# Intelligent Infrastructure: Mobile Networks as Tactical Transportation

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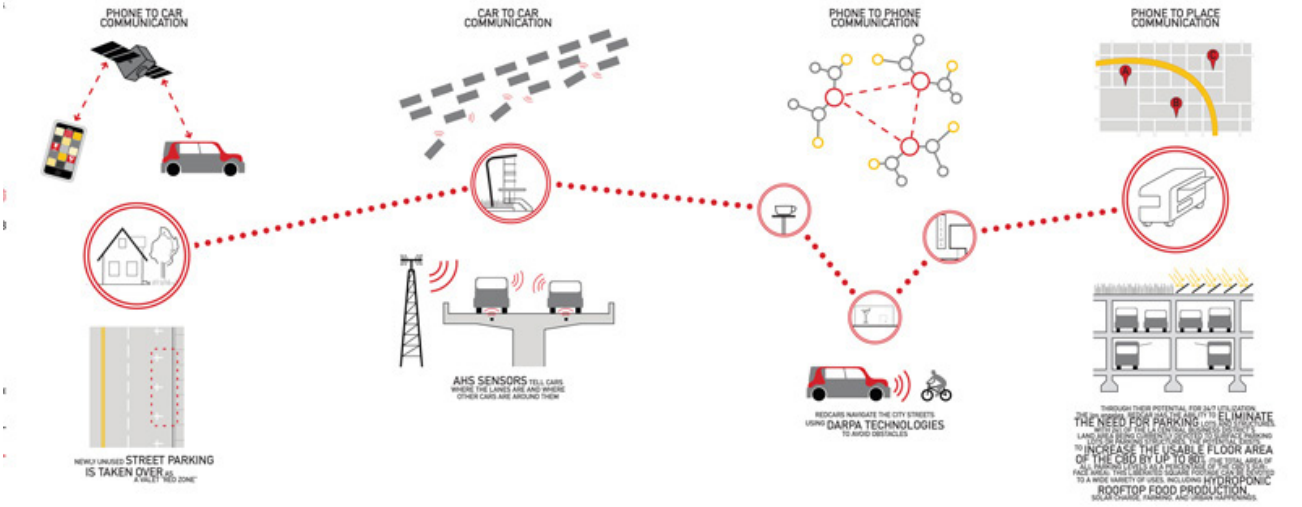
## INTRODUCTION

What exactly is meant by the term intelligent infrastructure? I use it to refer to infrastructure imbued with self-awareness by sensors and computing.[1] This conception becomes increasingly important when considering future scenarios for metropolitan areas. Intelligent infrastructure comprises not only technological artifacts, but also social relations – the open source movement, hackathons, participatory practices, all of which today's mobile Web 2.0 makes possible. The term also includes networked social intelligence and crowd sourcing, both of which have their own generative potential – for example, when social media begins to initiate new political practices and becomes a platform for redistributing resources. In this paper and my own research, *intelligent infrastructure* denotes adaptive systems, e.g. wireless mobile communication devices, used as a means to organize people and vehicles through sensors. One prototype project will be described in detail: Los Angeles REDCAR.




While some of the technology described is still nascent, this paper outlines how new protocols and adaptive systems are poised to instigate new metropolitan forms, programs, and practices.

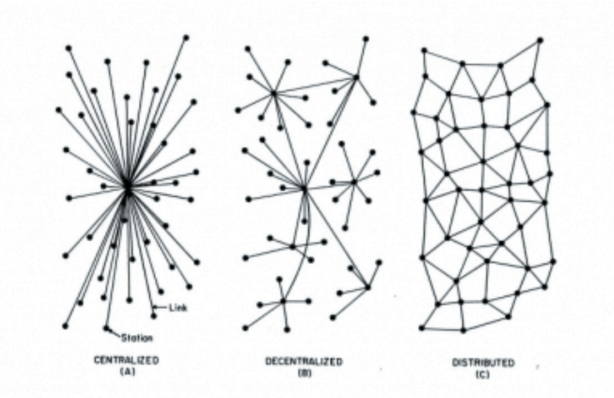
## THEORY AND BACKGROUND

Although many advances in transportation and transportation technologies have occurred in the last decade, the theoretical foundations originated much earlier -- during the 1960s when a discourse on "spatial practice" emerged. Drawing upon the political and cultural ferment of the time, Melvin Webber, an urban planner at UC Berkeley argued that the quality of the "urbane" might not be defined by buildings, but instead by a rich exchange of information.[2] Webber's theories aligned within other avant-garde architects, artists, writers, and critics, known as "spatial urbanists" who envisioned a set of possibilities for future human settlement and transportation. Many of these projects were in large part a response to the government's planning policies and its Kafka-esque bureaucracy, which many architects considered the first obstacles to the implementation of their radical urban designs.[3]

The spatial urbanists formed an international network of experimental practice that included the Situationist International, Archigram, the Metabolists, Superstudio, and others. Other spatial theorists envisioned relational structures as conceptual models that could be projected onto physical social space. In particular, Webber's "city as a communication system" from "Community without Propinquity"[4] and Reynar Banham's "autopia" from "Los Angeles: The Four Ecologies"[5] – these publications contributed to an increased understanding of the urban condition as a dynamic social space.

Some designers of that time envisioned Utopian cities taking the form of massive grids or meshes suspended above the ground, with all parts (and inhabitants) circulating in a smooth, synchronous rhythm; the streets and buildings constituting a gigantic work of plastic art or interactive machine.[6] In this new urban world, technology and automation were expected to be positive forces, providing for material needs as well as time and space for leisure. The architect and mathematician Christopher Alexander analyzed urban organizational structures and made an even simpler distinction between trees and semi-lattices in order to describe the social organization of the contemporary city. He argued that the unnatural tree structure, as a diagram of discreet and non-overlapping sets, formed the basis of virtually all modernist urban plans. In place of an exclusionary tree model, he argued that architects and planners should be designing urban space in a semi-lattice organization, in order to create a better fit between physical spaces and social practices that energize them.

By 1996, Manuel Castells' seminal notion of "spaces of flows" expands Alexander's ideas – describing cities that are conditioned by cultural networks that fall across a spectrum, from centralized to distributed, in other words, from trees to semi-lattices. The




distributed semi-lattice network offers up a very different model of social organization than centralized or tree models, which still dominate the hierarchical structure of the city.[7] A distributed network is dispersed and non-hierarchical; it is not self-organizing in the sense of functioning automatically, but in the sense that its organization is not determined by a centralized, dominant power within or above the network. As Peter Mortenbock likewise suggests, contemporary networked cultures, which operate according to distributed structures, offer up new possibilities for urban organization.[8]

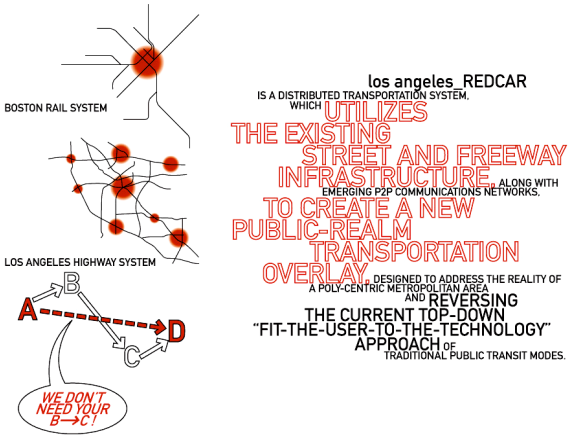
## PROJECT DESCRIPTION

If contemporary designers take the approach that networked cultures as offering new social practices and protocols, what are the potential implications for urban form? For the last two years, I have been part of an interdisciplinary team of architects and industrial designers – 510 Collective: Ben Feldman, Tyron Marshall, Gerry Tierney, and Format Design: Katherine Handy, Dinesh Perera – in conversation with with Christopher Borroni-Bird, Director of Advanced Vehicle Concepts at GM, taking up the issue of how networked cultures might offer up new possibilities for urban organization.

The philosophy underlying my research holds that design, as a way of thinking, plays a distinct and important role in the advancement of knowledge and human well-being, a role complementary to those of science and technology, because designers are concerned with the application of technologies to specific human needs in particular contexts.[9] The projects that the team has engaged concern the public sphere, and in particular, leveraging existing technologies and infrastructure and repurposing towards a distributed urban transportation system.

The background research employed a mixed methodology in order to better understand the relationship between information access and transit riders, e.g. commuters, students, tourists, and others. It was structured in three parts comprised of a literature review, ethnographic studies and data analysis – all of which contributed to the concept design of Los Angeles_REDCAR. This prototype system utilizes existing street and freeway infrastructure, along with emerging P2P communications networks to create a new public realm transportation overlay by reversing the current top-down fit-the-user-to-the-technology approach of traditional public transit.

The Los Angeles_REDCAR is a novel system that builds on other existing systems. For example, Paris introduced *Autolib*, an electric 'floating vehicle' program similar to their free bike program, *Velib.* Diamler AG's *car2go* is an electric carsharing system launched in four North American cities. The Google+ autonomous car was recently legalized in the state of Nevada.[10] While Los Angeles_REDCAR system acknowledges existing precedents, it goes beyond precedent by combining components in a new way, creating a condition that engineers and planners term, *ubiquitous mobility.* Los Angeles_REDCAR is a public transit infrastructure for locating and sharing cars that is intelligent, responsive, and individualized – in real time.




## TEST CASE: LOS ANGELES

Many metropolitan areas continue to experience rapid growth with some cities, such as Los Angeles, receiving over 700 new residents each day. One of the current challenges for expanding cities is the design

of a flexible transportation infrastructure that can respond to an ever-increasing demand – and one that can also carry forward the vision of a socially equitable and sustainable society. This model of infrastructural response necessitates a rethinking of traditional personal mobility strategies. Networked systems, in particular, can solve some of the problems that the modern city has inherited, including a fixed infrastructural system that is expensive and slow to respond to changes in the activity of a city.

This research project confronts four principal urban issues:

1. **The Polycentric City** Most mass transit systems are designed around an assumed centralized urban core, which does not address the polycentric organization of Los Angeles and many rapidly growing cities in the developing world.[11]

2. **Low Density** Suburban population dispersion over a wide geographic area, with resulting reduced densities, does not make optimal use of a centralized transportation system.

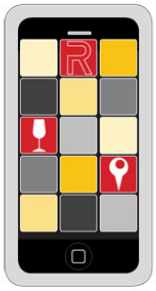
3. **User Preference** Traditional mass transit systems are predicated on a top-down, fit-the-user-to-the-technology methodology, which ignores user preferences (i.e. autonomy) and usage patterns (pre-work versus post-work social practices).

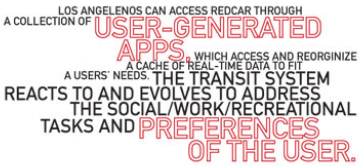
4. **Ride Sharing** Current ride sharing scenarios have limitations: (1) They can only accommodate one or two additional riders per one-car unit; (2) In our current cultural climate, sharing rides with strangers raises perceived safety issues amongst segments of the population.

Los Angeles_REDCAR is an example of a networked system – one that combines technology with social, economic and cultural exchange. In this respect, Los angeles_REDCAR is a tactical intervention that builds upon the region's existing autopia ecology by leveraging social software with ubiquitous mobile technology as a means to promote connectivity. If adopted, flexible networked systems have important implications for the future of urban development. Along with increased zoning densities and new models of transit-oriented development (TOD), networked systems can create a better transit experience for many urban residents.

## TACTICAL SYSTEM COMPONENTS

The positive effects of sustainable transportation practices are already well documented. It has also been established that the personal automobile is inefficient in its manufacture, marketing and utilization. In *Reinventing the Automobile*, the late William Mitchell sets out four ways in which personal transportation will likely adapt to fuel scarcity: 1) an underlying design system based on electric-drive and wireless communications; 2) a Mobility Internet for sharing traffic and travel data; 3) smart electric grids based on renewable energy; 4) dynamically priced markets for electricity, road space, parking space, and shared-use vehicles.[12] Those four future systems describe some of the ways in which intelligent infrastructure will impact the urban experience. All could be considered *adaptive systems*, e.g. wireless mobile communication devices as a means to organize people and vehicles through sensors. As part of an ongoing reconfiguring of urban transportation, Los Angeles_REDCAR prototype system integrates three components: 1) mobile communication device which is 2) overlaid with a social software application operating in real time and 3) an autonomous vehicle.




**Mobile Communication Device** (i-phones, droids, other) While the cell phone started out as a mobile communication device, it effectively evolved into a portable computer enabling any number of social practices: image sharing, banking, purchas-

es, etc. that will only become more extensive in the future. The wider acceptance and distribution of wireless and episodic networks enable what could be termed "personal infrastructure" characterized by the ad hoc dynamic sharing of physical and virtual resources among heterogeneous devices. Information, entertainment, and financial services on demand effectively replace fixed shared services. With Los Angeles_REDCAR, wireless networks connect vehicles to riders in realtime.

**Application** The application organizes people, goods, and services. Importantly for Los Angeles_REDCAR, apps can organize and coordinate transportation options dynamically, in real time and on the go – especially leasable (timeshare) cars such as from Zipcar or other such services. This may be the future direction of the automobile industry -- no longer selling cars but instead leasing vehicle usage in units of time to urban dwellers equipped with smartphones apps that will reserve, locate and lease cars by the minute.[13]

Angelinos will be able access REDCAR through a variety of designed and developed applications such as:

- "I need to get somewhere fast" (solo - speed priority)
- "I need to do errands" (vehicle timed-transfer ok)
- "I need you to be my designated driver" (help!)
- "I'm new to the city and want to see the sights" (timing less important)

This networked transit system is intelligent, bespoke and responsive; it reacts to and evolves to address the social / work / recreational tasks and preferences of the user. These preferences and/or profiles access and reorganize a cache of real-time data to fit users needs. This distributed transit system solves many of the problems inherent with fixed transportation infrastructure.

**Autonomous Vehicle** Google's driverless car is being developed by Sebastian Thrum, director of the Stanford Artificial Intelligence Laboratory (and Google engineer) whose team at Stanford created the robotic vehicle that won the 2005 DARPA Grand Challenge. The system combines information gathered from Google Street View (which Thrum invented) with artificial intelligence that combines input from video cameras inside the car, a sensor on top of the vehicle, radar sensors on the front of the vehicle and a position sensor attached to one of the rear wheels that helps locate the car's position on the map. Google anticipates that the increased accuracy of its automated driving system could help reduce the number of traffic-related injuries and deaths, while allowing for more efficient use of energy and space on roadways.[14] As of summer 2011, the Google+ driverless car was legal in the State of Nevada.

Sustainability figures prominently in the development of alternative transportation systems. It is projected that by 2020, peak oil production will have been reached.[15] The zero-carbon emission Los Angeles_REDCAR can be configured to carry more passengers than conventional private automobiles. The intent is that through higher utilization rates the REDCAR technology will allow for the replacement of conventional automobiles at a 1:3 ratio.

Vehicle Configuration: Building upon the National Automated Highway System Consortium NAHSC/PATH I-15 demonstration project "platoons" of up to 25 cars can gang together to share part of a route or they can "mate" to create a shared mobile social interest platform.[16]

Emergent Nodes: Commercial development will naturally emerge from the urban fabric in response to social hotspots triggered by both physical space, i.e. locations of transfer from vehicle to transit, and social swings. The overlay of efficient route-processing software upon the physical realm will create serendipitous social and transit "hot-spots" to emerge creating an organic evolution of true TODs.[17]

## NEW SOCIAL PRACTICES

While the previous section focused on functional aspects of transportation systems, such as everyday commuting, mobile technologies are rapidly modifying other urban spaces and practices. It follows that new forms of urban space might emerge attendant upon new media. One of the most compelling is the upswing in mobile restaurants connected via micro-blogging platforms, such as Twitter. In Los Angeles, one of the best known is Kogi (Asian fusion), whose late night itinerary is disseminated to Twitter followers. In San Francisco where the price of real estate prohibits many small neighborhood restaurants, hungry hipsters flock to Seoul on Wheels or Chairman Bao after receiving a pre-lunch time text announcement via their cell phones. Today Manuel Castells would define this as a "material organization of time-sharing social practices that work through flows."[18] These examples, however, are not meant to explain a theory of social network culture, which is outside the scope of this paper, but to document occurrences of emergent urban practices.[19] Additional social science research is recommended to determine to what extent urban dwellers are prepared to organize their lives through mobile technologies.

## TRANSIT ORIENTED HOUSING

In much the same way that transportation alternatives can arise vis-à-vis social and technological innovation, urban habitation can also respond to change. Two significant economic and social trends have potential implications on urban form. Among 18-34 year olds, there is a conscious decision to drive less. That decision is partially influenced by economics (high cost of car ownership is making it difficult to own a car, with the result that this demographic is buying fewer cars), in addition to environmental concerns.[20] A second important trend among 18-34 year olds is a locational preference for central urban areas, i.e. higher-density, walkable, mixed-use environments, representing a choice away from the low-density, single-use, car-dependent sprawl that has predominated since World War II. Demographic patterns can be translated into formal strategies for future urban development, for example, with transit oriented infill (TOI) projects, particularly affordable multi-unit housing. Designs for transit-oriented urban infill (TOI) are being explored at University of Illinois Urbana Champaign's URL: Urban Research Lab by Braulio Soto who employs algorithms to create various morphological prototypes based on predictive analysis of reduced car ownership within an urban context. In these projects, urban habitation is not viewed exclusively, but as a specific node within a larger infrastructural system – thereby requiring infill sites to be located within one block of public transit lines. TOI projects yield higher densities and result in a smaller carbon footprint.[21]

New ways of organizing existing transportation resources demonstrate that design ideas can be leveraged into strategies that are environmentally responsible and socially equitable, enabling new urban forms and public interaction.

## CONCLUSION

While it is clear today that we are deeply embedded in cultures which are formed in part by new information technologies, we still move within existing transportation infrastructure: Roads, rails and subways, are not disappearing. In the example of Los Angeles_REDCAR, both hardware *and* software are components of extensive mobile social networks that are supported and distributed through fixed roadways, guideways, transportation.

Mitchell suggested that the digital revolution will alter patterns of human settlement and land use to the same degree as the industrial and agricultural revolutions did before. For the future of cities, Mitchell proposed our intelligent interaction with them; an interweaving of information and matter will fundamentally change the way that we use space, distribute resources, and interact with our communities.[22] As architects and engineers work across a variety of disciplines to solve seemingly intractable urban problems, there is still tremendous potential and cause for future research.

## ACKNOWLEDGEMENTS

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## ENDNOTES

1 Richard Cook. "Ecotopia," lecture at *Intelligent Infrastructure*, New York, NY (Feb 16, 2011)
2 Melvin Webber. "The Urban Place and the Non-Place Urban Realm," in *Explorations into Urban Structure*, ed. Webber et al. (Philadelphia: University of *Pennsylvania* Press, 1964**)**
3 Larry Busbea. *Topologies:Urban Utopia in France* (Cambridge MIT Press, 2007)
4 Melvin Webber. "Order in Diversity: Community Without Propinquity," L. Wingo, Jr., ed., *Cities and Space*. (Baltimore: Johns Hopkins Press, 1963)
5 Reynar Banham. *Los Angeles: The Four Ecologies* (New York, Harper & Row, 1971)
6 Mark Wigley. "The Architectural Brain" in *Network Practices: New Strategies for Architecture + Design,* eds. Burke + Tierney (New York: Princeton Architectural Press 2007)
7 Manuel Castells. *The Rise of the Network Society,* 2nd ed. (Malden, MA: Blackwell Publishers 2000): 1-76.
8 Peter Mortenbock. "Placemaking Dialogues," *Gateways: Art and Networked Culture.* http://blog.goethe.de/gateways/archives/10-Peter-Moertenboeck-about-Placemaking-Dialogues.html (accessed August 16, 2011)
9 At UIUC, URL: Urban Research Lab projects have investigated systems, both physical and virtual, as they pertain to infrastructure, software, ecologies, and environments.
10 Other research in this area has been completed by: Margot Brereton, et al (Queensland University of Technology), Ryan Chin (Smart Cities, MIT) Eric Paulos (HCI Institute, Carnegie Mellon), Carlo Ratti (Senseable City Lab, MIT), Mark Shepard (Sentient City, SUNY Buffalo), among others.
11 Rem Koolhaas and Bruce Mau SMLXL (New York: Monacelli Press,1998)
12 William Mitchell, C. Borroni-Bird, and L. Burns, *Reinventing the Automobile: Personal Urban Mobility for the 21st Century.* (Cambridge, MIT Press, 2009)
13 Christopher Borroni-Bird *Mobility and the City Colloquium 2010, San Francisco.*
14 Sven Bieker, Stanford University argues that there are still many legal issues to resolve. California Department of Motor Vehicles raised concerns that "*The technology is ahead of the law in many areas*" citing state laws that "*all presume to have a human being operating the vehicle*."
15 There is an ongoing debate whether "peak oil" has been reached or if it will be reached in 2020. Refer to Kenneth Deffeyes (January 19 2007). "Current Events: Join us as we watch the crisis unfolding." Princeton University: *Beyond Oil* and Zittel, Werner; Schindler, Jorg (October 2007). "Crude Oil: The Supply Outlook. Energy Watch Group." EWG-Series No 3/2007. Accessed July 27, 2008.
16 A successful platoon control demonstration was held in San Diego by the National Automated Highway System Consortium (NAHSC) on August 7-10, 1997. PATH showed an 8 Buick *LeSabre* platoon in combined longitudinal and lateral control on the I-15 HOV lanes. The vehicles were driving themselves at 6.5 meters spacing and 60 mph. The scenario involved vehicle #2 splitting, doing a lane change, falling back and doing another lane change to join the platoon back as vehicle #8. http://www.path.berkeley.edu/PATH/Research/demos/
17 In conversation with Ben Feldman, architect and urban planner, June 23, 2009.
18 Manuel Castells, *The Rise of the Network Society,* 2nd ed. (Malden, MA: Blackwell Pub 2000): 1-76.
19 For a general theory of social network culture, please refer to the author's publication, *Public Space/ New Publics: Social Media's Connected Culture* (forthcoming 2012)
20 Department of Transportation Federal Highway Administration's National Household Travel Survey Census data: The share of automobile miles driven by people aged 21 to 30 in the U.S. fell to 13.7% in 2009 from 18.3% in 2001 and 20.8% in 1995. The proportion of people aged 21-30 actually increased from 13.3% to 13.9%. To summarize, twenty-one to thirty-four year olds went from driving a disproportionate amount of the nation's highway miles in 1995 to under-indexing for driving in 2009. " Is Digital Revolution Driving Decline in U.S. Car Culture?" Department of Transportation Federal Highway Administration's National Household Travel Survey Census Data: http://adage.com/digital/article?article_id=144155 (accessed November 27, 2011)
21 Therese F. Tierney, *New Urban Mobilities as Intelligent Infrastructure* (publication forthcoming 2012).
22 William Mitchell, *City of Bits* (Cambridge, MA: MIT Press, 1996).