Journal of Transport Geography xxx (2013) xxx–xxx

Contents lists available at SciVerse ScienceDirect

Journal of Transport Geography

journal homepage: www.elsevier.com/locate/jtrangeo

Beyond sharing: cultivating cooperative transportation systems through geographic information science

Harvey J. Miller *

Department of Geography, The Ohio State University, 1036 Derby Hall, 154 North Oval Mall, Columbus, OH 43210-1361, United States

ARTICLE INFO

Keywords:
Transportation
Cooperation
Game theory
Big Data

ABSTRACT

Transportation systems are facing unprecedented challenges in the 21st century. Increasing the efficiency of transportation systems alone will not solve these problems and may exacerbate them. Instead, we must extract new transportation capabilities related to more cooperative decision-making across a wide range of time horizons, spatial scales and decision contexts. This paper discusses the role of sensed transportation, geographic information science and social media to cultivate transportation systems where participants share, cooperate and act collectively to solve operational, tactical and strategic mobility and accessibility problems. This paper also provides a vision of the future by imaging a seamless multimodal transportation system combined with a virtual environment where data streams are fused, interpreted and made available with tools for human engagement and shared decision making. This paper concludes by outlining a GIScience-centric research agenda.

1. Introduction

Transportation systems are facing unprecedented challenges in the 21st century. In some parts of the world, such as the United States and Europe, increasing travel demand combined with aging infrastructure, flat or declining investment, and physical, environmental and social constraints on infrastructure expansion are leading to saturated and strained transportation systems (TRB Executive Committee, 2009). Other parts of the world, such as China and India, are experiencing rapid rates of urbanization and especially motorization as new wealth creates increasing demand for personal mobility (Purcher et al., 2007). In addition to these rising pressures, our current methods for generating mobility are inequitable (particularly for excluded populations such as the poor and aged), lead to public health problems, are not necessarily conducive to well-functioning communities and impose substantial environmental costs at scales ranging from toxic airsheds to global climate change (Black, 2010; Morency et al., 2011; Roorda et al., 2010; Steg and Gifford, 2005).

These challenges cannot be addressed using the technologies and processes that created the current problematic systems. We must extract not only more capacity but also new *capabilities* from our transportation infrastructure. By itself, wresting greater efficiency from transportation systems is not sufficient. In fact, making a system more efficient can induce more resource consumption due to demand elasticity; an effect often referred as *Jevons' Paradox* after its 19th century discoverer, English economist William Stanley Jevons. Consequently, efficiency increases must often be accompanied by constraints such as quotas and rationing (Alcott, 2005). Similarly, *Braess' Paradox* in transportation science shows that adding capacity to a congested network can reduce overall performance if travelers attempt to minimize their individual travel times and ignore the effects of their decisions on others (Braess, 1968; Murchland, 1970; Pas and Principio, 1997). Experience with the classic "predict and provide" paradigm in transportation planning illustrates these effects: it is difficult to solve transportation problems only by building infrastructure (Banister and Button, 1992; Noland and Lem, 2002; Owens, 1995).

There are opportunities for extracting new capabilities at the convergence of transportation and information technologies. *Sensor technologies*, embedded in vehicles and infrastructure, carried by travelers or remotely positioned, and connected via wireless communication, are generating massive amounts of fine-grained data about transportation systems and their dynamics. *Geographic Information Science* (GISci) and *Geographic Information Systems* (GIS) provide theory and methods for managing, exploring, analyzing and sharing georeferenced spatio-temporal transportation data and information. *Social media* can allow more meaningful interactions among travelers, managers and stakeholders. The potential for a data-driven revolution in planning, management and use of transportation systems is inspiring some to call for a new interdisciplinary field, *computational transportation science*, encompassing transportation, computer and geographic information sciences (Winter et al., 2011). In addition, private sector companies such as IBM envision a smarter planet through by making systems more instrumented, intelligent and interconnected (www.ibm.com/smarterplanet).

* Tel.: +1 614 292 2514.
E-mail address: harvjmiller@gmail.com

0966-6923/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jtrangeo.2013.04.007

Big Data has arrived in transportation and will get much bigger soon. To what end should we direct these streams of data and computations in order to resolve or mitigate the challenges facing transportation systems in the 21st century? Similar to the Jevons and Braess paradoxes, flooding transportation systems with data and information may be counterproductive: these are types of additional capacity that can have a negative effect on system performance if travelers use that information to make selfish choices (Unnikrishnan and Waller, 2009).

Transportation is a classic social dilemma where individually rational behavior (being mobile) leads to collectively irrational outcomes such as congestion, accidents, environmental degradation, social exclusion and loss of community. One method for resolving collective action dilemmas is through cooperation (Kollock, 1998). *Cooperation* means compromising to work together since some may be worse-off (lower benefits, higher costs or both), at least in the short term. Cooperation does not necessarily require altruism: *pro-social behavior* can be altruistically motivated (intended to benefit other people based on empathy and understanding) or egoistically motivated (helping someone to ultimately benefit oneself; Avineri, 2009; Bierhoff, 2001). Regardless of the underlying motivations, the results are transportation systems with better collective outcomes (Levinson, 2005).

There is a growing body of theoretical and empirical evidence regarding cooperation and pro-social behaviors, much of it from the perspective of evolutionary and experimental game theory. Although classic results from game theory regarding cooperation are well-recognized, there are recent breakthroughs in the biological and social sciences regarding cooperative behavior. It is more common and powerful in both the biological and social worlds than previously recognized (De Waal, 2009; Rifkin, 2009). Time, space and networks play a central role in facilitating cooperation and collaboration (Nowak, 2006; Nowak and Highfield, 2011).

This paper discusses the role of sensed transportation, geographic information science and social media to cultivate cooperative transportation systems. Cooperative transportation requires some individuals to make sacrifices for the greater good. This can be as easy as sharing information and resources. But it also includes more difficult behaviors such as *collaboration* or collective action that require shared credit and responsibility (Shirky, 2008). *Cooperative transportation systems* are integrated technological and human systems where participants share information and resources, and collaborate on solving accessibility (mobility and communication) problems at all scales from local and operational (“How do we get to work today?”) to regional and strategic (“What do we want our transportation systems and communities to look like in twenty years?”).

Nascent examples of cooperative transportation systems have been around for a long time and have been growing in recent years. Proto-examples include spontaneous carpooling to take advantage of high occupancy vehicle lanes in urban areas such as Washington, DC (Mote and Whitestone, 2011). First generation examples include crowdsourced navigation through social media such as Waze (www.waze.com), community car sharing programs such as Zipcar (www.zipcar.com) and bike sharing programs such as those available in cities such as Washington, DC, Paris and Melbourne, Australia. These programs involve third party ownership of vehicles by private sector companies, often under contract with local governments. A more recent development is the rise of direct peer-to-peer vehicle and ride sharing systems such as Getaround (www.getaround.com) and Avego (www.avego.com). These developments are part of a larger trend sometimes referred to as *collaborative consumption* or the *sharing economy*. The idea is to convert goods into services through an economy built on access rather than ownership of vehicles, tools, homes, workspaces, garden plots and other forms of capital (Garthwaite, 2012; Shirky, 2008). While these trends are promising, they are only the beginning. A mature cooperative transportation system would extend capabilities for sharing, cooperation and collaboration across a wider range of spatial and temporal scales (from real-time route choice to long-term decisions such as home and business locations and automobile ownership), across multiple transportation modes (facilitating seamless integration of mobility services) and integrate transportation and non-transportation solutions to accessibility problems (such as substituting virtual access for physical access and activity coordination that minimizes aggregate mobility).

Facilitating greater cooperation and collaboration in visioning and strategic planning can also help reduce the contentious atmosphere that has become seemingly endemic to transportation planning. The potential for conflict has increased with wider recognition of the complexity of transportation problems and the need to address difficult issues such as social justice and sustainability (Weiner, 2008). Consequently, there has been a call for a more inclusive planning process that goes beyond the community only providing input on strategic goals and commenting on predetermined alternatives (Wilson et al., 2003). This has encouraged the development of technologies such as collaborative decision support systems (Jankowski et al., 1997) and community-based planning efforts such as Envision Utah that facilitate engagement and dialogue among a wide range of community citizens and stakeholders (www.envisionutah.org). A challenge is to leverage the coming torrent of data from transportation systems and cities – much of it fine-grained and near real-time – to extend collaborative transportation decision-making across a wider range of scales and contexts.

Geographic information science and technologies have a key role to play in facilitating cooperative transportation. First, and perhaps most superficially (but nonetheless important) is that transportation systems are geographic, and the streams of data that emerge will be referenced in geo-space and time. How do we leverage these data to generate the information and knowledge necessary to facilitate cooperative behavior? This requires integrating and expanding functionalities we currently see in digital earth, *location-based services* (LBS), social media and collaborative spatial decision support systems, and connecting this environment to the torrent of data that will be flowing from transportation systems. Given the volume of data expected, the geospatial infrastructure and management issues are formidable, as are needs for effective and scalable geographic knowledge discovery, spatial analysis and geovisualization techniques.

Beyond helping to resolve the technological and infrastructural challenges faced by processing massive spatio-temporal data from sensed transportation systems, geographic information science can contribute to the social processes that facilitate cooperative transportation systems. There are fundamental questions surrounding the nature of cooperative behavior – how to encourage cooperative behavior, how many people need to cooperative to achieve desirable outcomes, and what objectives are best served by cooperative behavior versus competition. Recent scientific insights on the role of time, space and networks in cooperative behavior suggest properties that can be leveraged through GIScience and tools for making sense of spatio-temporal data and supporting collaborative spatial decision-making.

How do we leverage Big Data to facilitate more cooperative transportation systems? More than two decades ago, computer scientist David Gerlernter presciently anticipated the ability to converge massive real-time data streams and information technologies to develop virtual environments for managing complex real-world systems. *Mirror Worlds* are virtual environments that parallel the real world to facilitate its understanding and engagement through tools for interpreting massive data streams and shared decision-making at varying temporal and spatial scales (Gelernter, 1991).