CONCLUSION

As mobile sensors proliferate, the data available about urban areas will continue to increase, even in places like Dhaka. This glut of urban information has the potential to revolutionize planners' understanding of how cities perform and how people use them, at a scale and level of precision previously unseen. Big data should be considered an asset for managing cities because it allows for immense flexibility in scope and in degrees of aggregation. Mobile sensors permit real-time data about the urban environment and the human activity underlying it, which can be used to inform and adjust long-term planning. With these constant data feeds comes greater connectivity, creating an increasingly complex world, as expressed by Manual Lima:

> The complexity of connectedness of modern times requires new tools of analysis and exploration, but above all it demands a new way of thinking. It demands a pluralistic understanding of the world that is able to envision the wider structural plan and at the same time examine the intricate mesh of connections among its smallest elements. It

> ultimately calls for a holistic systems approach; it calls for network thinking. (2011, 46)

Such complexity necessitates tools that improve our ability to generate useful, accessible information from big data. Dynamic visualizations facilitate the extraction, interpretation, and dissemination of data, giving them great potential as communications tools for urban planners and designers. Such technologies enhance the planning process by acting as "mediators of a conversation that invests and connects all parties" (Quirk 2012, 1). They also improve transparency, planners' ability to represent the city, and their capacity to engage communities to envision new futures.

To manage the influx of big data, programmers are rapidly developing the tools necessary to manage, analyze, and understand large datasets. Open-source representation tools are being used to effectively communicate and engage with the public by non-planners, such as journalists. The types of information being communicated are in many ways similar to the types of information planners often hope to communicate, conveying information on events, proposals, and conditions often related to the built environment.

While mastery of visualization tools requires a familiarity with programming languages and environments that eludes many planners, recognition that visualization can be an effective means of communication should motivate planners to partner with the appropriate experts, just as they do for engineering or economic analysis. Additionally, planners should consider the Web as an increasingly significant platform for communication with the public.

5.0

RECOMMENDATIONS

As seen in this thesis, planners should further explore the applications of dynamic visualizations as a contemporary medium for communication. New examples of dynamic visualizations are constantly being produced, continually pushing the boundaries of the uses of big data and its expression through Web-based media.

Planners should consider using dynamic visualizations as a strategy to establish a common visual language in public communications, empowering people with better information on complex subjects. Visualization supports participatory planning because it enables an accessible mode of expression "to which all participants—technical and non-technical—can relate" (Al-Kodmany 1999, 38). A new era of open-source data exploration is beginning that allows non-experts to construct their own narratives from data. Open-source visualization tools are also being developed for journalists and designers, challenging the dominance of the traditional cartographer over representation methods. Some planners may even have the technical capacity to integrate Web-based media into their planning toolkit. The open-source nature of these tools may also allow for more democratic methods for participatory planning by demanding "transparency, the opportunity to see through the implications of any change or habit or livelihoods" (Hamdi 2010, 176).

Dynamic visuals can aid in formalizing complex networks and large-scale systems because they layer information that can be accessed as necessary. Computer algorithms alleviate barriers to working with large datasets and enable connections to be drawn that would be tedious or difficult through manual visualization methods. Representational strategies enable knowledge of complex systems to be transferred to non-experts. With images, animation, and graphic representation, visualization enhances planning processes by facilitating better understanding for users who are not familiar with the specific topic or situation (Jankovics 2000).

Planners should consider using dynamic visualizations as a strategy for conveying data more democratically. Visualization enables the translation of data into a formal language more accessible to those that may not be data literate. Because they can be deployed on interactive Web-based platforms, dynamic visualizations can utilize a rhetorical feedback loop that catalyzes public input through mechanisms like responses, comments, direct input of new data, or even crowd-sourced proposals.

Interactive visualizations also allow for datasets to be viewed through different lenses and various statistical transformations, helping to eliminate the distortions that can occur when planners are limited to one mode of representation. This also permits new and comparative readings of data in an efficient format that can broaden planners'and their constituents' understanding of a subject. As described by Ben-Joseph, planners need to use multiple modes of representation even in a single project:

> ...to convey different kinds of information and aspects of the design. It is this separation between various representative forms that increases the cognitive load on both the designer and the audience, who must draw relationships between dislocated pieces of information. (2005, 153)

The practices of exposing or sharing base code in programming environments and providing access to source data opens up new degrees of info-structural honesty. In some cases, visualizations on Web platforms permit users to access the parts and processes used to create the representation. This practice is facilitated by digital platforms, as analog platforms lack the mobility of hosting large datasets.

Operators and regulators of urban systems, such as transit agencies, could use dynamic visualization strategies to create Web-based, non-narrative dashboards that showcase the outputs of real-time (or near-real-time) data feeds. Information is increasingly available for planners as technological infostructures are further integrated into the systems of the built environment. This increase in data also leads to an increased "level of complexity, interconnectivity and volatility with which planning and public policy-makers must contend" (Raford 2011). Planners should consider the use of dynamic visualizations as core components of dashboards that provide updatable displays of information. Dynamic visualizations enable higher degrees of data density, efficiently linking the display of multiple datasets and providing better access to information using flexibility of Web-based interaction. These benefits increase the value of working with large datasets representing complex systems by allowing planners to make and communicate decisions based on more detailed information.

5.1

FUTURE RESEARCH

While this thesis explores the many recent connections between planning, data, online tools, and public empowerment, several questions give rise to opportunities for future research:

- **If dynamic visualizations become more prevalent as a medium for exchanging information, how can the impact of their use be measured?** Future research on the use of Web-based analytics can provide insight into how users actually interact with dynamic visuals, showing what data are of interest to particular audiences and how they navigate through information. It is also worth exploring strategies for integrating direct input forms that help planners to understand what conclusions users draw from data. The effectiveness of different visuals can be observed with the help of such analytical feedback loops because interaction activity is recorded through tools that can reveal which aspects of a visual are most relevant, salient, or noticeable to people.

- **What methods can planners use to further contextualize representations in different cultures and social settings?** By exploring the predominant visual culture of the context in which they are working, planners and designers can customize narratives using the relevant visual cues and conventions. Understanding the core audience of a visualization is key to effectively focusing a visualization. Related to the assessment of visual literacy, planners could help determine the overall efficacy of visuals as a communication form relative to other methods a community uses.

- **How do dynamic visualizations work in analog contexts?** In places with limited access to high-tech platforms, strategies should be explored that allow planners to export or translate dynamic visuals onto non-digital platforms. Planners will benefit from learning to interchange between analog and digital modes based on specific project needs.

- **How to integrate dynamic visualization skills into a planning curriculum?** New cartographic and representational tools using Web platforms could be taught in tandem with more analysis-heavy tools such as ArcGIS, empowering future planners to make their findings more accessible using Web platforms and encouraging them to focus on the digestibility of information.

- **How do visualization strategies make the decision-making process more democratic?** Dynamic visualizations can act as platforms for equitable access and increased functionality in exploring data. Using Web-based communication can facilitate or expedite conventional public processes in urban planning, such as land use reviews, zoning hearings, or environmental assessments.

- **How can users define the metrics of a "successful" city?** Visualizations provide a method of illuminating things that are not obvious. If planners strive for more democratic processes, they need to understand the issues and concerns that are not being communicated clearly through current methods. What would a successful public engagement model based more heavily on visual communication and iterative user input look like?

ACKNOWLEDGEMENTS

To my family, for their encouragement, support, and faith, an unwavering characteristic blind to the fact that they may have no idea what it is that I do.

To my mother and father, for never ceasing to provide for me, but perhaps more importantly, for teaching me first hand the value of hard work and dedication.

To Anne Kennedy and Wit MacKay, for providing a much-needed retreat that included warm meals and laughter when I needed it most, and for always having an inquisitive spirit.

To my grandmother, for being my biggest fan. And for a lifetime supply of cheesecake.

To my cousins and brother, for continuing to grow up together.

To my collaborators across the world: the NOLA crew, Solo Kota Kita, and the Tel Aviv University team; you have made every project a joy and an adventure. Thank you for letting me work alongside you.

To the Firm Foundation team, for bringing it in London. And specifically to Alice Shay, for surviving a summer together. Here's to crossing paths again and again, and (at least) one more adventure in Indonesia.

To my studio mates in Design Skills, the Bronx, West Philadelphia, and Kiryat Gat, for the long nights and inside jokes.

To Anne Emig, Christophe Chung, Kate Dineen, and Daniel Tien Simon, for guiding me through my first year, and making fun of me the entire time.

To the Panamania crew, for always dancing.

To Alyse Knorr, Lili Knorr, and Dom Tribone, for being my not-so-silent angels and molding my mess into something more digestible. I would never have made it through this without you.

To Amy Glasmeier, Dennis Frenchman, Anne Spirn, Jim Wescoat, and Chris Zegras, for giving me the space to run with my own ideas and teaching me how to improve upon them.

To Eran Ben-Joseph, for being more than a professor. As an advisor, mentor, boss, and friend, your guidance and support have been invaluable.

To Albert Ching, for dragging me into this, and always being there to pull me out. Best friend and brother, here's to more adventures.

To Muntasir Mamun and the Kewkradong team, for spending each of my days in Dhaka showing me humanity and humility.

REFERENCES

CRITICAL CARTOGRAPHY, DATA VISUALIZATION, & VISUAL CULTURE

Al-Kodmany, Kheir. (1999). Using visualization techniques for enhancing public participation in planning and design: process, implementation, and evaluation. Landscape and Urban Planning 45: 37-45. Chicago, IL: Elsevier.

Al-Kodmany, Kheir. (2002). Visualization tools and methods in community planning: From freehand sketches to virtual reality. Journal of Planning Literature 17 (2): 189-211.

American Planning Association. (2006). Planning and urban design standards. Hoboken, NJ: John Wiley.

Bellinger, G., D. Castro and A. Mills. (2004) "Data, information, knowledge, and wisdom". ←http://www.systems-thinking.org/dikw/dikw.htm→.

Bosselman, Peter. (1998). Representation of Places: Reality and Realism in City Design. Berkeley: University of California Press.

Corner, James (1999). "The Agency of Mapping: Speculation, Critique, and Invention." Mappings, 213-252. London: Reaktion Books Ltd.

Cranshaw, Justin, Raz Schwartz, Jason I. Hong, and Norman Sadeh. (2012). "The Livehoods Project: Utilizing Social Media to Understand the Dynamics of a City." Pittsburgh: School of Computer Science, Carnegie Mellon University.

Friendly, Michael, and Daniel J. Denis. (2006). Milestones in the history of thematic cartography, statistical, graphics, and data visualization.

Hamdi, Nabeel. (2010). The Placemaker's Guide to Building Community. London, England: Earthscan.

Harmon, Katherine. (2004). You Are Here: Personal Geographies and Other Maps of the Imagination. New York, NY: Princeton Architectural Press.

Heer, Jeffrey, and Ben Schneider. (February 2012). "Interactive Tools for Visual Analysis: A taxonomy of tools that support the fluent and flexible use of visualizations." ACM Queue 10 (2): 1-26.

Heer, Jeffrey, Michael Bostock, and Vadim Ogievetsky (June 2010). "A Tour through the Visualization Zoo." Communications of the ACM 53 (6): 59-67. ←doi :10.1145/1743546.1743567→.

Illinsky, Noah, and Julie Steele, eds. (2010). Beautiful Visualization. Sebastapol, CA: O'Reilly Media, Inc.

Kalaga, Wojciech, and Marzena Kubisz, eds. (2010). Cartographies of Culture: memory, space, representation. New York: Peter Lang.

Kwartler, Michael, and Gianni Longo. (2008). Visioning and Visualization: People, Pixels, and Plans. Cambridge, MA: Lincoln Institute of Land Policy.

Lima, Manuel. (2011). Visual Complexity: Mapping Patterns of Information. Princeton, NJ: Princeton Architectural Press.

Livehoods. (2012). [Interactive map May 9, 2012]. Livehoods: Understanding cities through social media from the Mobile Commerce Lab at Carnegie Mellon University. ←http://livehoods.org/→.

Masud, Luca, Fracesca Valsecchi, Paulo Ciucarelli, Donato Ricci, and Georgio Caviglia. (2010). "From Data to Knowledge: Visualizations as transformation processes within the Data-Information-Knowledge continuum." 14th International Conference Information Visualization: 445-449.

Monmonier, Mark. (1996). How to Lie with Maps; 2nd edition. Chicago, IL: University of Chicago Press.

Nonaka, I. (1994) "A dynamic theory of organizational knowledge creation." Organization Science 5 (1): 14-37.

Offenhuber, Dietmar. (2010). Visual Anecdote. Leonardo 43 (4): 367-374.

Pousman, Z., J. T. Stasko, and M. Mateas. (2007). "Casual Information Visualization: Depictions of Data in Everyday Life." IEE Transactions on Visualization and Computer Graphics 13 (6): 114.

Quadir, Iqbal. (2005, July). Mobiles fight poverty. TedGlobal 2005. ←http://www.ted.com/talks/iqbal_quadir_says_mobiles_fight_poverty.html→.

Rubin, Elihu. (2011). (Re)presenting the Street: Video and Visual Culture in Planning. Urban and Landscape Perspectives: Multimedia Explorations in Urban Policy and Planning: Beyond the Flatlands, 85-104, Volume 7. New York, NY: Springer.

Ryan, Brent D. (2011): Reading Through a Plan, Journal of the American Planning Association, 77:4, 309-327. ←http://www.tandfonline.com/doi/abs/10.1080/01944363.2011.616995→.

Mitchell, William J. (2000). E-Topia: "Urban Life, Jim—But Not as We Know It." Cambridge, MA: MIT Press.

Schultz, Jonathan. (2010, October 28). "A census process that works—in Indonesia." Retrieved from Design Observer ←http://changeobserver.designobserver.com/feature/solo-kota-kita/21048/→.

Shneiderman, B. (1996). The eyes have it: a task by data type taxonomy for information visualizations.Proceedings of the IEEE Symposium on Visual Languages. ←http://portal.acm.org/citation.cfm?id=832277.834354→.

Shepard, Cassim. (2011, Summer). On Data and Design. Next American City, 30. ←http://americancity.org/magazine/article/on-data-and-design/→.

van Ham, F., and A. Perer. (2009). Search, show context, expand on demand: supporting large graph exploration with degree-of-interest. IEEE Transactions on Visualization and Computer Graphics 15 (6): 953-960. ←http://dx.doi.org/10.1109/TVCG.2009.108→.

SMART CITY, DEVELOPMENT, AND TRANSPORTATION

Arndt, Rachel Z. (February 13, 2012). Captcha Companies Cash In On Advertisers. Fast Company, Issue 163. ←http://www.fastcompany.com/magazine/163/march-2012→.

Ben-Joseph, Eran. (2011). City design in the age of digital ubiquity. Companion to Urban Design. New York: Routledge.

Ben-Joseph, Eran. (2005). Technogensis and the Onset of Civic Design. The Code of the City: Standards and the Hidden Language of Place Making. Cambridge, MA: MIT Press.

de la Peña, Benjamin. (2011, Summer). Smart Cities for Whom?. Next American City, 30. ←http://americancity.org/magazine/article/ideas-smart-cities-for-whom/→.

Jankovics, Adrienn. (2000). "Interface Design for Spatial Data Visualization: A Web-Based Integrated Multimedia Approach for the Tren Urbano Project." MCP Thesis, MIT.

Key Indicators for Asia and the Pacific 2011, 42nd Edition. (2011). Mandaluyong City, Philippines: Asian Development Bank, Deutsche Gesellschaft für Internationale Zusammenarbeit.

Manzoni, Vicenzo, Diego Maniloff, Kristian Kloeckl, and Carlo Ratti. (2009). "Transportation mode identification and real-time CO2 emission estimation using smartphones: How CO2GO works." SENSEable City Lab, Massachusetts Institute of Technology, and Dipartimento di Elettronica e Informazione, Politecnico di Milano. ←http://senseable.mit.edu/co2go/images/co2go-technical-report.pdf→.

Measuring the Information Society 2010. Geneva, Switzerland: International Telecommunication Union, 2010.

Mitchell, William J. (2003). Me++: the Cyborg Self and the Networked City. Cambridge, MA: MIT Press.

Hagen, Erica. (2010). "Putting Nairobi's Slums on the Map." Development Outreach: Growing Out of Crisis 12 (2): 41-43. World Bank Institute.

Hickman, Robin, Paul Fremer, Manfred Breithaupt, and Sharad Saxena. (2011). Changing Course in Urban Transport: An Illustrated Guide. Asia Development Bank.

Quirk, Vanessa. (2012, May 11) "Can You Crowdsource A City?" Huffington Post. ←http://www.huffingtonpost.com/2012/05/11/crowdsource-city_n_1509070.html→.

Raford, Noah. (2011). "Large Scale Participatory Futures Systems: A Comparative Study of Online Scenario Planning Approaches." PhD Dissertation, MIT.

Ratti, Carlo, and Anthony Townsend. (2011). Harnessing Residents' Electronic Devices Will Yield Truly Smart Cities. Scientific American, September 2011 Issue: 42-48.

STP (Strategic Transport Plan for Dhaka). (2005). Final Report, Louis Berger Group and Bangladesh Consultants Ltd., Dhaka.

Townsend, Anthony, et al. (2011). A Planet of Civic Laboratories: the Future of Cities, Information, and Inclusion. The Rockefeller Foundation.