THE MOBILE–STATIONARY DIVIDE IN UBIQUITOUS COMPUTING ENVIRONMENTS: LESSONS FROM THE TRANSPORT INDUSTRY

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The emergence of ubiquitous computing offers new possibilities and opportunities for organizations attempting to improve their productivity and effectiveness. In particular, the promises of ubiquitous computing are attractive to organizations such as transport firms, in which coordination of diverse sets of mobile units is central to organizational performance. This article analyzes the use of ubiquitous transport systems in Swedish road haulage firms and discusses the opportunities and challenges for the early adopters. It pays specific attention to the mobile–stationary divide; that is, the set of challenges associated with integration of mobile and stationary people and systems into a seamless computing environment.

ACCELERATED BY RAPID DEVELOPMENTS

in mobile and wireless communication technologies and continuing miniaturization of computing devices, the emergence of ubiquitous computing offers new possibilities and opportunities for organizations attempting to improve their productivity and effectiveness (Lyytinen and Yoo, 2002a). In particular, the promises of ubiquitous computing are attractive to highly mobile organizations such as transport firms, in which coordination of diverse sets of mobile units is central to organizational performance.

In this article, we use an analysis of road haulage firms, a particular type of transport organization, as a mechanism to study the broader effects of ubiquitous computing on mobile organizations. The typical road haulage firm coordinates a workforce mainly consisting of drivers who are geographically distributed and constantly moving, providing timely pickup and delivery of goods. For a decade or so, continuous advances in mobile, embedded, and wireless technology such as global positioning systems (GPS), radio frequency identification (RFID), and embedded vehicle systems have enabled the development of a wide range of sophisticated applications supporting these daily activities (Akinci et al., 2003; Angeles, 2005; Giannopoulos, 2004; Roy, 2001). Tactical information technology (IT) support includes positioning of trucks and cargo, recording of performance parameters from the vehicle, and wireless communication of data from some or
Integrating traditional business and mobile computing with pervasive computing functionality into ubiquitous computing architectures is a critical challenge.

All of these tools. The positions of individual trucks can be displayed on maps, offering dispatchers a quick overview of the geographic distribution of the mobile resources. Route calculation done by the driver in the field or by the dispatcher is intended to minimize the cost of a transport assignment in terms of time and fuel expenditure.

Road haulage firms are an excellent example of an industry that is implementing a wide variety of distributed support tools to conduct its day-to-day business, and thus, seeking to interconnect various technological and social elements into an assemblage that enables physical and social mobility of computing and communication services (Lyytinen and Yoo, 2002a). We use the term ubiquitous transport systems (UTS) to discuss seamlessly integrated computing environments applicable to the transport industry. UTS can be described as a special case of a distributed and heterogeneous enterprise computing architecture intended to facilitate efficient and seamless integration of people and systems in a transport organization (March et al., 2000). Yet, there is limited theoretical understanding of how IT architectures can be designed to support core business activities of highly mobile organizations and how distributed computing and communication capabilities can enable such organizations to exploit resources and explore business opportunities. It is not obvious how the traditional logic of understanding IT infrastructures applies to the context of distributed and heterogeneous computing environments; thus, new experiences and insights based on a thorough understanding of the requirements of such environments are needed (March et al., 2000; Sambamurthy and Zmud, 2000).

To offer transport organizations seamless information integration and sharing in their everyday activities requires capabilities for integration of people, distributed and heterogeneous mobile and embedded technologies, and stationary transport business systems. As recognized in the literature, however, integrating traditional business and mobile computing with pervasive computing functionality into ubiquitous computing architectures is a critical challenge (Banavar and Bernstein 2002; Lyytinen and Yoo 2002b). Inspired by recent calls for IS research efforts targeted at the design, use, and impacts of mobile and wireless technology in organizations (Jessup and Robey, 2002; Lyytinen and Yoo, 2002a), we seek to understand required infrastructure capabilities of UTS (as seamlessly integrated computing environments applicable to the transport industry) and, through this example, the broader implications of ubiquitous computing technologies on organizations depending on distributed capabilities.

In view of this ambition, we have chosen to concentrate our efforts on knowledgeable managers in several Swedish road haulage firms. The rationale behind this approach is our aim to capture experiences and expectations of enterprisewide support in the Swedish road haulage sector through the lens of influential individuals likely to have the responsibility to ensure that IT investments produce long-term organizational value in their organizations. What we set out to capture is these individuals’ general notion of the role of UTS in the day-to-day practice of road haulage firms. On the basis of our empirical findings, this article discusses important insights related to infrastructure capabilities of UTS. Addressing infrastructure challenges in ubiquitous computing environments, the article contributes general managerial implications for organizations attempting to integrate mobile and stationary information systems.

This article proceeds as follows. First, it outlines infrastructure challenges associated with integration of technological and social components in ubiquitous computing environments. This is followed by a presentation of the research context and the method used. We then present expectations and experiences of enterprisewide support in road haulage firms. Thereafter, we discuss insights related to infrastructure capabilities of UTS. In addition, we also spell out explicit managerial implications for organizations attempting to integrate mobile and stationary information systems. Summarizing our findings, we highlight important venues for future IS research on ubiquitous computing environments.

**INFRASTRUCTURE CHALLENGES IN UBIQUITOUS COMPUTING ENVIRONMENTS**

The main purpose of enterprisewide support systems is to remedy the information fragmentation of function-oriented legacy systems (Davenport, 1998). This is typically achieved by incorporating functionality, similar to that of previous legacy systems, as modules in an enterprise IT infrastructure intended to support all business activities in one bold leap. Markus and Tanis (2000, p. 173) define enterprise support systems as “... software packages claiming...”
An effective ubiquitous computing architecture must thus be capable of identifying, adapting, and delivering the appropriate combination of stationary, mobile, and pervasive applications to the organization’s computing environment.

to provide a total, integrated solution to companies’ information-processing needs? Enterprise-wide support systems can thus be described as large-scale organizational systems containing “a set of packaged application software modules with an integrated architecture, which can be used by organizations as their primary engine for integrating data, processes, and information technology, in real time, across internal and external value chains” (Shang and Seddon, 2002, p. 272). As noted by Lee et al. (2003), the notion of integrated enterprise support reflects the capability of IT architectures to integrate a variety of different system functionalities.

IS researchers have gained considerable knowledge about forces and issues influencing the design of effective organizational architectures. As recognized by Sambamurthy and Zmud (2000), however, this accumulated wisdom may be inadequate for understanding the requirements of contemporary business organizations demanding information processing capabilities that enable and facilitate management of dispersed operations, dynamic business partnerships, and integrated supply chains. Facilitated by recent advances in Internet technologies, portable information devices, and high-speed wireless communication services, these business environments are increasingly heterogeneous and distributed, requiring hybrid, best-of-breed, and adaptive architectures and platforms that provide scalability, flexibility, and openness to emerging mobile and ubiquitous technologies (see, e.g., Sambamurthy and Zmud, 2000). A key challenge for IS researchers is thus to generate appropriate insights for how to construct distributed and heterogeneous computing environments, enabling the utilization of computing capabilities with which organizations can address core information processing problems and opportunities (March et al., 2000).

According to Lyttinen and Yoo (2002a, p. 378), a ubiquitous computing environment can be portrayed as a “heterogeneous assemblage of interconnected technological, and social, and organizational elements that enable the physical and social mobility of computing and communication services between organizational actors both within and across organizational borders.” Fundamental characteristics of a ubiquitous computing environment are high levels of mobility, services, and infrastructures, and the diverse ways in which data is processed and transmitted. Whereas services refers to the application of the infrastructure resources to provide a computational solution to a client’s requirements, the infrastructure concerns technological specifications, standards, and protocols and their technical implementations, and institutions and communities critical for developing and sustaining such standards and technical implementations (Lyttinen and Yoo, 2002a).

The shift toward ubiquitous computing environments will render multiple novel technological, social, and organizational challenges (Jessup and Robey, 2002). At the technology level, for example, a main challenge originates from integrating traditional business and mobile computing with pervasive computing functionality into ubiquitous computing infrastructures (Banavar and Bernstein, 2002; Lyttinen and Yoo, 2002b). At a general level, traditional business computing can be described as computing taking place in fixed physical sites. In contrast, mobile computing is about increasing people’s ability to physically move computing services with them. Reflecting the idea of computers having the ability to act “intelligently” relative to its surrounding context, pervasive computing is about computers being able to obtain information from the environment in which they are embedded and use it to dynamically build models of computing. An effective ubiquitous computing architecture must thus be capable of identifying, adapting, and delivering the appropriate combination of stationary, mobile, and pervasive applications to the organization’s computing environment.

As recognized in the literature, at least three infrastructure challenges are associated with integration of both stationary and distributed social and technical elements as effective components of ubiquitous computing environments (Lyttinen and Yoo, 2002a; Lyttinen and Yoo, 2002b). These are as follows:

- Providing infrastructure support for applications effectively using context information to provide organizational awareness of coexisting stationary and mobile computing environments (Dey et al., 2001). Indeed, a clear understanding of context is critical in organizational attempts to create such awareness.
- Design, integration, and maintenance of a seamless assemblage of stationary information systems and highly distributed and heterogeneous mobile and embedded computing resources with high degrees of interoperability, scalability, and reliability (March et al., 2000). As noted by Lyttinen
and Yoo (2002a), “we can predict that information management in organizations will hit a new wall of complexity when organizations migrate to mobile environments.”

Developing infrastructure support, facilitating local as well as remote interactions between people and technologies (Luff and Heath, 1998). In this context, for example, it is important to find a good balance between technologies supporting asynchronous and synchronous collaboration among both stationary and mobile workers.

Viewing this literature review as a theoretical backdrop for the research problem, we can understand UTS as a heterogeneous and distributed computing environment intended to facilitate traditional business, mobile, and pervasive computing resources in transport organizations that share information and interoperate seamlessly. Thus, studying managers’ expectations and experiences of UTS, we are likely to gain important insights addressing general challenges related to integration of both stationary and distributed technological and social components in ubiquitous computing environments.

RESEARCH CONTEXT AND METHOD
The Anatomy of Swedish Road Haulage Firms
Road haulage firms typically transport some kind of goods from one place to another, using trucks. At first glance, these organizations appear to be similar, dealing with the same slice of reality often in similar ways. The most obvious example suggesting such similarity would be that trucks, drivers, and transport activities constitute the core of the organization. However, the road haulage business sector is far from homogeneous in that core business activities, organizational structures, and size vary. Road haulage can be characterized as a diversified line of business, covering both local distribution of goods requiring loading and unloading several times each day and long distance transports for which it can take days between loading and unloading. Accordingly, the nature of work differs, ranging from rather static work in which transport activities can be planned ahead to dynamic situations in which assignments have to be communicated to the driver during the day.

Regardless of the actual setup in different organizations, a number of roles are typically found in a road haulage firm: dispatcher, driver, management, administrative personnel, and vehicle maintenance personnel. Dispatchers handle the incoming assignments and organize drivers and trucks, being the key resources involved in transporting goods. Drivers transport goods, which involves loading, unloading, driving and planning the routes, as well as interacting with clients. Managers are responsible for economic planning and followup. Administrative personnel handle tasks such as wages and invoicing. Finally, there are personnel involved in activities such as vehicle maintenance, supervising of fleet status, service time scheduling, and tire changing. The borders of these task-related roles are fluid. Depending on the business size, the same person can have more than one role or several persons can have a similar role. The larger the organization, the more specialized personnel you are likely to find.

According to the Swedish Road Haulage Association, in the late 1990s almost 90 percent of their members operated approximately five vehicles, indicating that most Swedish road haulers are small firms. Currently, the Swedish transport industry is experiencing changes caused by the European Union’s open market. For example, foreign transport firms have increased their haulage share considerably, which is a direct result of lower costs in nearby countries (15–20 percent lower in countries such as Denmark, Germany, and the Netherlands, and 30–40 percent lower in countries such as Poland). This cost disadvantage has resulted in minimal profitability margins for small and independent road haulage firms. In this context, contractors of haulers such as Danzas and Schenker have strengthened their market positions.

Analogous to counterparts in Europe and North America, Swedish road haulage firms are implementing different types of IT support to improve their competitiveness (Roy, 2001). However, as noted by Williams and Frolick (2001), the size of transport organizations is an important factor in that it determines the available amount of resources for procuring and administering IT support. Whereas UPS spent approximately $1 billion (USD) annually during the 1990s, smaller companies do not have and cannot afford to invest this amount of money to secure the same technical advantage. As a practical implication, Swedish road haulage firms rarely can afford to develop a custom-built system, forcing them to consider the various off-the-shelf solutions available. Yet the wide variety of business activities in road haulage firms can make this choice complicated, especially for small organizations. Nevertheless,
it seems that road haulers try their best to overcome such struggles associated with implementing diverse technologies, indicating a desire to explore the potential benefits adequate system support could bring.

**Research Cases and Methods**

The primary method of data collection for this study was semistructured interviews, lasting between one and two hours, with key business and technology managers in 12 road haulage firms in the fall of 2002. We selected these firms based on recommendations from the Swedish Road Haulage Association, representing approximately 11,000 road haulers with some 30,000 vehicles and machines. Whereas all of these organizations used IT support as a means for improved business performance, they were diverse in terms of core business, structure, external relations, and size. Our data collection was also informed by an IS literature review in a search for research contributions addressing enterprise architectures in highly mobile organizations. This review included top IS conferences and journals and covered the period between 1990 and 2004. More details about our research methods and descriptions of the 12 case studies can be found in the appendix.

**THREE MAJOR IT SERVICE CHALLENGES**

Three major IT service challenges identified from the interviews with the 12 road haulage firms are discussed, along with selected quotations from the managers we interviewed. (The appendix contains brief descriptions of the organizations referred to here by letters only.)

**Improve Mobile Resource Evaluation**

As noted by the respondents, management of an inherently mobile workforce and equipment is a delicate issue in the road haulage business. Addressing this issue, several managers saw technology as a means not only to get a better view of the field of operations, but also to enforce and evaluate company routines and policies (organizations D, E, I, J, and L). Technologies such as GPS and embedded vehicle systems were seen as enabling technologies to make visible the consequences of patterns of action in a wide variety of field activities. This includes information about activities of human actors as well as information pertaining to the mobile equipment; that is, trucks and associated hardware. An illustrative example of the former is the reports created by drivers stating their working hours. In fact, most of the road haulage firms included in the study used dedicated IT support for the actual wages calculation. However, a recurring topic among the respondents was the difficulty to check if the reported working hours were correct. Potential problems associated with the privacy of the drivers seemed important; however, although such aspects were acknowledged, the benefits were assumed to outweigh the potential social problems that may arise. The following account from the manager of organization E depicts the experience of an embedded vehicle system capable of monitoring driver activities:

The main reason why we invested in onboard computers was the reporting of working hours. […] Most drivers are really good at reporting, but you know, fifteen minutes here and there. Fifteen minutes a day per employee and year amounts to quite large sums. We’ve had drivers reporting both seven and eight hours extra per week. […] We can see when they have started [working] and we think that it’s good because it’s fair on the drivers. I think that those who have nothing to hide have nothing to fear.

Interestingly, managers from organizations E and L claimed that this embedded technology was also beneficial to drivers in that such systems offered them an opportunity to check detailed records for errors. The manager from organization E said:

This only makes it easier for them [the drivers]. They don’t need to worry about anything else than pushing these buttons. Then they get a list that they check before the salary is paid. If there’s a discrepancy, they can point that out.

Considering driver-vehicle interaction, many of the managers interviewed highlighted challenges related to the use of technology support for minimizing fuel consumption. In particular, sustaining an approved driving behavior was viewed as difficult, because drivers frequently reverted to undesirable habits. There was also an experienced tradeoff between carrying out assignments as quickly as possible and driving as economically as possible. Several systems vendors offer dedicated applications to provide drivers with instant feedback on driving performance, thus constantly enforcing company policies. Presenting
this information to management, these systems also facilitate managers’ or dispatchers’ monitoring of individual drivers’ performance, further strengthening the control of driver behavior. However, as recognized by our respondents, the outcome of field activity in terms of fuel consumption and related costs are a combination of human and machine performance.

Technology support for monitoring vehicle performance was a topic discussed by several respondents (B, D, J, and L). Because road haulage is a resource-heavy business, maintenance of vehicles is crucial. Embedded vehicle systems target precisely this, because they in essence make the equipment itself convey its condition. The ability to correctly plan maintenance to avoid costly breakdowns or untimely rescheduling is vital, and stationary systems geared with planning and follow-up features, as discussed by the manager of organization D, were used by many:

We have a really good maintenance program now. You put in anything you want and you get service orders, when the vehicle is up for service and testing and so on. And you also get a lot of historical accounts of costs, like if some vehicle is expensive regarding tires or fuel or something. That’s really good actually. The next step might be to connect it directly to the vehicle, as Volvo and Scania are doing, so that you don’t have to feed all this data into it. That’s excellent.

In this case, knowledge of the possibility to employ embedded vehicle systems to automatically record and receive maintenance-related vehicle data raised the expectation of further improvements by reducing manual handling. However, few respondents saw any immediate feasibility of such improvements. This was attributed to the fact that most road haulage firms had a mixed fleet of trucks. Discouraged by incompatibility issues between different embedded vehicle systems for different truck brands and associated stationary systems, most of the interviewees did not intend to invest in such technology.

Beyond the evaluation of drivers or vehicles, assemblages of technologies (such as GPS, mobile communication, embedded vehicle systems, and office systems) were seen as enablers of detailed and timely followup on field activities directly connected to business goals. Generally speaking, the distributed mobile nature of road haulage firms makes it difficult to assess organizational performance in detail; that is, the net profit of individual assignments. To accurately gauge the performance of drivers and vehicles, managers relied on dispersed sources of information in disparate formats, ranging from computerized information to paper documents. Not surprisingly, respondents frequently lamented the difficulty of planning future action based on incomprehensive, dated, and imprecise information on internal performance (C, D, E, F, J, and L). However, discussing the relations between embedded vehicle systems and stationary business systems, the manager of organization E illustrated an awareness of the great potential of the two combined:

I think that when you have access to all these statistics [in a system], you could find informative ratios. You earn less on some transports, of course, but it would be interesting to see. If you get a comprehensive view of the costs, including working hours, then you can see how capable and efficient a driver really is. You need to include the cost of salaries when you calculate how profitable a transport is. Costs for service and repairs should also be included, because you need to see when the vehicle is becoming expensive, when it gets unprofitable.

Essentially, this support requires joint contextual information on both driver actions and vehicle performance coupled to the stationary systems. However, none of the road haulage firms in the study had been able to accomplish fully such computational support, connecting cost to income. There was also widespread concern about the difficulty involved in interpreting contextual data for evaluation purposes (C, E, F, G, H, and L). Using fuel consumption as an example, the manager of organization E highlighted the need for comprehensive information to obtain meaningful metrics on driver efficiency:

Fuel consumption [data from an embedded vehicle system] is nice to have. But it varies depending on what kind of trailer the driver has attached, the tires he has and which route he drives, and the like, so it is very hard to get a just picture.

Arguing that an acceptable representation of field activity largely depends on the specifics of the various environments, several managers
considered simplified context parameters to be of limited use.

**Facilitate Seamless Transport Data Management**

Furthermore, technology as facilitator of seamless transport data propagation by automating presently manual tasks was a frequent topic of interest among the respondents. A primary concern was the amount of time elapsed from completion of a transport assignment to invoicing. Without the assistance of reliable wireless communication, invoicing was generally not possible until the driver returned to the office with the required documents. Depending on the character of the assignment, this could take days. Interviewees frequently mentioned the detrimental effects of delays in this process on the cash flow of the firm. In addition, manual handling of such documents was demanding in terms of personnel (A, B, D, E, G, I, and K). Indeed, such documents went lost at times. Expectations of the gains of technology were high in this area, and the manager from organization G regarded this as the main reason to invest in mobile IT:

> Why do we need this type of system? So that we can send the bills earlier, that’s why. That’s the only reason; otherwise we can use pen and paper. We want to send the bill as soon as the transport is carried out, that’s where we can make money. The rest of the system is not very important just as long as it makes us able to bill five to ten days faster. If we can shorten the invoicing time five to ten days, the investment in a system would not be a great burden.

However, according to some respondents, there is a common lack of system integration involved in handling transport data (A and E). With separate systems, time-consuming and error-prone manual input or transfer of data was required. In the following quote, the manager from organization E expresses his frustration over the fact that the main customer’s order handling system was not integrated with the local cargo planning system, forcing dispatchers to manually transfer data between the two systems:

> We cannot sort of connect [the system] by pushing one button, export [data] from the transport order system to the cargo planning system … this must also be possible to do. So far we can only read the orders, print them, and then we enter the orders into our cargo planning system manually.

Pursuing a strategy of selecting an assemblage of mobile and stationary systems to facilitate seamless transport data management from a best-of-breed perspective was considered problematic (A, D, E, G, J, and K). According to the managers who had tried such a strategy, vendors frequently claim that the best solution is to implement their full systems suite, regardless of the vendor’s core competence. This was not necessarily the opinion of the road haulers, who wanted the best technical solution available for each and every organizational function, be it stationary or mobile. The manager from organization K discussed personal experiences of that nature regarding a primarily mobile systems vendor:

> They have been confined to their own world. I mean, if we’re to have something in the truck, it must be something that we can adapt to what we have in the office … our traffic control system. They have been unwilling to do that and have suggested that we should use their stuff both in the vehicles and in the office, and that has not worked for us.

Although technology was attributed the ability to facilitate seamless transport data management, existing problems associated with the integration of both mobile and stationary systems were seen as prohibitive. A contributing factor asserted was the complexity created by unresolved problems related to standards and specifications of mobile and stationary technologies, making advanced solutions too complicated to realize. As a consequence, the vision of an uninterrupted flow of information between distributed workers and office personnel was at best only partly realized.

**Rationalize Dispatcher–Driver Communication**

A key aspect in road haulage is the communication involved in the execution of transport assignments. Information about assignments must be transmitted from transport buyers to dispatchers, between dispatchers and drivers, and from drivers to goods receivers. In many road haulage firms, much of this interaction is still handled by phone. However, several respondents considered this heavy telephone usage both stressful and time consuming (A, D, H, I, K, and L). Describing the current situation at
his firm’s dispatch office, the manager of time-consuming and error-prone organization D pointed out the potential increase in efficiency by reducing dispatchers’ verbal communication with drivers:

There are many incoming calls to the office, which is problematic. Not only do the drivers call but also customers and contractors of haulers and what have you. It can be quite overheated there. So, although it sounds strange, the idea is that we try to talk to the drivers as little as possible … just so that the situation becomes both effective and manageable.

Technology was perceived to have the ability to address this communication overload in two ways. First, technology was assumed to have the potential to reduce verbal communication through the transmission of formalized messages (A, D, I, K, and L). One problem associated with verbal (i.e., telephone-based) communication is dispatchers’ time spent failing to reach drivers already engaged on the phone or working outside the truck. By sending text messages, dispatchers need not rely on synchronous verbal communication. Written data was also perceived to be more exact than spoken messages, thus reducing potential misunderstandings. As illustrated by the manager of organization A, facilitating this type of communication between dispatchers and drivers was important:

[It is important] to get the orders out and communicate with the drivers in an easier, smoother way so that the communication involved in dispatching becomes easier. They [the dispatchers] are spending two hours a day talking to the drivers using mobile phones — get rid of that. Dispatchers are really stressed these days and we need to reduce their workload.

Second, technology was attributed the possibility to entirely eliminate the need for verbal communication in certain types of information gathering (A, I, L, and D). Before communicating new transport orders to drivers, dispatchers need to gather information that is vital for the allocation of assignments (e.g., the location of individual trucks and drivers). In contrast to the transmission of formalized messages, which still demands limited human interaction, joint positioning technology (i.e., GPS), mobile transport management systems, and embedded vehicle systems facilitate automated transfer of information from vehicle to dispatcher. In this way, the mobile context would be at hand at all times to the stationary actors. According to the manager of organization D, this would certainly play a part in increasing communication efficiency on behalf of both dispatcher and driver:

A dream would be to have a complete map over the whole district. Then you could see the vehicles, how they move, and how much cargo they carry. That would have been perfect; it would make their job so much easier. Although you can never replace humans, a lot can be done to assist a person in taking decisions and making choices.

However, the respondents also saw limitations to the rationalizing potential of technology. Although system support for data transfer between office and trucks was believed to reduce phone communication between driver and dispatcher, some interviewees argued that such technology would not make verbal communication redundant (A, I, J, and K). First, the respondents assumed that some forms of communication do not fit into the format of formalized messages (i.e., discussions and complex questions). Second, road haulage firms have communication needs crossing the boundaries of their own organizations. Whereas transport buyers transmit information to dispatchers, drivers contact the client at the delivery site before arrival. As noted by several managers, external communication partners cannot be supposed to share a system for electronic data transmission. The manager from organization A said:

The clients demand that he [the driver] can call when under way. I would say that they call three or four clients out of ten. Regardless of what kind of mobile communication system we get, they can never manage without the mobile phone.

Thus, in spite of the rationalizing potential of system support with regard to communication, respondents asserted that drivers will always need mobile phones for certain forms of communication.
Indeed, we believe our lessons learned from the transport industry are applicable also to general infrastructure challenges in ubiquitous computing environments.

DISCUSSION: THE MOBILE–STATIONARY DIVIDE
Integration Challenges
In this research, we studied infrastructure capabilities of UTS in Swedish road haulage firms to gain insights about the relevance for general infrastructure challenges in ubiquitous computing environments. Clearly, our respondents’ expectations regarding technology support were high, and they assumed a positive impact on several key business activities. However, as noted, the organizations studied were diverse in terms of size, core business, and external relations. Whereas differences in core business seemed of limited importance to the expectations of our respondents, size was a frequently mentioned deterrent in terms of technology investments or in-house development. More important, the nature of external relations coupled with the frequent reactive stance to various technology investments affected expectation levels with regard to UTS service requirements. Elaborating on integrated computational solutions to the service requirements of their firms, the interviewees foremost saw technology support as a means to improve mobile resource evaluation, facilitate seamless transport data management, and rationalize dispatcher–driver communication. Although these requirements are not claimed to be exhaustive, they indicate a desire for organizational and technological integration of people as well as the systems they use.

However, as is evident from our study, well-functioning best-of-breed mobile–stationary assemblages are difficult to accomplish. In the quest for a total solution to the service requirements of road haulage firms, specific challenges concern the integration of people, distributed heterogeneous mobile and embedded technologies, and stationary transport business systems. Typically, stationary office systems increasingly target mobile resources (drivers and vehicles), thus extending their reach. Correspondingly, mobile systems target the stationary part of the organization, offering opportunities for surveillance and evaluation. As highlighted by our respondents, however, road haulage firms were unwilling to embrace mobile system vendors’ solutions for both mobile and stationary parts. Instead, they had to seek assemblages of mobile and stationary systems originating from very dissimilar sources.

As a result, services offered by mobile and stationary system vendors were typically implemented in parallel rather than integrated. In effect, the organizations included in our study were at best marginally successful in their attempts to integrate mobile and stationary people and systems into a seamless computing environment.

Overcoming the Mobile–Stationary Divide
Despite these negative experiences, attributing to technology the ability to seamlessly interconnect various technological and social elements, respondents in several of the organizations were determined to overcome what they experienced as a mobile–stationary divide. In what follows, we highlight challenges surrounding mobile–stationary assemblages that transport organizations must tackle in efforts to efficiently use existing transport business systems while adding mobile technologies that exploit additional opportunities. Indeed, we believe our lessons learned from the transport industry are applicable also to general infrastructure challenges in ubiquitous computing environments.

Because road haulage firms are constituted mainly of a distributed and constantly moving workforce, they are well aware of the potential opportunities residing in technology support for mobile resource evaluation. Such technology support is receiving much attention from system vendors, and commercial service packages are available. Although beneficial for dispatchers and management, to monitor the digital traces of distributed working activities in this way raises the delicate issue of supervision on behalf of the drivers. Indeed, our study indicates a concern among road haulage firms about the potential effect on drivers’ attitudes toward system support and their organizational commitment. This dual nature of ubiquitous technologies on one hand supporting work processes and on the other hand facilitating surveillance of employees is a topic previously addressed by, for example, Jessup and Robey (2002).

Furthermore, designed to bridge the gap of geographical dispersion and mobility, sophisticated embedded vehicle sensor networks make sources of potential knowledge available for road haulage firms. More specifically, formalized assignment processing within the confines of an integrated computational solution, combined with automated instant retrieval of vehicle performance data, facilitated by wireless communication ensure constantly updated sources of timely information. In filtering and combining these sources of information lies the potential of increased understanding of the
Merging mobile and ubiquitous computing with stationary business computing will thus pose specific challenges.

organization (Jessup and Robey, 2002). However, arguing that an acceptable representation model of field activity is heavily dependent on the specifics of the various environments, several managers considered simplified context parameters to be of limited use. Furthermore, the perceived need for interaction between mobile and stationary actors highlights the situated character of context creation in organizational settings.

Indeed, in the attempts to achieve a mutual understanding of the context of everyday actions in organizations reveal that the nature of context and its encoding are challenging questions (Dourish, 2004). Hosting a combination of stationary, mobile, and pervasive applications, ubiquitous computing architectures potentially grant stationary actors detailed digital traces of mobile work; not only through positioning technology, but also via embedded sensor networks and similar technologies. The interpretation of this newfound organizational context awareness is far from obvious, considering the difference in work practice between mobile and stationary actors. Our first managerial implication is thus, that the meaning and use of new context information will have to be negotiated in organizations.

A significant reason for road haulage firms to invest in technology support is the promise of improved efficiency by automation, facilitating seamless processes throughout the organization. The rationale behind most enterprisewide infrastructure implementations is to eliminate manual keying of data from one system to another. As our study verifies, recent technological advances have brought such promises also to highly mobile transport organizations. In the road haulage context, there are high expectations of new services promoted to greatly reduce the human effort in dispatching, invoicing, and auditing by ensuring an unbroken and streamlined flow of information throughout a cross-functional, geographically dispersed process. The great potential of technology as facilitator of seamless transport data propagation (by automating presently manual tasks) was a topic highlighted by many respondents. However, existing problems associated with the integration of mobile in-vehicle telecommunication services for order management and stationary transport order systems in the office were seen as a major barrier. Consequently, as asserted by several managers, the vision of an uninterrupted flow of transport data between mobile and stationary actors was at best only partly realized in the present situation.

Analogous to most distributed computing environments, a critical factor was the diversity of data and information formats used (March et al., 2000).

In the current situation, several unresolved technical issues exist regarding the development of UTS with the capacity to meet the service requirements of transport firms. Geographically dispersed ubiquitous computing architectures for transport organizations will be technically complex in terms of the number of portable devices, embedded applications, databases, and systems involved, requiring a common platform of protocols and data standards to ensure systems interoperability and enable the integration of a plethora of distributed technologies. As our study indicates, this situation can be traced to rivalry and competition between various technological solutions, originating from diverse innovation regimes (Godoe, 2000). Merging mobile and ubiquitous computing with stationary business computing will thus pose specific challenges. Our second managerial implication is that organizations migrating to ubiquitous computing environments will not be able to manage the increased system heterogeneity without a supportive infrastructure and a sound organizational strategy. In particular, this requires an understanding of knowledge bases of mobile and stationary system vendors and the interactions between these actor groups.

Whereas verbal communication related to transmission of transport order data can be minimized, gathering of vital information can be performed without any form of human interaction (e.g., real-time positioning of vehicles), thus increasing efficiency. Our study shows that, compared to the telephone, alternative forms of communication technology such as in-vehicle support for message handling, although viewed as efficient, were also perceived as inflexible and limited to the confines of the organization. This finding suggests that workers in highly mobile environments may need to use older technologies (such as telephones) to complement their dependence on distributed message-based communication services (Jessup and Robey, 2002). Furthermore, managers in road haulage firms seem to focus primarily on the positive impact on stationary actors’ (e.g., dispatchers) work situation when considering the effects of improved efficiency.

It goes without saying that this tradeoff between efficiency and flexibility also entails social issues. The flexibility of verbal communication
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offers opportunities for spontaneous communication. Minimizing the need for instances of verbal communication is likely to reduce these opportunities. In a longitudinal study, Sarbaugh-Thompson and Feldman (1998) noticed tendencies of less organizational commitment in the long run resulting from electronic communication within an organization. This suggests that casual conversations facilitate organizational activity by establishing or maintaining relationships between dispersed fellow workers. In the context of transport organizations, increasing efficiency by reducing verbal communication may reinforce the solitary nature of drivers' work. In terms of attempts to integrate social and technological elements in distributed environments, this indicates a delicate balancing act of fostering efficiency while maintaining sufficient flexibility.

In attempts to deploy computer-mediated communication, transport organizations must investigate how mobile and stationary actors use electronic media in formulating and engaging in social action. In addition, they must also identify what types of electronic media enable and constrain specific types of action (Ojelanki and Lee, 1997). As suggested by our empirical study, the combined efforts of mobile and stationary work require flexible communication technology. Social complexity and flexibility is found on one end of the scale ending in augmented organizational efficiency. To be able to provide opportunities for flexible and rich communication in mobile–stationary assemblages, while rationalizing mobile–stationary communication, our third managerial implication is that organizations must consider a multiplicity of interaction media.

Table 1 summarizes the service requirements, infrastructure capabilities, and core managerial implications identified in this research.

**CONCLUSION**

In this article, we use the term UTS to discuss seamlessly integrated computing environments applicable to the transport industry. The article reports expectations and experiences of UTS in Swedish road haulage firms. A central issue in the quest for a total solution to the service requirements of road haulage firms is the mobile–stationary divide. We refer to the mobile–stationary divide as a set of challenges associated with integration of mobile and stationary people and systems into a seamless computing environment. Our lessons learned apply also to other ubiquitous computing environments that depend on the successful integration of both mobile and stationary technological and social elements.

Addressing general infrastructure challenges in ubiquitous computing environments, this article contributes explicit managerial implications for organizations attempting to integrate mobile and stationary information systems. The three managerial implications identified and discussed in the article are as follows: (1) the meaning and use of new context information will have to be negotiated among organizational stakeholders; (2) organizations migrating to ubiquitous computing environments will not be able to manage the increased system heterogeneity without a sound organizational strategy; and (3) the integration of mobile and stationary communication requires that organizational members have a multiplicity of interaction media available to them.

Organizations should not blindly rush into ubiquitous technologies. We recommend that managers first try to understand their business and needs for ubiquitous computing support, but they must not forget about the multifaceted challenges likely to surround attempts to integrate traditional business and mobile computing with pervasive computing functionality into ubiquitous computing architectures. Finally, further IS research is imperative to comprehend the challenges reported in this article. We encourage detailed studies of attempts to bridge the mobile–stationary divide by developing supportive infrastructures (involving heterogeneous, geographically distributed computing resources) that span far beyond the

<table>
<thead>
<tr>
<th><strong>TABLE 1</strong> Service Requirements, Infrastructure Capabilities, and Managerial Implications</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Service Requirements</strong></td>
</tr>
<tr>
<td>Improve mobile resource evaluation</td>
</tr>
<tr>
<td>Facilitate seamless transport data management</td>
</tr>
<tr>
<td>Rationalize dispatcher–driver communication</td>
</tr>
</tbody>
</table>


stationary parts of organizations. IS researchers are encouraged to study organizational consequences caused by the complexity created by such attempts to integrate both mobile and stationary technological and social elements into distributed architectures. Equally important is the need for studies addressing the changes in social action that the development of such ubiquitous computing environments is likely to render.

APPENDIX

The primary data collection method was a series of interviews with key personnel in 12 road haulage firms in the fall of 2002 (see Table 2). The Swedish Road Haulage Association, representing approximately 11,000 road haulers with approximately 30,000 vehicles and machines, recommended a number of potentially interesting member road haulage firms. These organizations used IT support as a means for improved business performance, but they were diverse in terms of core business, structure, external relations, and size. This diversity was beneficial in view of our attempt to understand the situation experienced by road haulage firms in general. Examining potential similarities and differences between organizations, we chose to interview influential individuals in leading managerial positions (business and technology managers). Due to the limited size and complexity of small- and medium-sized firms, managers are usually involved in every organizational process and tend to have a comprehensive perspective of organizational issues (Caldeira and Ward, 2002). Besides the managerial perspective of the interviewees, most of

<table>
<thead>
<tr>
<th>Case</th>
<th>Respondent</th>
<th>Ownership</th>
<th>Size</th>
<th>Business &amp; Regional Coverage</th>
<th>IT Support</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Managing director</td>
<td>Independent</td>
<td>35 vehicles</td>
<td>Recycling, waste disposal, some local less-than-truckload (LTL), and mobile construction equipment</td>
<td>Stand-alone transport management system; Searching for new management system with integrated mobile support</td>
</tr>
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<td></td>
<td></td>
<td></td>
<td>40 employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Managing director (Schenker)</td>
<td>Contractor dependent</td>
<td>45 vehicles</td>
<td>Regional distribution</td>
<td>Local access to Web-based order system with contractor; Dispatcher on site at contractor terminal with integrated transport management system; Basic credit-invoicing control system; Only one Mobitex-based mobile system; Awaits contractor or haulage association IT initiatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>50 employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Managing director</td>
<td>Independent</td>
<td>15 vehicles</td>
<td>Sea container goods (LTL); Operates in Nordic countries and Portugal; Manages a small terminal; Assignments from local contractor (DFDS) plus direct customers; Direct invoicing</td>
<td>Largely spreadsheet-based planning; Mobitex fax in one vehicle; Awaits others' initiatives and contractor demands</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>25 trailers</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>30 employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>Managing director (Danzas)</td>
<td>Contractor dependent</td>
<td>71 vehicles</td>
<td>Distribution and parcel delivery</td>
<td>Transport management system; Vehicles equipped with bar-code scanners integrated with contractor's systems; Mobitex-based mobile messaging system developed by contractor; Stand-alone maintenance/ environmental system; Reacts on contractor demands and initiatives</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>85 employees</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Case</td>
<td>Respondent</td>
<td>Ownership</td>
<td>Size</td>
<td>Business &amp; Regional Coverage</td>
<td>IT Support</td>
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</tr>
<tr>
<td>E</td>
<td>Account manager</td>
<td>Independent</td>
<td>20 vehicles 25 employees</td>
<td>Chemical transports for one customer&lt;br&gt;Operates in Scandinavia plus some continental transports&lt;br&gt;Credit invoicing</td>
<td>In-house-developed, stand-alone planning system&lt;br&gt;New in-vehicle computers in long distance vehicles&lt;br&gt;Web access to customer stock levels&lt;br&gt;Reacts to customer IT demands</td>
</tr>
<tr>
<td>F</td>
<td>Managing director</td>
<td>Independent</td>
<td>60 vehicles 70 employees</td>
<td>Parcel delivery</td>
<td>Limited use of transport management system for pricing and invoicing (integrated with pricing and invoicing systems)</td>
</tr>
<tr>
<td>G</td>
<td>Managing director</td>
<td>Independent</td>
<td>15 vehicles 30 employees</td>
<td>Mover Member of a road hauler network</td>
<td>Stand-alone transport management system&lt;br&gt;Simple Web-based costumer system</td>
</tr>
<tr>
<td>H</td>
<td>Managing director</td>
<td>Independent</td>
<td>26 vehicles 30 employees</td>
<td>Waste distribution, construction bulk, and parcel delivery (single customer)&lt;br&gt;Manages small terminal&lt;br&gt;Credit invoicing from contractor of waste distribution</td>
<td>Limited use of IT-support (automatic fueling system)&lt;br&gt;Previously sported vehicle Mobitex systems sponsored by parcel customer; now withdrawn&lt;br&gt;Reacts to customer demands</td>
</tr>
<tr>
<td>I</td>
<td>Site manager</td>
<td>Alliance with French postal services to expand range</td>
<td>3000 employees in 7 national regions&lt;br&gt;Local unit: 45 vehicles 75 employees</td>
<td>Distribution (pallets and parcel)&lt;br&gt;Manages a terminal&lt;br&gt;Credit invoicing</td>
<td>Previous use of Mobitex units; replaced by mobile phones&lt;br&gt;Drivers equipped with handheld devices for bar-code scanning for track and trace purposes&lt;br&gt;Little or no managerial drilldown support&lt;br&gt;Order management system integrated with central organization&lt;br&gt;IT support for route calculation and pricing</td>
</tr>
<tr>
<td>J</td>
<td>Managing director</td>
<td>Member of a local independent hauler association</td>
<td>12 vehicles 15 employees</td>
<td>Metal transports and recycle material&lt;br&gt;Regional&lt;br&gt;Long-term contracts</td>
<td>A few vehicles equipped with Mobitex units&lt;br&gt;Manually fed fuel and time control systems&lt;br&gt;No drilldown capabilities&lt;br&gt;Reactive stance to new IT investments</td>
</tr>
<tr>
<td>K</td>
<td>Account manager</td>
<td>Contractor dependent (Schenker)</td>
<td>100 vehicles 145 employees</td>
<td>Regional distribution</td>
<td>Transport management system integrated with contractor since 1993&lt;br&gt;Mobile communication of assignments since 1995 (Mobitex-based); currently SMS-based, but legacy remains in use (radio, old Applicom units)&lt;br&gt;Credit invoicing control system (partly Web-based)&lt;br&gt;Invests in response to contractor demands&lt;br&gt;Involved in a national road haulage association IT group&lt;br&gt;Transport system is a joint venture of contractor and hauler association</td>
</tr>
<tr>
<td>L</td>
<td>Transport manager</td>
<td>Part of an international organization</td>
<td>70 vehicles 100 employees</td>
<td>Household and industry waste disposal&lt;br&gt;Manages waste handling sites</td>
<td>Mobitex printers in vehicles, connected to vehicle scales&lt;br&gt;Mobile handheld units for bar-code scanning of bins and deviation reporting&lt;br&gt;In-house spreadsheet application for maintenance (fed by information from brand maintenance workshops)</td>
</tr>
</tbody>
</table>
these individuals also had previous personal experience as truck drivers or dispatchers, thus providing interesting information on these roles as well.

Intricate organizational interdependencies with substantial situational variations can be hard to identify using formal data collection methods (Walsham, 1995). Therefore, to acquire a rich picture of the actions and processes in the organizations, we used semistructured interviews, lasting between one and two hours, as the primary method of data collection. This technique can illuminate potential particularities of the individual organizational settings, by allowing forming and reforming of alternative questions as well as detailed explanations and interesting detours whenever necessary (Walsham, 1995). However, some structure is retained so that there is satisfactory correlation between the different interviews. The interview sessions were focused on the perceptions of technology in relation to seamless integration of diverse technologies, distribution of contextual awareness throughout the organization, and communication.

The interviews were recorded and later transcribed. During the analysis, the data was first examined for statements reflecting the respondents’ expectations and experiences of technology support and its implications for work and their organization’s processes. After this, we approached the data with an open mind, meaning that the data itself suggested concepts and categories. The concepts and categories were revised and refined until they sufficiently explained as much of the data as possible. Our empirical findings can thus be said to have emerged from an iterative and interpretive analysis of the collected data (Walsham, 1995).

In addition to our empirical efforts to capture experiences and expectations of enterprise-wide support in the context of the road haulage business, we also conducted an IS literature review to search for research contributions addressing enterprise architectures in highly mobile organizations. This review included top IS conferences and journals and covered the period between 1990 and 2004. Although our review indicated the scarcity of research efforts focusing on this topic, recent literature on challenges in heterogeneous and distributed computing environments has served as useful input in our quest to understand infrastructure capabilities of UTS.

References


