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Measuring the Consequences of Ubiquitous Computing in Networked Organizations

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Abstract
This paper discusses the challenges of measuring productivity impacts with ubiquitous computing environments (UIE). We note two specific challenges in measuring such environments: the networked and borderless nature of such technologies and the specific nature of change associated with the deployment of such services. Both of these make measuring the productivity impacts of UIEs challenging as measuring the consequences of UIE need to address complex causality, layered impact within a multi-level network, comprehensiveness of performance measures, and delayed impact detection due to slow and circular nature of the impact. In the paper we present a framework that offers a disciplined way to examine organizational and productivity consequences of UIEs. We will finish the paper by discussing some of remaining issues in studying UIE impact in organizations

Keywords: Ubiquitous computing, productivity gains, organizational consequences of IT.

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Measuring the Consequences of Ubiquitous Computing in Networked Organizations

Introduction

A *ubiquitous information environment* (UIE) forms an assemblage of interconnected technological elements that enables the mobility of computing and communication services (Lyytinen and Yoo 2002b). Ubiquitous computing[2] has been triggered by dramatic developments in mobile and wireless communication technologies such as WAP[3], Bluetooth™[4] and 3G mobile phones[5] (Cerf 2001; Kleinrock 2001), continued miniaturization of chips and computing devices and new software service models. Handheld computing devices such as personal digital assistants, digital mobile phones, or embedded chips and sensors will pave the way to the digitalization and integration of diverse sets of information services at personal, organizational and societal levels. Radically new types of computing devices and services will be offered that we call ubiquitous computing services. Such ubiquitous services represent unprecedented opportunities to access, manipulate, and share information with others on the move – *any time, any place, any person, any service, and any device*. Consequently, future organizations will offer a rich set of computing and communication capabilities and services to their employees (Kleinrock 2001).

Given the size and the scope of the business and social investment necessary to build robust UIE, understanding and possibly demonstrating the positive outcomes of the investment in UIE is of critical importance for both practitioners and scholars. One reason for this is the huge size of required investments to make these environments truly ubiquitous. Another is the promise touted in the press and professional literature that these new technologies will produce an unprecedented change in organizational productivity and capability. This is not news to anybody who has witnessed the reporting of information revolution over the past twenty decades- the jury is not in yet and what we know from the past is that the impact is going to be much more elusive and hard to pin down. Moreover, what we currently know of such impacts is meager and deals mostly with sociological studies of life-style changes among youth, and micro level studies of changes in organizational practices (e.g. Luff and Heath, 1998; Fagrell et al 1999). There are no careful and systematic studies of the productivity impacts on organizational or industry level. In addition, we know that a true understanding of the consequences of information technology (IT) has always been elusive, often couched in paradox and contradictions (Brynjolfsson 1993; Robey and Boudreau 1999).. There is not reason to believe that understanding and measuring the consequences of UIE will be less problematic.. In contrast, it will be more so for the following reasons.

[2] See for example http://www.technologyreview.com/magazine/jan01/buderi.aspThe Evolution of Computing, and http://www.acm.org/technews/articles/2001-3/0131w.html#item19, or its impact on the different industries denoted as "gadget wars" see http://www.acm.org/technews/articles/2001-3/0316f.html#item12.

[3] WAP stands for Wiress Application Protocol. It is an open global standard that specifies standards for mobile users information and service access. For more information, refer to http://www.wapforum.org.

[4] Bluetooth™ is a de facto standard for wireless communication among various devices in short to medium distance. For more information, refer to http://www.bluetooth.com.

[5] 3G refers to the third generation mobile phone systems which allow broadband access for enhanced wireless service. For more information, refer to http://www.3gpp.org.

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First, UIEs will be deployed in networked organizational contexts that span organizational boundaries in terms of space and time, as well as institutional borders. This is because many global companies rely increasingly on information technology that enable networked organizational structures to manage their operations (Ahuja and Carley 1999; Lipnack and Stamps 1994; Nohria and Eccles 1992). Therefore, to understand consequence of UIEs, researchers will need to examine their consequences at multiple levels and within multiple contexts *within* the work carried out in and enterprise and between enterprises. In contrast, most past research on the productivity consequences of IT (Brynjolfsson 1993; 1994; Hitt and Brynjolfsson 1996) has analyzed financial data only at the aggregated level of the firm and has not been sort out the impact of significance of new boundary breaking activities (work outside office, work outside organizational boundary) or changes at different levels of the work process. Firm level analysis is, of course, essential to understand the logic of economic returns for companies making investments in information technology, but this level of aggregation is too high to identify the effects of the new technology within and between work processes (Ichniowski and Shaw 2002). This calls for the use of the additional engineering measures to track performance changes at different levels within of the work processes (e.g., error rates, process delay, turn-around time and the average number of processes per hour per employee). By doing so we develop a more nuanced understanding how UIEs alter organizational practices and capabilities and thereby their productivity.

Second, UIEs are expected to fundamentally change the use of computing services in terms of time-space constraints when compared with traditional desk top computing. In the past the users had to be located in a largely constrained a specific time-space region (office hours, their desk). The amount and scope of services available in that region changed fundamentally as a result of Internet computing so that new information services, in principle *any service* offered in the Internet computing platform became accessible for stationary knowledge workers. This has resulted in significant transformations in the way work is organized including increased flexibility to allocate work among different sites and workers, increased information access with increased coordination capability, and the substitution of knowledge with fixed assets (lower inventories, better use of office space) (see e.g. Davenport and Short 1990). The introduction of the UIEs promise to radically relax the relatively fixed time-space constraints of computing regions (Lyytinen and Yoo 2002a) so that any service will become available at *any time and any place*.. This may add new capabilities and create new transformations including creation of placeless processes where organizations do not any more specify specifically geographical regions where the work gets done, or overcoming time constraints of some activities as the processes can be coordinated real time. Work processes may increase also in terms of level of information exploitation and intelligence as more intelligence can be embedded at the front line activity. While we remain critical of many of the much hyped *anytime-anyplace* promises of mobile technologies, we expect that the relaxation of time-space constraints in computing services with UIEs can potentially alter the fundamental dynamics of interactions in socio-technical systems. Past computing applications, and the way we measure their organizational consequences, have been developed with the assumption of fixed time-space constraints for computing activity which will now disappear. Likewise, the work practices and task processes in organizations have been developed over the last two centuries with the assumptions of fixed time-space constraints for information access. Yet, a mere investment on new pervasive technology *per se* will not bring about anticipated results without complementary changes in organizations as in their work practices and task processes as shown by our examples. These

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together may or may not result changes organizational performance. Some of these complementary changes can be anticipated and even planned, while some will be much more emergent and hard to envision beforehand.

These new challenges will demand us to critically re-examine current approaches to measure the value and consequences of computing in organizations. Measuring the consequences of UIE needs to address issues of complex causality, layered impact models within a multi-level network, comprehensiveness of performance measures, and delayed impact detection due to slow and circular nature of the impact. In the following, we present a framework that offers a framework to examine in more disciplined way organizational consequences of UIEs. We believe also that they help address these challenges in the future impact research. We will finish the paper by discussing some of remaining issues in studying UIE impact in organizations.

Research Framework

Figure 1 illustrates a proposed research framework to study the impact of UIEs in organizational contexts. It builds on and extends the existing research on the impact of IT in organizations and recognizes them as important contributors for theorizing about UIE impact. Over the past two decades, three primary lines of IT research have emerged in the literature to study IT impact. First, IT research examining human-computer interactions, computer-supported collaborative work, and other socio-technical design issues have looked at the technical design of IT artifacts and its co-determination of work processes and coordination mechanisms (in figure 1, it is A --> C) (Bellotti and Bly 1996; Luff and Heath 1998; Nunamaker et al. 1991; Shneiderman 1980). Second, behavioral IT research has looked at the relationship between technology and other organizational factors and their impact on organizational processes (A x B --> C)(Brown and Duguid 2000; DeSanctis and Poole 1994; Orlikowski 1992; Robey and Boudreau 1999). In this stream, the impact of IT on organizational performance and productivity has been seldom examined. Third, IT research drawing upon theories from economics and strategic management has focused on the relationship between the use of IT along with the deployment of other complementary assets and their combined impact on the organizational (firm) performance (A x B --> D) (Brynjolfsson 1996; Brynjolfsson et al. 1998; Clemons and Row 1991; Hitt and Brynjolfsson 1996; Scott Morton 1990; Weill 1992). In this last stream, internal changes in work practices and coordination mechanisms have been aggregated firm level investments decisions rather than studying the impact of changes at specific work and business processes within firms.

In the framework we seek to combine the valuable insights gained from each of these streams of research in order to address the impact of UIE adoption in organizations so that there is a possibility to obtain clear understanding of the changes in organizational performance and which mechanisms together produce this. Figure 1 offers a schematic representation of the unified model of the impacts of IT innovation how it emerges from this literature. Here, arrows A x B → C postulate a causal relationships between specific investments in IT capabilities and infrastructure and simultaneous investment and mobilization in complementary organizational assets and capabilities. These together produce new organizational practices, services and coordination mechanisms that are placeless, rely on simultaneous information access and awareness, or offer new types of business intelligence. These over time will lead to changes in

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organizational performance as shown by the arrows Ax C →D. Here the quality and accessibility features of the infrastructure together with the transformed organizational practices produce the changes in the organizational performance. There can be significant time lags in producing impacts through paths AxB→ C and AxC → D due to learning and appropriation barriers and the layered nature of the impact. We also assume that over time organizations learn and change their design and investment patterns. This is shown by dashed arrows which illustrate significant feed-back loops that operate within the organizational adoption of IT technology. These feedback loops introduce over time path dependency in adoption, appropriation, and organizational transformation. We will next elaborate elements of this model by adapting it to the specific context of evaluating UIE impact.

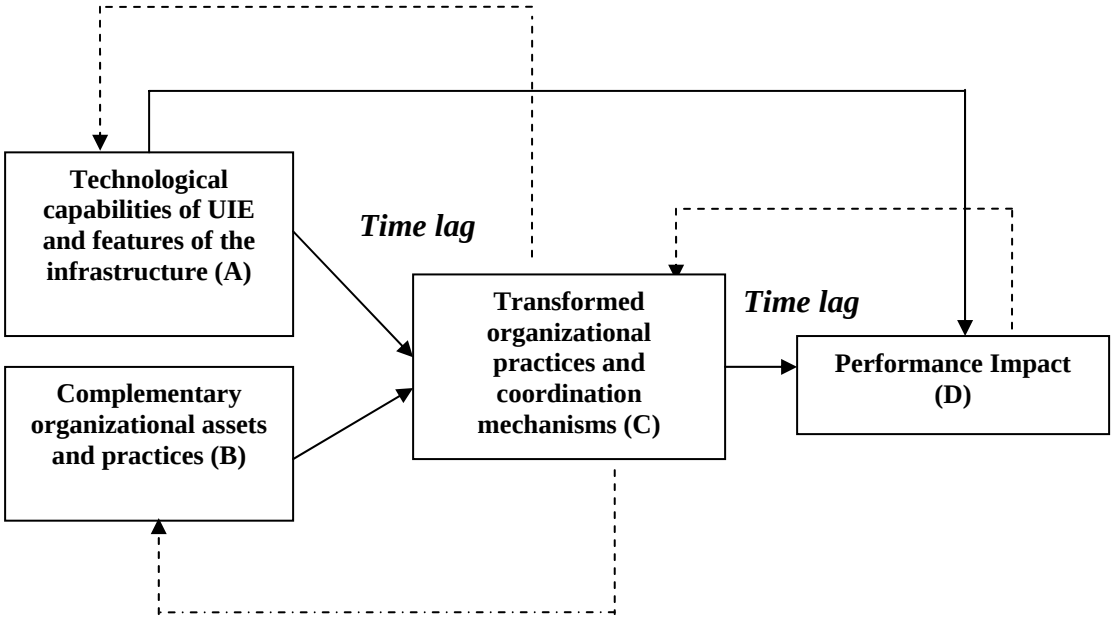

Figure 1. A Research Framework to study the impact of UIE technologies

What to measure: Specific research issues in UIE impact research areas

Figure 1 suggests four areas of analysis in UIE impact study: technological capacities and infrastructure development; investments in and mobilization of complementary assets and practices; transformed organizational capabilities, coordination and intelligence, and organizational performance.

A) Technological Capabilities: What technological capabilities and services are embedded in the ubiquitous computing environment?

The essential characteristics of a UIE are high levels of *mobility, large scale* services and infrastructures, and *digital convergence*, i.e., agreement on the diverse ways in which data are processed and transmitted (Lyytinen and Yoo 2002a). These three key drivers both influence and enable continuous developments in *infrastructure* and *services*. The infrastructure is defined

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here as a set of technological specifications, standards and protocols, their technical implementations necessary to support mobility, scalability of service and digital convergence, and the associated family of institutions and communities needed to develop and sustain such standards and technical implementations. The services here cover any functional application of the infrastructure capability in order to provide a computational solution to a client's needs.

We argue that when studying UIE impact one cannot examine this technology as a "black box," but rather as a dynamic set of capabilities, which range in terms of their convergence, scale and mobility features as well as the specific set of enabling functionalities that are embedded in the service. It is these specific families of functionalities and capabilities that are appropriated by organizations' members and become embedded into the settings of everyday work (Orlikowski and Iacono 2001). Specifically, we observe the following three sets of enabling capabilities of UIEs that underlie their transformative capacity: *automating; embedding*; and *connecting*. First, Automating eliminates mundane and repetitive tasks by capturing information from the business process without manual human intervention thus simplifying business processes, reducing errors, increasing the speed of information processing and offering new ways to organize work processes where information capture is not any more the focus[6]. The *any time, any place* capability of UIE's will move and embed such processes of information capture into localized background processes which draw upon local resources (Fano and Gershman 2002). By automating most of their repetitive business interactions organizations can expect significant productivity gains due to high volume of such transactions. Second, organizations can *embed intelligence and information processing capacity* into mobile services that are offered *at any time and at any place.* This will help them standardize organizational responses, amplify behavioral monitoring and offer better information support both through providing application services from organizations' backbone information systems or configuring localized computing resources to support specific organizational tasks (Fano and Gershman 2002). All these will increase over time organization's information processing capacity and help manage increased task complexity thus reducing slack (Galbraith 1973). Third, *any time, any place* services can connect mobile work force to the organizational processes in which they are embedded thus offering unprecedented means to local and more global information access and awareness of other actors' behaviors and capabilities. This *all the time connectedness to unlimited number of organizational actors* can provide new lateral capabilities and new mechanisms to coordinate tasks and monitor task outputs. We expect that these unique characteristics of UIEs will create novel transformations on organizational practices and coordination mechanisms.

These capabilities need to be socially embedded into the work processes in order to produce any changes in organizational behaviors and processes outcomes. Our framework, suggests that we must understand how technologies achieve such status and what types of organizational properties can strengthen these processes (Orlikowski 2000). Therefore, we need to develop a more refined model of technological capabilities that can be used to explain and/or align specific UIE capabilities into specific work processes which share specific features in terms of their time and space organizations and coordination requirements (for a early typologies of work processes see e.g. Lee and Sawyer 2002, Luff and Heath, 1998)[7]. Currently such a taxonomy of both UIE capabilities and work process characteristics is lacking.

[6] We do not have any specific studies of interactions between companies and customers but most of them are normally repetitive, boring and error-prone processes where customer is inquired about mundane information.

[7] For a similar approach as applied in GDSS research see for an overview of group decision support systems capabilities in Dennis et al. 2001)

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B) Complementary Assets: What complementary assets and practices must organizations mobilize to successfully deploy an UIE?

While UIE promise exciting new information processing capabilities to organizations such technological innovations will fail to contribute to organizational capability and performance (Orlikowski 1993a; b) unless organizations are *capable to appropriate them.* Therefore such process innovations must be carefully coordinated with the deployment and mobilization of other complementary. Complementary assets are resources (both tangible and intangible) in which organizations make investments in order to complement the successful deployment of a particular innovation. These include investments in human resources like teaching effective team-building or creation of other skills as well as physical capital such as new machinery and buildings (Brynjolfsson et al. 1998; Ichniowski and Shaw 1999; Ichniowski et al. 1997).. In the case of UIE such complementary assets include e.g. general computer literacy to use various devices, users' understanding of the capabilities and coordinative impacts of specific UIE applications, the general level of IT service deployment in the organization (e.g. e-mail, intranet). All these can be improved by training. Other complementary assets may involve investments in specific physical assets like new types of office and factory organization, new types of support functions for mobile work-force and so on. Many of these reflect the general management capability to invest and manage the deployment of UIEs and foster the overall IT capability of the organization

C) Transformed organizational capabilities, practices and coordination mechanisms

The third element in our framework is changed organizational practices. Organizational practices can be defined as emergent work practices and business processes that result from appropriating over time by organizations' members prior investments in UIE innovation and related complementary assets. These new transformed organizational practices will be outcomes of creating new forms of automating, embedding or connecting with the any time and any place capability of UIEs which changes the time and place parameters offering an organizational service or carrying out an organizational task. Developing a more complete analysis of a set of potential transformations is beyond the scope of this paper but such taxonomy of potential transformations offers a good starting point to develop a deeper understanding of UIEs transformative capacity. Hence any careful study of UIE impact should not only explore the final performance changes (D), but also the changes in organizational practices. The challenge, however, here is that, often such changes are incremental and unintended. Furthermore, such comprehensive measurement approaches mean mixed methodologies as will be noted below.

Studies of previous waves of information technology-driven innovation emphasize the central importance of understanding and investigating transformed organizational practices that govern coordination and knowledge sharing as a result of organizational change or IT investment (Crowston 1997; Galbraith 1973; Malone and Crowston 1990; Malone et al. 1987; Nadler and Tushman 1997; Thompson 1967). In line with this the current high expectations for UIE impact are based on a host of assumptions that organizations can and will readily redesign their work processes, coordination mechanisms, and knowledge creation and sharing processes to fully utilize the new features of the technology. Past research on IT implementation, however, points out that the changes in organizational work processes, coordination mechanisms and knowledge sharing may be slow to come, and many IT adoptions may have a different form and other

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consequences than were originally intended (Orlikowski 1992; Orlikowski 1993a; Orlikowski 2000; Robey and Boudreau 1999; Swanson 1994; Zack and McKenney 1995). Furthermore, emerging new practices and processes could sometimes be unintended and hidden (Orlikowski 1993a; b; 1996; Robey and Boudreau 1999). Hence, our research framework must be able to observe both "intended" and "unintended" changes in the transformative model of organizational practices.

D) Organizational Performance: How does UIE affect organizational productivity and performance?

The empirical literature on high performance organizations offers a preliminary model for studying the changes in organizational performance. These changes must be analyzed along two different dimensions. The first dimension recognizes the *types of performance changes* while the second recognizes the *level of performance analysis.*

Types of performance changes

Along the dimension of types of performance changes we will observe three types of changes. The first one views UIEs as productivity enhancing innovations (Dunlop and Weill, 1996; Ichniowski and Shaw, 1999; Ichniowski et al., 1997; MacDuffie, 1995; Osterman, 1994; Osterman, 2000). This suggests to measure of the efficiency of the organization's core (production) processes. These would include e.g. the efficiency of an operating room, the efficiency of delivering a packet by an integrated logistic integrator, or the efficiency of handling customer requests. Typically productivity enhancing measurements take the form of "down time" for capital intensive equipment, error rates, or rates of physical production such as garments sewn or calls handled per minute. 8 One of the opportunities offered by studying a new technology such as UIE is that IS researcher can analyze the "roll-out" of the technology.

The second level of analysis to study types of performance changes is to explore changes in the *organization's financial performance or position* especially at the firm level. This is the most common approach in studying the value of IT investments due to the availability of good panel data (e.g. financial statements of companies), or ready access to internal cost accounting data. This type of analysis is welcome when it is appropriate. It requires that there are sufficient data sets for the type and level of analysis what one wants to carry out. The problem from the view point of our impact model is that in most cases we cannot link cost accounting data with appropriate changes and measures in sets B and C and therefore most of such analyses can only observe causal relationships between A→ D. In most studies such relationships have been found to be spurious and the results we have from the past IT impact research are conflicting. We would not expect that the situation with UIE impact would be any different and would be cautious to use such research methodologies to explore UIE impact.

Finally, UIEs will also catalyze the development of *radically new products and services*

[8] The research design involves sampling over otherwise similar sites that differ in the presence or absence of a UIE. This is then combined with the need to collect data on the presence or absence of complementary organizational assets or practices and map that with the expected organizational transformation. Given the sample and the measures over items A, B, and C we can use multivariate statistical techniques to compare performance in the presence or absence of UIE with or without complementary assets with a specific organizational transformation. This design allows one to answer such questions as follows: (i) is the presence of a UIE associated with higher productivity levels? (ii) does the magnitude of the performance differential depend on the presence of assets or practices that are likely to be complementary to the high performance work systems?

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by providing the mobility and intelligence to products and services at any time or any specific place (Fano and Gershman 2002). This enables companies to introduce intelligent products and intelligent environments, and offer unprecedented information service related to their products (e.g. telematics, smart clothing, smart furnace).. Mobility and intelligence embedded into the products and services offer radically new services by: (a) offering completely novel service experiences to the customers; (b) changing the traditional assumptions about the cost-profit relationship; and (c) bundling different types of services into one. For example, using global positioning system and cellular technology, Progressive Auto Insurance has offered usage-based premiums to customers, which provides substantial discounts if the customers are willing to avoid driving at certain times.. We can therefore expect that UIE related innovations in many information intensive industries (or those becoming such) will produce products and services that are disruptive for market incumbents and market structure. (Anderson and Tushman, 1990; Christensen, 1997; Garud and Karnoe, 2001; Tushman and Anderson, 1986) though in many industry sectors such as pharmaceuticals, radical changes in technological capacity have not proven to be disruptive, since dominant organizations have a more incremental and evolutionary approach to control their environment (Brown and Eisenhardt, 1997; Eisenhardt and Tabrizi, 1995; Henderson and Clark, 1990).. In studying changes in organizational performance related to new strategic services measures like agility and capability to sustained innovation and market positioning are critical.

UIE applications often challenge existing assumptions of organizational practices and task processes that have been associated with the traditional computing paradigm. Therefore, real consequences of UIE will be not be observed until these assumptions are challenged and new work practices and task processes emerge. Studying such emergent and unintended consequences forms therefore a major challenge in studying the performance impacts of UIE both at the productivity and strategic impact levels. One approach to adopt is to examine current work practices and task processes in terms of the mobility of actors and artifacts in time and space. Such careful examination of mobility in the current work practices will help researchers to identify emergent and unintended changes (Jessup and Robey, 2002).. Therefore researchers will have to be more reflective and critical of the value and impact of UIE and their distribution. For example, due to their mobility and personalized nature, UIE applications will necessarily blur the boundary between personal and public domains. It is possible that the *improvements* of organizational performance due to UIE might come at the expense of individuals' leisure and family time. Much of the social meaning of UIEs will have to be negotiated among various actors. Researchers will, thus, have to critically observe this social negotiation process and be reflective in their theorization of terms like *productive gains,* or *performance improvements.*

Given the type of data sets available and our current understanding of the nature of the relationships between sets A, B, C and D our bet is that best research outcome can be obtained from combination of qualitative data on organizational practices and coordination processes (C) which have been transformed by specific new UIE capabilities (A), and where the appropriation has take place over a varying set of complementary assets (B). At the level performance measurement we prefer either quantitative engineering-type productivity measures which allow us to understand precisely where and how the deployment of UIE influences a specific organizational process or task, or more qualitative analysis of changes in organizations' strategic positioning, and competitive capabilities.

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Multiple levels of performance analysis

Consequences of UIE at the level of organizational performance manifest themselves in multiple levels. Therefore, we need to understand the performance at the individual level and the multiple levels of the organizational network: work groups, geographical sites, departments or work units, business processes, and whole network of firm's business processes, and industry level.. Clearly, each level requires different types of performance measures and for some levels only productivity related measures are appropriate, while for other levels either financial or strategic measures are appropriate. In addition, various technical capabilities (i.e., automating, embedding, and connecting) will have different performance impacts at different levels of measurement. By combining levels, types of performance measures and types of impact we can organize different impact measurement into a more coherent set of approaches that are applicable for a specific situation. Of course, measures of performance that focus on the workings of the entire network (such as the time it takes to deliver a package from country A to the right address in country B) preclude the kind of "differences-in-differences" estimates that are typical from producticity measures at lower levels. Nevertheless, by combining data on the evolution of network performance with qualitative data describing transformations in all lower levels of the analysis, we can expect to learn something about the direct causal impact of the UIE technology to the efficiency of coordination across the business process network over time.

One must also note that when planning for multi-level performance measurement, one must always carefully consider the inter-level dependencies affecting performance at a specific level. For example, the work group performance is dependent and influenced by each of its members, while each member's performance is dependent on the performance of the others in the group. Furthermore, at the business network level, consequences of both different processes and their connections should be examined.

How to measure the causes of impact?

As figure 1 point out there are several critical issues in planning for UIE impact measurement. The first one deals with which areas need to be included in the measurement model for a given study. Due to the multi-causal and complex nature of impact we suggest to include normally broad sets of measures which cover all sets A, B, C and D. This requires that researchers must develop more carefully their measurement instruments and data collection techniques for each area in a given set of studies and vary the types of measures and techniques over time- in particular when it applies to sets A and C and D. Another critical issue is that UIE impact researchers should be careful in delineating the type of capability or function which creates transformations in organizational practices and also how these practices become transformed as a process (Orlikowski 1996).

Another critical element in observing the transformations is to observe necessary and some time significant time lags in relationships AxB→ C and AxC → D. These time lags are caused by both learning and appropriation barriers which relate to both changing organizational processes and learning to deploy technologies at hand effectively. The second type of time lag is caused by the layered measurement system and the dynamics of adopting UIE technologies in that not all parts of the organization adopt necessarily these technologies at the same time. There are therefore significant time differences in observing local impacts, and in particular changes on higher levels of analysis. Third, for most organizations, UIE will be a novel innovation, and it is novel not only in terms of embedded technology, but also the nature and scope of organizational

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work. Some of these changes will be fundamental in that they change the prevailing assumptions and expectations of time and space that are used to organize and coordinate work. Therefore, the true consequence of UIE will take even longer time to take place than traditional organizational computing. All this suggests that UIE impact studies must prepared to observe slow paced and longitudinal changes. Normally the impact measurements should compare performance at any level at least for one year before adoption time at t, and at least one year (t+1) to several years (t+2, t+3, t+4 in some cases) after the introduction of UIE. By comparing changes in performance over the same time period in locations with and without the new technology, we can detect changes in performance pre- and post-introduction of the new technology with changes in performance over the same period at stations with no new technology. Provided that the rollout of the new technology is not first implemented at the locations expected to gain most from the technology, these difference-in-difference estimates will allows us to examine the initial effect of the UIE deployment in particular when engineering types of measures are used.. Specifically, they will allow us to estimate how much of the improvement in performance that may accompany a technology rollout would have occurred even in the absence of the new technology[9].

Our research framework also recognizes the necessary and critical feedback loops that are involved in the adoption of UIEs and therefore their presence (or lack of) will have a significant impact on observed performance changes. The figure clarifies the nature and type of most critical feedback loops from the transformed capabilities (C) into new sets of complementary assets available and / or needed, and into new technical capabilities and requirements that are needed to expand or modify developed technical capabilities. In the same way observed changes in performance (D) will affect how organization observes and manipulates its organizational practices. Observation of such feedback loops and their impact on successful appropriation and deployment of UIEs will be many times critical in creating successful UIE with strong organizational impacts. Therefore researchers interested in UIE impact have to continually consider learning effects of both new technology and work design.

Discussion and Conclusion

In this paper, we described a preliminary research framework that can be used to identify various decisions and issues that need to be addressed when measuring the impact of UIEs in organizations. The framework is based on the fundamental premise that UIEs will bring a fundamental shift in organizational computing by relaxing the time-space constraints and the impact study framework must therefore recognize the specific features of the UIE applications and their implications for performance measurement. We suggest that in order to faithfully understand the consequences of UIEs, the measurement approach need to recognize the type of service, its specific time and space constraints (if any), the nature and level of complementary assets that have been mobilized, the nature and scope of organizational transformation taking place, the type of measurement being used, the level of analysis being used, and the necessary time lags in observing performance changes. The paper invites more research in developing better taxonomies for observing type of UIE impact, work organization requirements related to time and space, scoping and identifying also non-intended consequences to impact studies, and

[9] In our preliminary conversations, the order of the rollout at stations appears to be guided by convenience rather than careful analysis of expected benefit. As our identification strategy relies on the corporations' rollout strategy, this is something we will continue to monitor and investigate.

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integrating and deploying multiple levels of analysis in UIE impact studies. The paper also calls for more comprehensive and multi-methodological approaches to study changes in organizational performance caused by UIEs.

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