Three Languages for Urban Mobility

Addressing 21st Century Urban Mobility with Information Systems Techniques

Tristan Stull[1][0000-0003-0851-8990] and Jean-Pierre Kuilboer[0000-0003-3800-080X]

University of Massachusetts at Boston, Boston MA 02125, USA
Tristan.Stull001@umb.edu

Abstract. The 21st century urban mobility system (UMS) entails how people physically move about their cities and environs. As a multi-modal system, it is a complex and dynamic sociotechnical construct. Optimizing this system is a multi-disciplinary effort involving work from areas such as urban sociology, decision analysis, operations research, and information systems. It is necessary to be able to map from social and economic drivers to the technical infrastructure. To accomplish this, we must be able to negotiate effectively between very different realms: from the fundamental social drivers that come in qualitative wrappings into operationalized parameters that can be used in numerical models. Further, the life of the technical system in its usage must be systematically understood as part of a feedback loop that will affect the social drivers and through them expose modified aspirations for the system moving forward. To support this, we need an epistemological framework that addresses the complexity in its static structure as well as in the fluid act of design. From long habits of cross-disciplinary thinking in management science and information systems, we propose the synthesis of a new language from three techniques that have proven useful: decision analysis, design patterns, and iterative development.

Keywords: Urban Mobility, Agility, Pattern Languages.

1 Introduction

The world population is both growing and urbanizing. The United Nations anticipates that about two-thirds of us will live in cities by 2050 (Sumantran, Fine, & Gonsalvez, 2017). Congestion is building in urban environments (Morlok & Chang, 2004), (Cortright, 2010). The car-oriented "architecture" of urban mobility systems is unsustainable (Haghshenas & Vaziri, 2012), inefficient (Richardson, 2005), and expensive (Mitchell, Hainley, & Burns, 2010). Congestion is a particular problem on several fronts. Apart from pollution and wasted efficiencies, it also leads to large road works projects that - expensive and frustrating to live through - do not actually solve the problem. Yet, this basic assumption of cars has remained the basis for virtually all transportation-related urban planning and investment (Givoni & Banister, 2010), (Janasz, 2017). Information systems plays key roles in many solutions in the tangled web that is urban mobility. Here, we propose that they have something to offer beyond their physical manifestations: the loan of certain guiding principles to guide requirements-gathering and design work.

The term ‘urban mobility system’ (UMS) as used here describes the complete network of networks of personal urban transportation. This begins with the road network and all conveyances that use it. It extends to transit systems (subways, street cars), to pedestrian walkways, bicycle paths, dedicated bus lanes, ferries, etc. It also includes the infrastructure used to operate and manage the networks. In short, it is a holistic label to encompass any means by which the city supports the movement of people within its boundaries. It is a ‘system’ due to its interdependencies, unity and boundaries. The design, operation, use and performance of the UMS are influenced by a number of internal and external factors, many of which are dynamic. Internally, these include the demand for mobility, municipal decisions, operator capacity levels, charges, rules and restrictions. External factors might include the price of gasoline, patterns of urban migration, state and federal rules and regulations. The causal relationships as well as the effects under various scenarios can be partially modeled using decision science methods. In decision analysis, values-focused thinking is used to capture and quantify peoples’ aspirations for the system. Following, probabilistically modeled ranges of expert opinions can be combined with the structured articulation of stakeholder goals to frame the planning decisions and map expected scenarios and expected outcomes. Design questions are then matched to pattern “templates” that have been developed to describe fundamental transportation problems in the aggregate. Once the problem, objectives and decisions have been precisely stated, numerical optimization methods (such as linear programming) can be used to define precise or heuristically-estimated results that support planning and operational management of the system. Operational changes are then monitored to detect aspirational changes in use that impact planning moving forward. Our research focus is in how we can best describe a holistic urban mobility planning process that will ultimately yield sustainability while satisfying the daily needs of the traveling public.

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2 The Problem: Why it is difficult to model mobility systems?

2.1 The Social Problem

Sociologists have related transportation to urban design in both physical and social senses (Yago, 1983). While the breadth and type of transit linkages fueled the spread and shape of cities, access and dependence on mobility systems play roles in segregation and inequality issues (Feitelson & Cohen-Blankshtain, 2018). As a key urban system, transportation directly or indirectly impacts every significant social theme (Sheller, 2014). The recent trend has been to "bolt on" a social interpretation to what are otherwise technical studies in data-driven transportation analysis (Lovejoy & Handy, 2011), (Hackney & Marchal, 2011), (Mote & Whitestone, 2011), (Toole et al., 2015). There is excitement around new tool sets such as big data analytics, GIS traces, and access to online social media platforms. Glimpses of habits can be seen in aggregate movements caught by a handy data set of a million cell phone traces, but there is no evidence that these observations manifest from fundamental social archetypes, and are broadly applicable. By *social archetypes*, we mean labels that allow useful generalizability of behavior with respect to a specific type of activity or domain. Examples might be *urban professionals*, *service workers*, *suburban retirees*, *regional tradespeople*, *elderly tourists*. This can be used to help build urban mobility patterns. One example might be an "urban walker +" who lives in a urban center close to work and shopping. He or she opts not to own a car but might use a car-sharing service occasionally to get away for the week or run certain errands. Another might be a "long distance commuter" who needs a car every work day, but might choose to get about in some other way on holidays and weekends.

To understand the system, we must avoid an opportunistic attitude towards available data sources and emerging processing techniques and develop a well-grounded, holistic system of insights. Yago calls for sociological research that will enable us to delineate on the basis of population, transportation, employment, and urban organizational trends, and for examination of the "social psychological dimension of urban transportation" (Yago, 1983). Should field sociologists answer this call and supply this research, we need to know how it can be consumed by those who create the infrastructure.

2.2 The Technical Problem

On the technical side, traffic analysis and modeling have a long research heritage extending back to the 1940s. In recent years it has extended to include multimodality and decision sciences (Ayed, Galvez-Fernandez, Habbas, & Khadraoui, 2011), (Amirgholy, Golshani, Schneider, Gonzales, & Gao, 2017), (Ribeiro & Vale, 2017), (Dibbelt et al., 2017), etc. It seeks a 'holy grail' in the sense of a single computable model that reveals the behavior of the system well enough to support planning. Its weakest link in this effort is the development of demand models (Manheim, 1979), (Moeller, 2014). Disaggregate activity-based demand models are the most popular as they fit well with modern data sources (Ben-Akiva & Bowman, 1997), (Bierlaire, 2013). They are an abstraction: a manufactured, artificial concept arranged to provide the inputs to models the mathematical aspects of which are well-understood (such as linear numerical formulations). The transportation modeler, always pedantic about the technical methods, is inevitably obliged to set down assumptions about human mobility demand which are – at best – 'sociologically incomplete'. Critically, Manheim (1979) shows how disaggregate demand functions in travel analysis are based on economists' assumptions of perfect information and rational choice. These assumptions have been challenged in behavioral economics and psychology (Ariely, 2008), (Kahneman & Egan, 2011). To address this, we must find a socially robust demand model. Expressed in information systems terms, this means we must ensure that our requirements-gathering efforts are effective in the sense of leading to functional user stories to guide design and development.

3 The Solution in Three Parts

3.1 Part 1: Value-Focused Thinking

To start to address the above challenge, we develop a narrative of three different languages. The first language gives voice to the broad desires of urban mobility users. It is adapted from the efforts being made to harness a technique called value-focused thinking (R. Keeney, 1994) and its specific application in the field of community-based operations research ('CBOR'), (Midgley, Johnson, & Chichirau, 2018). Value-focused thinking is a process of first de-constructing decision making into more socially foundational entities (values) versus the traditional alternatives or 'options'(R. Keeney, 1994). The process then proceeds to create value models which can be used in quantiative methods (R. L. Keeney & von Winterfeldt, 2009). CBOR leverages value-focused thinking, and further contemplates how to use contemporary data sources and analytics techniques in conjunction with traditional OR methods such as linear optimization. However, challenges obtain. Per Johnson et al.:

> *In community development and many aspects of urban planning .. the opportunity to capitalize on "big data" is much less clear. These domains tend to involve 'wicked problems' that are often open-ended, multi-faceted and politically controversial. Such problems have complex social choice dimensions for which there is little agreement about values, beliefs and desirable trade-offs (Johnson et al., 2015).*

Decision analysis as a method provides detailed, proven approaches for working in 'politically controversial' contexts to identify, evaluate and prioritize shared purpose (Raiffa, 2002), (Kirkwood, 1997), (Howard, 2007). In UMS planning, the shared values, once they are extracted and understood, can take the form of objectives for a multi-objective optimization approach (Stull, 2019). However, we still need a means to translate these objectives into a design language. We need to define a system of patterns for urban mobility that flow directly from the communal objectives, and will capture the complexities of the system in the form of re-usable templates. They will also suggest - at least broadly - the overall technical parameters, while continuing to identify and accede to user prerogatives. With this mechanism in hand, we can then situate the voice and the practical usage and design ideals into a stakeholder-centric, deliverable-oriented, iterative development model.

3.2 Part 2: A Pattern Language for Urban Mobility

The architect Christopher Alexander presents the idea of patterns in his discussions of how to fix building architecture in the latter part of the 20th century (Alexander, 1977). This concept was borrowed from urban planning and then deeply internalized in information systems - specifically in the area of software architecture and design. Alexander's work is a well-acknowledged inspiration for a number of influential works in software architecture (Gamma et al, 1995), (Fowler, 2002), etc. Patterns are descriptions of age-old problems in building design along with their solutions. They reflect deep, timeless values people have about the spaces they inhabit, and are both simultaneously aesthetic and practical. They are articulated such that the instantiation of any particular solution is guaranteed to not interfere with the proper workings of the building 'system.' The building system can be an individual building, a complex, a neighborhood, or an entire town. We can adapt this to the UMS by discovering the urban mobility patterns along Alexander's dialectical terms as expressed in modern technology. In this adaptation we are *inspired* by the same philosophical basis: that social spaces come first, and technical artifacts such as buildings are designed for them. We can see this philosophy seeking some form of implementation in contemporary planning documents, such as the Union Square Development Plan for Somerville, Massachusetts (Somerville, 2016). As researchers, we might wonder how we can formalize and generalize this philosophy to extend its usefulness.

Structured problem definition involves re-expressing the originally stated problem in a way that is semantically close enough to remain faithful to the stakeholder's viewpoint, yet shifted to include a set of technical 'markers' that will help the designer later lay out the corners of his/her task. In this sense, the languages of value-focused thinking and design patterns will actually become facets of the same theme, with slightly different foci and an amended vocabulary that addresses both. They are both concerned with the process of distilling a shared vision. One starts from the perspective of active conflict resolution, the other from a determination to morph chaos into order.

In italicizing the word 'inspired' above, we will not simply translate Alexander's building philosophy directly into mobility. Alexander and his collaborators passionately attacked the idea that a building design should force people to change their lifestyles. Contemporary thinking shares that view – up to a point. While improving materially over a completely distracted technical approach to infrastructure that had severe consequences for many urban stakeholders, the 21st century design paradigm also sets itself the task of playing a normative role in the effort to bring cities to sustainability. It is consciously critical of the 20th century developed-world 'lifestyle.' Yet, it must also proceed in a way that respects the social constraints as expressed in the design language. It will not propose solutions that force the elderly and disabled to get on bicycles or walk everywhere, nor will it expect the poverty-stricken to pay for expensive mobility-as-a-service solutions. These burdens add to the complexity, yet must be completely addressed by the architectural language selected. To develop a system within this complexity, we must abstract every possible technical detail out of the conversation until only the salient questions remain. For what the object will be used? How will it be perceived and experienced by its users? The approach is leveraged in the Agile method of developing information technology solutions. Its basic characteristics are complexity reduction and on-going stakeholder inclusion. In these, it joins the other two methods in their basic mission as realized through adaptive design idioms, structured decisioning, and iteration.

3.3 Part 3: An Iterative Development Model for the UMS

By seeking to re-humanize building design, Alexander proposes language as an affordance, rather than as a data structure. The difference is significant. In stressing the role of inhabitants as the designers of the buildings, Alexander purposely removed the precise technical strictures of the pendant-specialist. This does not mean that Alexander's buildings will fall down for not having been conformed to technical specifications. It means rather that the technical work to assemble the structure is contextualized within the perspective of the user-as-designer. This statement evokes the impact that Agile and earlier iterative development movements have had on complex software development. Every complicated question about what technical tools to use and how to implement them is abstracted out of the requirements discussions with user-stakeholders. All that remains is what is essential to communicate between the stakeholders and the designers. By moving through the process together using a shared language, Agilist parties learn their way through the complexity. By this, we mean that the solution emerges as a whole from the individual parts of the problems that are being solved, stage by stage. The movement causes the parties to learn how to communicate and work more effectively with each other, as well as to grow a shared view of the system over time.

The object of this paper is not to define the pattern language of urban mobility systems. Yet, we can at least move the conversation from buildings to mobility in adapting Alexander. We can begin to see them as facets of the same theme. A space is defined by its uses: by what people will do in it when they are there. However, in a world of movement and options, it is also defined by how one reaches and leaves it. In other words, the space has a mobility dimension. If we take away the parking lot in front of the shopping mall, the bus stop in front of the diner, the taxi stand outside of the hotel, we take away in each case an attribute intrinsic and necessary to that place, without which anyone would sense an important difference. One might argue that the buildings and the mobility system are parts of the same thing: the texture of the city. One stabilizes when the other changes, and vice-versa. This observation, which follows from a close reading of Alexander, has natural consequences for how we think about the design of any one urban system. In modern cities, the architecture of which has been so profoundly defined by mobility systems, every large planning exercise has essentially become a mobility planning effort.

We can see both the beginnings of this convergence and the current gaps by studying contemporary urban plans. The Union Square Neighborhood Plan, a typical artifact of this kind, does not merely include a section on mobility; it is - ontologically - a mobility plan, albeit an incomplete one. Parts of the solution are hinted at. The transit system extension (“Green Line Extension”) is considered essential and intrinsic. An analysis is done of parking space usage as a resource and one-way street layouts as mechanisms to support the re-imagination of the streets as space. At the same time one can easily sense that every description in the plan is only a shadow, that the plan yearns for a ‘complete’ language that will capture the vision and forms of the solutions. Without specifying the grades of concrete to be poured, etc. the artifact should describe the UMS completely, as the community wants it to become.

Another important finding in modern UMS planning literature is the idea of continuity and iteration (Poli, 2011). Once we develop the language we need to fully instantiate these kinds of plans it will inform and guide our data-gathering work. Practical technical work can then populate the instantiated plans with tactical details. For instance, text analysis / topical analysis as a technique can be used to parse online social network content and assign values to relevant mobility patterns in specific spatial-temporal contexts.

4 Conclusion

Lessons learned in tackling complexity in information systems can support the understanding and design of complex sociotechnical systems such as the UMS. This is part of the larger exercise of adapting well-understood business science techniques to urban planning. By focusing on techniques that have been effectively and systematically improved over some time, we can introduce method to urban systems planning to make it simultaneously more effective and more inclusive.

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