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Modern Information Infrastructure in the Support of Distributed Collective Practice in Transport

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Abstract. Transport is one of the oldest and most important forms of distributed collective practice. This paper traces the role of information and communication technologies in the transformation of transport-based distributed collective practice, focusing on the evolution of technologies that place control of the transport infrastructure in the hands of end users. Examples of this shift are provided, including an analysis of the events of September 11, 2001 as forms of distributed collective action.

Key words: communications, distributed collective practice, information infrastructure, transportation, terrorism

An interesting promotional story about automation emerged in mid-20th Century America. The American Telephone and Telegraph Company had taken note of the time taken to switch an average phone call using patch panels and human operators in light of the growth rate in telephone calls and the population's labor capacity. Manual switching was unsustainable. A wholesale shift to national and international direct dialing was launched. To gain public acceptance, the telephone industry touted the new system placed advertisements saying that, without direct dialing, most of the population would have to become telephone operators.

In fact, automated switching made it both possible and necessary for most of the population to *become* telephone operators. The advertisements had the story backwards. This marked an important shift in the history of the industrial revolution. Machinery substituted capital for labor: one worker with a machine replaced many workers without machines. The automation of the telephone network *transferred* the labor burden from the service provider to the user. The user was willing to bear this burden because it came with a remarkable degree of flexibility and control. The calling party could connect to the called party at any time, without the need for the operator, thereby saving time and avoiding compromises in confidentiality and privacy. Through the adoption of centralized standards and conventions enforced by common machinery, automation decentralized the practice of telephone use and enabled telephony to evolve in support of *distributed collective practice*. That pattern has been followed consistently in the evolution of information and communication infrastructure since that time.

This short paper ties together information and communication with transport as complementary components in distributed collective practice. Transport is probably one of the oldest forms of distributed collective practice, and is undoubtedly the largest.[1] For millennia, transport was the primary mechanism by which distributed communities of actors accomplished shared tasks (King and Frost, 2002). In addition, the transport infrastructure was the only mechanism for long-distance communication: the message had to be carried by the transportation infrastructure to reach its intended recipient. Extraordinary progress has been made in transport over the past 250 years: the steam engine harnessed the thermal gradient for propulsion, improvements in materials and production technology made new conveyances possible and affordable, and so on. Following the telegraph, electronic communication eventually led to an inversion, where transport became deeply dependent on communication and information processing (Alt et al., 1995). Transport and information infrastructures emerged as a powerful and important complementary nexus of human capability, with profound implications for distributed collective practice.

It is relatively easy to recognize the relationship between communications and distributed collective practice. It is a bit harder to see the same relationship in transport. Transport is not merely a matter of physical and organizational infrastructure, although these are necessary components of transport. Transport is an essential human activity in terms of social communities in action. Transport exists for travel and exchange of physical goods within and between social communities, and is provided by professional and commercial communities bound together by shared expertise, technology, and social conventions in addition to ownership and regulatory structures (Forster and King, 1995). Although technical infrastructure enables transport, it is not the reason for transport and it does not provide value. Technology is used to make value available to social communities who extract that value.

The distinction between transport-as-technology and transport-as-community-activity helps to highlight the coordination required for transport. Some transport can be narrowly defined within a community, but most transport requires boundary-spanning across communities to allow expeditious use of transport assets via roads, rail, airports, and seaports. Transport infrastructure is very expensive in both capital and maintenance cost, requiring a significant tradeoff between efficiency and expediency in development of transport infrastructure. For many decades the primary strategy for improvement in transport was to expand the transport infrastructure. However, in the most developed countries that pattern has changed remarkably in the past quarter century. Using the US as a benchmark, the Interstate Highway System is no longer growing in terms of new miles, the rail network is shrinking, and few new airports or seaports will be constructed. This slowdown in expansion of modal infrastructure links is partly the result of the great success of earlier infrastructure building campaigns, but is also driven by newer concerns about social and environmental consequences of expanding the infrastructure. New transport projects trade off against other societal needs. In order for transport itself to evolve, new ways of using existing assets must be found.

User communities – those that take advantage of the transport infrastructure – are the main theme of this story. However, the important changes in the behavior of these user communities cannot be understood without examining the changes in the provider communities. The two provider communities of greatest importance historically have been engineering and management. Engineering has been important because the artifacts necessary for building the infrastructure must be designed to meet tremendous physical demands cost-effectively. Management has been important in capitalization and operation in the application domains of agriculture, industrial production, commerce and trade, and defense. For nearly all of the 19th century and much of the 20th century, these communities pushed the evolution of the transport infrastructure along the path of reliable technology for economic growth and, when the need was clear, for maintenance of national security. Following the WW II, new provider communities began to arise around sociology, geography, atmospheric chemistry, and the life sciences. These eventually began to change the dominance of the efficiently engineered economic growth paradigm. By the 1970s, coalitions of urban geographers and sociologists, ecologists and environmental activists had begun an assault on the simplistic growth-oriented vision of infrastructure, and a new focus on the negative externalities that arise from large transport infrastructure projects and the subsequent use of that infrastructure. Transport infrastructure development was no longer just a matter of good engineering and a sound business case.

In the last quarter century transport infrastructure planners have seen that the simplest approach to reducing the old problem of channel congestion in the transport systems – adding capacity – was not working. As each new lane was added to a clogged freeway, more traffic joined the system and congestion rose to previous levels. Economists have long pointed out that the only sensible way to control peak-load congestion is the application of pricing systems that charge more for use during periods of high congestion, driving cost-sensitive users into less congested periods. But in a freely accessible system in which users do not pay directly, such schemes cannot easily be implemented. Transportation engineers began to consider channel congestion management through controls on user behavior to make optimal use of existing channels. A good example of this was the implementation of expressway on-ramp meters to slow "births" into the network, thereby keeping congestion below the threshold of flow degradation, and high occupancy vehicle (HOV) lanes. Double-decked passenger and freight container cars were introduced to the rail sector. Larger aircraft made better use of constrained airport takeoff and landing slots and gates. Supercargo container ships and supertankers made more efficient use of seaports and more economical crossings. Perhaps the most important strategy has been that of load-leveling of demand across channels in different modes, such as shifting traffic off highways onto rail through major infrastructure projects such as the Alameda Corridor in Los Angeles that links the Ports of San Pedro (the busiest in the US) to the cross-country rail infrastructure.

The other major strategy for making more efficient and expeditious use of transport infrastructure has been redirection in the regulatory structure governing the various modes of transport. Liberalizing legislation has relaxed market entry and exit, increased freedom to set tariffs, permitted horizontal and vertical mergers, extended services, and increased competition within and between transport modes. The impact of deregulation has played out differently in each mode, but the general effect has been to increase interaction between modes and allow reorganization within modes.

The most powerful changes underway, however, have been in the aforementioned shift from communication's dependence on transport to transport's dependence on communication and information process. For most of human history, communications beyond the carrying power of the human voice was subordinate to the transportation infrastructure of the time. Written correspondence or other physical tokens had to be carried by the transport infrastructure from sender to recipient. There was some line-of-sight communications based on smoke signals, signal flags and semaphore, but generally communication could go no faster than transport conveyances. This dependence of communication on transport lasted until the development of electronically transmitted communication in the form of the telegraph in the mid 19th century. Communication was freed from its enslavement to transport, and subsequent developments in telephony and wireless broadcast of audio and visual signals brought about a revolution of enormous scope and scale. Communication became a separate world of enterprise. In some cases, it engendered substitutes for transport, as in the case of telephone calls and, more recently, video conferencing and electronic mail, as a means replace or supplement to face-to-face meetings. Of special importance to this story is the role communications, especially when coupled to digital information processing, came to play in the transport realm.

The telegraph enabled the railroad system, and the railroad system was central to the evolution of modern industry and commerce (Yates, 1986; Field, 1992). The railroad and the telegraph were essential complements in a powerful communication/transport nexus in which the physical infrastructure of the railroad enabled the telegraph right-of-way, and the infrastructure of the telegraph made the railroad manageable as an efficient and safe rapid-transit system. The nexus spawned secondary innovations, such as the publishing and distribution of written schedules of operation – departures, arrivals, and so on – vital for coordinating the movement of trains moving in opposite directions on single-rail lines. It also provided the means to get exception information, such as news of breakdowns or the travel of specials, down the line more rapidly than the trains themselves or written schedules could travel. From the rail era through the present, communications have become essential in coordinating every aspect of transport.

Information processing technologies have since emerged to play critical roles in physical process control, especially since the creation of the digital computer. Computer processors are now essential in many aspects of vehicle operation. This is most notable in avionics, but appears increasingly in visions of "intelligent" vehicles and highways. Less heralded but equally important has been the creation of technologies such as bar-coding and scanners that allow broader information processing networks to track and control passengers and cargo, and that are now being extended into radio identification tagging. Such systems have revolutionized the handling of documentation such as tickets, bills of lading, letters of credit, customs declarations, and so on. The importance of these developments was long buried in the "back offices" of transport firms, but it is now familiar in the sophisticated shipment tracking systems that enable time-definite delivery in the freight world, and in the computerized reservation systems that helped revolutionize the air travel industry. The goal of such systems is to make whole transport chains more "intelligent" so that they can operate effectively with greatly reduced labor inputs and at faster speeds.

Once again, however, this focus on improving performance of individual transportation modalities (e.g., road, rail, air) has not been fully successful. The average speed of transport in congested areas has been dropping, and although the technologies and techniques described above have arguably slowed the drive toward gridlock, they have not stopped it. The more radical strategy has been to move passengers onto alternative forms of transport – to go "intermodal." This is attractive for many reasons, but it requires a major increase in the coordination within and between the various transport modes. Of particular importance for passenger transport is the secondary infrastructure that allows the user – the traveler in this case – to operate the system. The most personal of transport modalities, the automobile/road system, has long had this in the form of maps, signage, driver training, on-air traffic advisories, and so on. The automobile/road system is comparatively simple to coordinate because the passenger/driver and can direct the vehicle expressly to his or her destination, as long as the road network goes there.

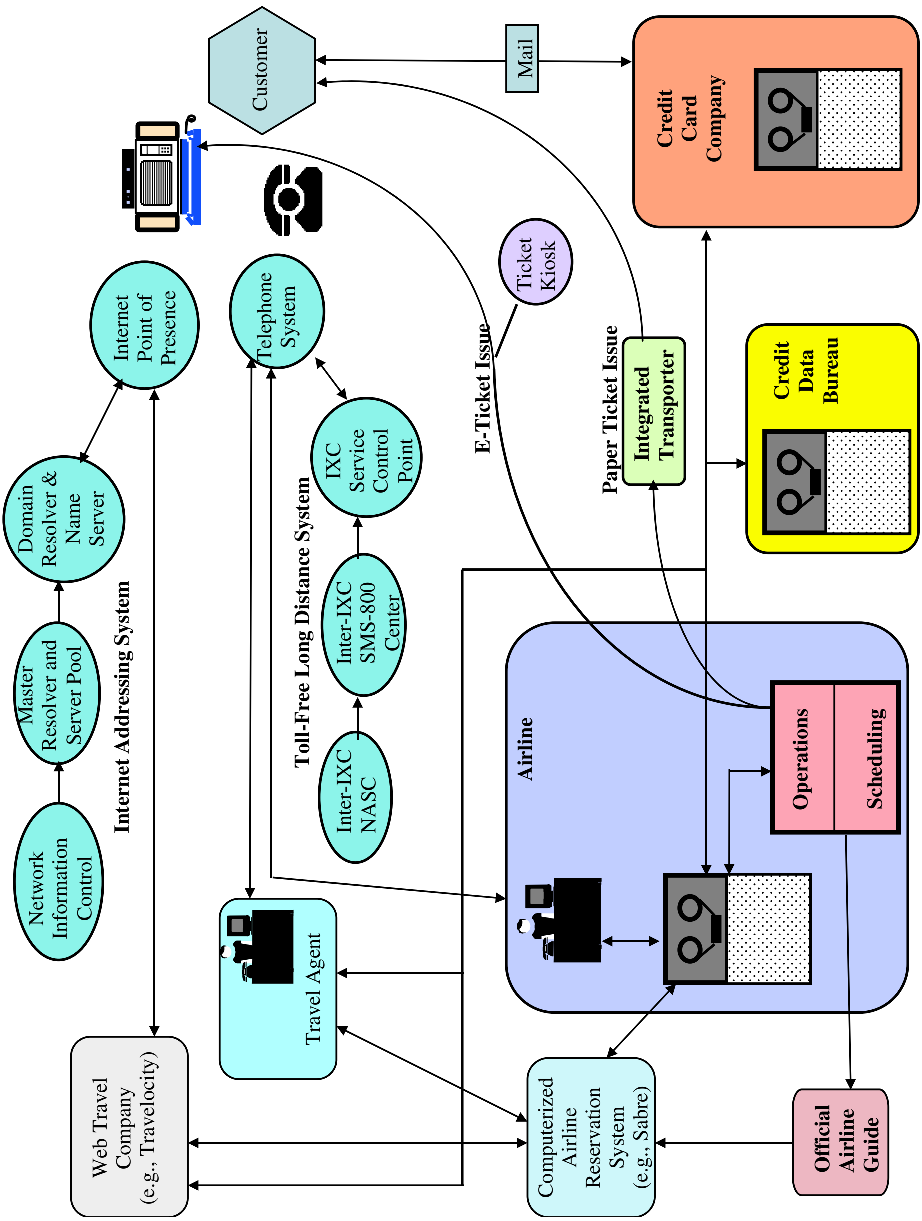

Figure 1. Internet addressing system.

The most serious difficulty facing substitutes such as buses, trains, shuttles, and so forth has been the challenge of helping the passenger make the right choices, in advance and underway, to enable the substitute to be as effective and reliable as the automobile/road alternative. There is much discussion of this possibility of using the global positioning system and portable computing technologies with wireless communications capability for this purpose, but it remains to be seen if this will work.

The transport infrastructure is increasingly like information infrastructure with respect to empowering the user. The guiding principle of common carrier communications (both telephony and radio common carrier) was to make the user into the operator of the system (Andeen and King, 1996; King and West, 2002). As noted above, this was accomplished by direct dialing, which expanded to direct distance dialing for long distance calls, and eventually to international direct distance dialing. That system subsequently expanded with digital switching to allow many different options for calling and billing using calling cards and other mechanisms, all controlled by the user from the terminal. Cellular telephony has extended this even further. Transport infrastructure has been going in the same direction. This is seen in all aspects of both freight and passage transport, but it is particularly evident in air passage transport. Virtually all aspects of air travel are moving into the control of the end user, disintermediating first the travel agents and, increasingly, airline personnel. Most major airlines have long provided reservations, booking, and ticketing via toll-free long distance telephony. Most now enable and encourage at users do these things on the World Wide Web. Many now issue boarding passes over the web or at computerized kiosks at the airport, and some are experimenting with the elimination of gate agents by having passengers self-scan their boarding passes prior to boarding. This kind of capability requires deep and varied infrastructures that are coordinated into an overall production system. With such capability, users can optimize their air travel for a variety of different objectives, from schedule-sensitive travel to lowest-cost travel, incorporating such incentives as frequent flyer mileage in the bargain.

The depth of this infrastructure is not easily seen because this infrastructure, like most successful infrastructures is invisible except when it breaks (Star and Ruhleder, 1996). To give a brief illustration of this infrastructure, consider the case of on-line reservations and booking. Figure 1 gives a highly simplified glimpse of the size and complexity of what's involved. The supply side of the air travel market is the inventory of seats aboard scheduled flights between commercial airports (city pairs). This inventory is a function of routes, frequency and timing of flights, and aircraft capacity. Further, the inventory is sensitive to dynamic pricing based on demand, with many flights exhibiting dozens of different tariffs for the same class of service based on options pricing (e.g., advance booking vs. last minute, refundable vs.

non-refundable, use of bonus premiums such as frequent flyer miles or promotions). This entire side of the enterprise is governed by three main components: the scheduling subsystem coordinated by the airlines and consolidators (e.g., the Official Airline Guide) and the CRS (computerized reservation system) infrastructure embodied primarily in just a few primary service providers (Sabre, Apollo/Amadeus, WorldSpan) that service most the airline and independent reservation/booking systems (e.g., Travelocity, Expedia, Orbitz) used by end users (Copeland and McKenney, 1988).

End users, in turn, gain access to these services over the telephone system using the public switched network and toll-free long distance calling system (SMS-800), or the Internet using internet service providers, the internet addressing subsystem, digital communications infrastructure for backhaul, and development/hosting services that create and maintain web sites. When users have chosen specific flights and wish to purchase tickets using credit cards (the only real payment mechanism in this realm), the infrastructure brings in the credit data reporting infrastructure to authorize the transaction. When the reservation is finalized, the inventory subsystem is updated (i.e., a seat on a specific flight is taken out of inventory and assigned to the user). Finally, the actual service – the ticket and the boarding pass – is delivered through automated mechanisms involving the Web, intranet-driven kiosks, or integrated packet forwarders (e.g., FedEx, USPS) when in paper form. Not only is this system amazingly complex, but it operates at huge scale. US airlines alone handle approximately 600 million annual passenger trips originating through this infrastructure. Even those trips booked using the traditional travel agent system use this infrastructure, because it supports the travel agents. A rapidly increasing proportion of travelers executed their whole itineraries using the network-based infrastructure that involved no direct contact with another person.

Many, perhaps most, uses of communication and transport infrastructure are in support of distributed practice by individuals, without significant collective dimension. Yet, the use of such infrastructure for distributed collective practice is more pronounced than might first be noticed. Members of organizations traveling to conferences are engaged in distributed collective practice. Similarly, sales and marketing professionals traveling for work are often engaged in distributed collective practice. Extended family members traveling to a wedding would be another example. What sets distributed collective practice apart from other kinds of practice is the fact that individuals act largely on their own recognizance to do things necessary for the accomplishment of larger, collective objectives. The infrastructure permits geographically distributed individuals to act independently but in a highly coordinated manner with their compatriots with respect to critical issues of scheduling, timing, and logistics. The overhead formerly placed on the individual participants to stay in close contact to achieve such coordination is absorbed by the infrastructure, empowering even resource-poor participants to participate in distributed collective practice in ways not formerly feasible. For resource-rich participants, it is possible to do much more with available resources.

Infrastructure that puts such power in the hands of individuals brings great benefits, but it can also be used for purposes beyond the original design. Unless the infrastructure itself or the oversight of human agents can discriminate between appropriate and inappropriate uses, the infrastructure empowers those who might perpetrate criminal acts. On September 11, 2001 ostensibly anti-modern terrorists turned the modern air transport infrastructure against those who created it. They used the infrastructure to gain access to fuel-laden commercial aircraft worth about $500 million, then appropriated and used those aircraft as cruise missiles to do direct damage in excess of $20 billion, and indirect damage (e.g., the ensuing wars) costing hundreds of billions of dollars or more. The terrorists did not have to design, build, or even launch these missiles. All they had to do was get aboard the missiles, take control of them, and exploit their power for ideological ends. The terrorists demonstrated the tremendous leverage that can be gained from infrastructure that enables distributed collective practice, provided that the infrastructure can be made to operate only slightly outside its design envelope. Interventions have been made since September 11 to prevent such events in the future, and it seems highly unlikely that the exact strategies used then could be used again with success. But note that it is not fundamental changes in the infrastructure that prevent a reoccurrence of the tragedy of September 11: that infrastructure is much the same as it was when the tragedy took place. Rather, the interventions are in the form of workarounds and redundancy regarding the "inputs" to the system – more careful matching of passenger to ticket and baggage, more detailed physical examination of what passengers are carrying, and so on. Perhaps the most interesting and often overlooked story of September 11 is the role of infrastructure for distributed collective practice that caused the failure of one in four of the terrorist missiles to reach its target. Passengers on hijacked United Flight 93 used cellular telephones to communicate with family members and friends on the ground who were, in turn, using ubiquitous communication infrastructure to follow the evolving story as it unfolded. Airborne cellular telephone calls are prohibited by the Federal Aviation Administration and the airlines, but they obviously work under some circumstances. This enabled the passengers on United 93 to grasp the larger scheme of the terrorists, and permitted a group of passengers to plan and execute a countermeasure that resulted in United 93 crashing in rural Pennsylvania instead of reaching the target the terrorists had in mind. The communication infrastructure enabled a completely unforeseen form of distributed collective practice that was, in effect, a kind of of error-checking and error-correction for the "failure" of the infrastructure in permitting the terrorist actions in the first place. This capability was not intentionally designed into the infrastructure, but was nonetheless enabled by it.

There are many other examples that might be gleaned from the current deployment and operation of the infrastructure of transport, and the capabilities of that infrastructure are growing all the time. Already, it is common for people attempting a rendezvous to dispense with detailed directions on where to meet, and rather, to use their cellular telephones to "vector-in" on one another using shared landmarks obvious to each once they are close enough to one another. When GPS technologies and extensive wireless communications are ubiquitously available in vehicles, it will not be long before geographically-contingent communications for everything from traffic direction (e.g., "slowdown ahead; execute this detour") to advertising (e.g., "steak dinner special at restaurant two blocks north"). It is important for those who are interested in distributed collective practice to make note of the fact that such infrastructural affordances are already heavily deployed and widely used to enhance such practices at this time. In the current experimentations with these affordances the likely trajectories of the future can be seen.

In closing, it is prudent to point out that some scholars of distributed collective practice might not agree that the kinds of transport coordination noted in this short paper really constitute the practices of concern. That is fair enough, and it is possible to limit inquiry to those distributed collective practices in which the participants are focused strictly on some shared objectives, such as the work of an engineering team or a fund-raising committee. However, this definition seems unduly narrow, given that most forms of intentional community activity are deeply dependent on transport and information infrastructure. At a deeper level, there is the philosophical question of what constitutes communication. It is easy to treat communication as limited to the interaction of those who have much in common, but sometimes communication is most critical among those with very little in common except for a small number of vital concerns. The naturalist Niko Tinbergen, who won the Nobel Prize in 1973 for his work in animal behavior, made particularly important contributions to the understanding of communications between predator and prey. One would think that predators and prey would not have much to discuss, and indeed they do not, but what they do discuss is of great importance to each. Insights such as this should guide future thinking about distributed collective practice.

Note

1. Passage and freight transport is estimated to equal between 15 and 17% of US GDP.

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