# Scaling with Digital Connection: Services Innovation

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*Abstract*—**Digitization of production factors, including the knowledge for knowledge workers and consumers, opens almost infinite potential to connect persons, systems, processes, enterprises, products, and services. This digital connection has ushered in computerized manufacturing, global supply chain integration, the Internet, e-commerce/business, P2P social media, and many emerging services innovation. Digital connection brings about increasingly large scale systems and applications, which present sweeping challenges to many academic disciplines. We provide an analysis for digital connection from the perspective of new services innovation. New results proposed include a formulation of new micro-economic production functions and a model for achieving economy of scale through the sharing of extended cyber-infrastructure.**

## I. The Large Scale Challenge

Computer science, in particular, is facing some fundamental challenges caused by large scale systems such as the Internet. Its traditional scientific foundations are based on models of single machines, and do not now seem sufficient to prove for massively multiplex environments that are underlying today's signature enterprises in service, manufacturing, and national defense. Emerging results such as collaborative computing, Web services, and ontologies attempt to respond to these large-scale challenges but without scientific proofs. Similar observations also arose from other disciplines of applied sciences, ranging from Industrial and Systems Engineering to Management and Economics.

Industrial and System Engineering were originated in the aftermath of Industrial Revolution to standardize, rationalize, and optimize design and operations. Previous studies tend to focus on off-line analysis and modeling that feature steady state solutions and inference based on small samples. Today's large scale applications, in contrast, require real-time regimes that perpetuate transient state and population-based planning and control. Their complexity, uncertainty, and dynamic nature defy many classical results. Examples include global network flows, mass-customization, and co-production of services [10]. In the service realm, a fundamental question that highlights the gaps existing in the field is how to standardize knowledge workers, and consequently, without such standardization, how to apply traditional engineering results to the rationalization and optimization of service enterprises.

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Management and Micro-Economics also have their traditional founding assumptions challenged [5], which are similarly put in redefinition by the emerging economic activities such as the practices of extended firms, or collaboration between firms and/or clients, as a significant if not primary mode of production. Global supply chain integration and many virtual enterprises of e-commerce and the New Economy are prime examples. We recall that a theoretical corner stone of traditional micro-economics is the concept of "firm", not extended firms; and Management always observes (or even promotes) the boundaries of a firm.

In a broad sense, all the Information Technology-enabled economic activities, ranging from manufacturing (CAD/CAM, CIM, CE, Agile Manufacturing, Virtual Engineering, e-Engineering, etc.) and service (e.g., health care and e-commerce/business) all the way to P2P social media, all pronounced the above challenges.

We submit that **the root cause of these large-scale challenges is the digital connection of economical production factors and users** across the society at the level of individual factors (beyond the reliance on firms as their intermediaries) [6]. Digital connection starts with the digitization of production factors and persons, including both the interface to factors (land and other physical materials) and the factors themselves (knowledge, capital, and institutions). Furthermore, we submit that **digital connection is also the solution to the large-scale problem by affording scaling and the potential economies of scale**. The solution starts with understanding how the cyber-infrastructure could standardize, rationalize, and optimize the design, use and implementation of the connection for enterprises, to thereby gain economies of scale. This is **innovation of enterprises**.

We analyze services innovation from this perspective, focusing on the role of enterprise engineering using cyber-infrastructure. Section II focuses the emerging industry-led call for a new Service Science onto innovation of Connected Services. Section III, then proposes enterprise engineering models to build digital connection for enterprises in the road of innovation: digitization, transformation, and collaboration. The analysis is general in nature, but was inspired by cyber-infrastructure-enabled services innovation. Sections IV and V propose, respectively, the model of sharing extended cyber-infrastructure and a model of production functions for the extended firm-based mode of production. Section 6 proposes development of new doctoral programs for services innovation using new paradigms.

## II. Services Innovation

### A. Service Science

A significant call for a new Service Science is emerging from the industry [2, 4], and a number of scholarly conferences have been organized in response in 2007. Is this a fad, or a reflection of some serious gaps in scientific knowledge about services [1, 7, 8, 11]? The recent IBM Conference on Service Sciences, Management, and Engineering (October 5-7, 2006, Palisades, NY) has provided a review of the current state of research and education on services [3, 9]. The results (74 position papers from academicians in twenty some countries in North America, European Union, Japan, China, Brazil, and other regions) show a wide range of sometimes conflicting perspectives as well as agendas and accomplishments. Although the need for significantly more study was echoed by all presenters in all these perspectives, the path to success remains a challenge.

A more fundamental question is: What is the intellectual nature of Service Science? Do we really need a ***NEW*** Service Science? Has our society already entered a new era which can no longer be explained sufficiently by the results obtained since the Industrial Revolution?

It may be that a service science is mainly an integration, synthesis, and formalization of the accumulated results in the service-related fields to date. Or, as evidenced by the challenges discussed in Section 1, it may also be that the new science requires a new fundamental scientific research basis characterized by new doctoral programs of the new discipline.

To explore the second possibility, one could be reminded of a world witnessing a constant and never ending array of new genres and models of services built on some new ways of connecting persons, firms, and production factors through digital means at a global scale. The scale and significance of the changes occurring since the late 20$^{th}$ century are arguably reminiscent of the previous Industrial Revolution - in fact, many people have popularly proclaimed an Information Revolution for the period. Could it be that we are actually witnessing a Service Revolution, characterized by digital connection and new paradigms of taxonomy, transformation functions, and production functions based on the connection?

It follows that an immediate task for recognizing the need for a new Service Science is to define what types of services – not any services – that intellectually challenge us, and what we wish to accomplish for them. Then, the field can deliberate on the research agendas.

### B. Innovation of Connected Services

An industrial reference point for characterizing the types of services is found in the IBM definition of service science, management, and engineering, which stresses that "a service is a provider/client interaction that creates and captures value". This definition can be expanded from the perspective of a digitally connected economy. We submit that the types of the provider, the client, and the interaction (co-production) determine ultimately the types of service; and ***the types can be characterized by the economical and technical nature of the digital connection they employ and deploy***.

On the demand or client side, the user of a service could be persons or enterprises, and they could join force with each other on demand if the utility that they gain from the service dictates so. On the supply or provider side, the producer of a service could also be persons or enterprises, who could collaborate on demand as well. Moreover, the service products could be inherently associated or even integrated with manufacturing goods at many levels; e.g., the utility-to-user of a vehicle, the operation/maintenance of a physical plant, and the execution or provision of computing services using a computing platform. Therefore, we have the types of person-to-person, habitat-based services that historically existed before the Industrial Revolution, such as hair cut and gardening. We have warrantee and after sale services for automobiles and machinery. We have service and operation contracts as a strategic product in heavy industry. We have the consulting industry, the telecommunications industry, the finance industry, the transportation industry, and other similar industries to provide mass-customized services to persons, companies, and global communities.

We also have services that are transforming from relying exclusively on personal contact to also being based on digital connection, such as health care and education. The transformation has even reached traditionally non-service sectors and made services harder to distinguish from non-services; examples include designer medicine and IC design foundry; which are catered to individual clients. In a similar way, we also have witnessed e-business – including Application Service Provider, On-Demand Business, and Exchanges and Supply Chain Integration – that innovated services into a New Economy.

Clearly, our intellectual curiosity does not lie in all these genres of services. The challenge and novelty arise primarily from the latest models and enterprises of services that are changing the traditional thinking and breaking the previous rules to give rise to new types of (extended) firms, production functions, and mode of production for our economy.

In particular, we are curious about the types of services which are important not just because they account for a large share of the economy, but more fundamentally because they are the agent of innovation for the society. We are curious about the paradigm shifting started with e-business and peer-to-peer practices, and now is deepening and widening throughout the global economy. We submit that the paradigm shifting should be recognized as what it really is – a service-led revolution towards an unprecedented mode of co-production fueled by digital connection, which promises to allow service production scale up like industrial production.

The Service Revolution uses societal as well as enterprise cyber-infrastructure to produce and provide services to persons and enterprises that are connected by the same cyber-infrastructure, on demand, as shown in e-business. We propose to call the new genres of services using digital connection the **Connected Services**, so as to distinguish them from the traditional isolated types of services that we do not study directly. The characteristics of Connected Services include **digital connection** (e.g., a massager performs in isolation, but connected knowledge workers could draw information resources from all over the world to assist the jobs on hand), **service scalability** (e.g., hair cut is not scalable, but distance learning is), **asynchronous co-production** (e.g., personal counseling has to be synchronous, but an ASP of enterprise processes does not), and **person-centered assistance** through cyber-infrastructure (e.g., newspapers are not person-centered, but car driver services such as On-Star are). A signature technical foundation required is the extended **cyber-infrastructure**, which couple embedded data and metadata, knowledge, and analytics with the usual computing and telecommunications infrastructure. This foundation will be able to support massive concurrent virtual configurations for the massive concurrent use of it. All these characteristics become both the enablers and the objects of innovation to create new types of firms and production functions – we refer to this **Services Innovation**.

We submit that these characteristics are not fully understood in the previous literature, and they are still evolving as Connected Services themselves are. Therefore, rigorous research and education programs are needed to substantiate the emerging Service Science and develop it into a complete discipline. We expect the new field to study and yield new basic results that help develop, rationalize, and optimize these characteristics to create new valuable services for the digitally connected persons, enterprises, and society.

## III. SCALING BY EXTENDED CYBER-INFRASTRUCTURE

The extended cyber-infrastructure consists of five basic types of elements, as categorized below.

**Cyber-Infrastructure Elements**

User: personal information, security, user interface, and embedded tools for interaction.

Process: public business process libraries, open standards, and embedded analytics for connection.

Data/Knowledge: ontologies and embedded intelligence.

Computing: common platforms and shared facilities.

Infrastructure: networks, telecommunications, protocols, and cyber-infrastructure application generators.

The road to enterprise innovation using digital connection is marked by digitization, transformation, and collaboration. That is, from the perspective of the above extended cyber-infrastructure (CI):

- Digitization: build/expand CI elements - convert paper-based data resources and manual processes into (stand-alone) digital enterprise systems, using application-level (dedicated and proprietary) models, designs, and technology.
- Enterprise Transformation: integrate CI elements – connect and configure enterprise digital resources into performance-enhancing systems for the whole enterprise, using (proprietary) models, designs, and technology of enterprise informatics.
- Enterprise Collaboration and Beyond: connect CI elements across enterprises – inter-operate the corresponding digital resources throughout the extended enterprise value chains (e.g., supply chain and demand chain), using open and scalable models, designs, and technology.

With the CI in place, enterprise engineering models can be recognized which promote digital connection.

**The Model of Enterprise Transformation**

- Objective: Reduce intra-enterprise transaction cost and cycle time (align business processes/resources)
- Means: use enterprise cyber-infrastructure to integrate (on-demand) IS elements; i.e.,

- Connect (on demand) users and tasks with data and knowledge, and process resources (*"Subject" oriented*)

- Provide enterprise informatics to users and enable sharing of resources across tasks (*"Subject" model*)

- Simplify business processes toward a user- and task-centered, service-oriented, (on-demand) architecture (*"Subject" paradigm*)

- Convert sequential processes into concurrent using teams approach as well as flexible CI configuration.

- Scope: the enterprise and the clients (on demand); i.e., (on-demand) co-production

An example of enterprise transformation is shown in Figure 1, which depicts a commercial loan approval process.

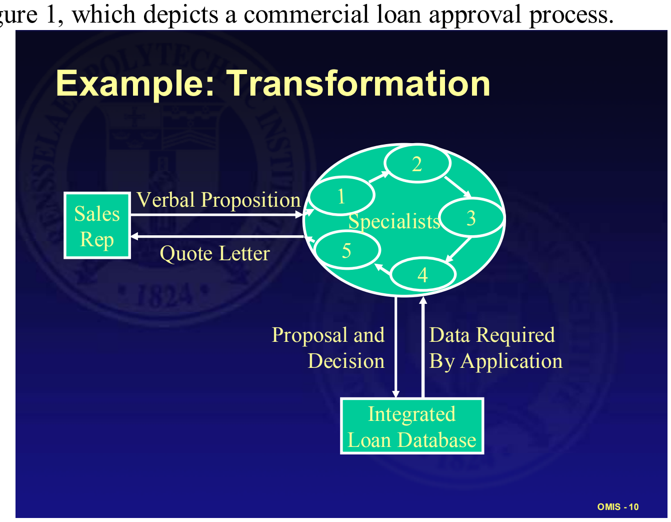


**Figure 1.** Enterprise Transformation.

The original workflow was sequential (processes 1 to 5 in the figure), but an integrated database that support all five processes helps converting them into concurrent. The key concept here is to integrate system resources into enterprise resources, and connect them to the needed enterprise users.

**The Model of Enterprise Collaboration**

- Objective: Reduce inter-enterprise/societal transaction cost and cycle time (join resources and align processes)
- Means: use societal cyber-infrastructure to globally connect related IS elements across enterprises to facilitate own, the client's, and/or the supplier's life cycle tasks and requirements throughout (extended co-production); i.e.,

- Follow the value chain to form (on-demand) extended enterprises and pursue opportunities of co-production.

- Apply the enterprise transformation model to extended enterprises, recursively if possible. (*"Subject" paradigm*)

- Put the "Person/Client" at the center; i.e., renovate the industrial value chain to connect (on-demand) enterprises along the life cycle requirements of a person/client.

- Employ innovative virtual organizations (e-business).

- Scope: Drill through the demand chain and/or supply chain.

Figure 2 shows an example of enterprise collaboration, where a retailer and a supplier join their enterprise processes to reduce the cycle time and transaction cost of their procurement process.

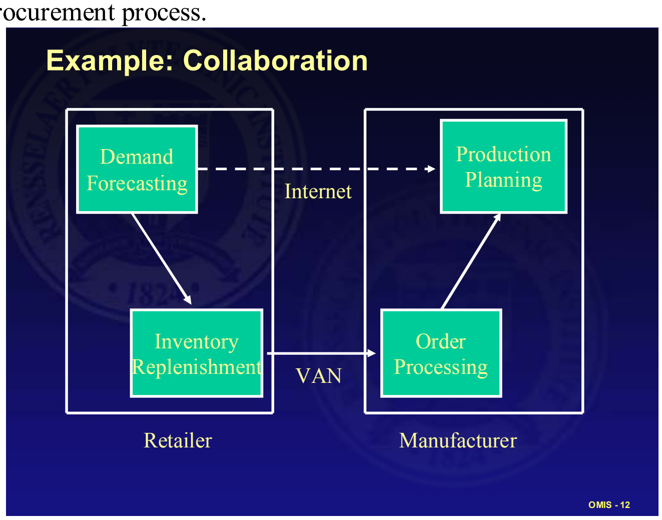


**Figure 2.** Enterprise Collaboration.

The collaboration connects directly the retailer's demand to the supplier's production, as depicted in the dashed line, rather than the previous sequential processing (the solid lines), in the figure. The key concept illustrated is considering the extended enterprise as a whole, and thereby apply the enterprise transformation model to the virtual whole.

## IV. ECONOMY BY SHARING CYBER-INFRASTRUCTURE

Scaling by digital connection, as illustrated in Section III, also opens the possibility of achieving economies of scale through digital connection – or, more accurately, the sharing of extended cyber-infrastructure upon which digital connection is implemented. A three-schema concept is proposed in [6] as a thought model for the sharing of the extended cyber-infrastructure. A key to this thought model is the formulation of the co-production of service – be it a consulting, a process, or an enterprising – to be a concurrent use of the cyber-infrastructure (e.g., running a client company's payroll processes). Therefore, the co-production is a session (e.g., payrolls) of the running of the cyber-infrastructure, rather than being a structure of it (e.g., a dedicated payroll EDI/network). Each co-production can be unique, in terms of the processes involved and the (virtual) configuration of resources required; but they will be supported by the cyber-infrastructure as sessions. The processes involved and production factors used in the co-production do not have to be repetitive, nor standardized. The economy of scale comes from the concurrent co-productions performed on the same cyber-infrastructure – or, simply, the sharing of digital resources. The economy will come primarily in the form of transaction cost and cycle time reduction.

The technology required will center first on the acquisition of an open, scalable, and re-configurable cyber-infrastructure for the enterprise. Next, person-centered "control levers" must be afforded to the users, including both the client/customer and the producer of the co-production, to enable virtual configurations of the cyber-infrastructure for individual co-production sessions, ideally with the assistance of the cyber-infrastructure itself. That is, the cyber-infrastructure should be able to customize its jobs (e.g., helpdesk processes, customer relations processes, and payrolls) for the particular sessions on the users' command, in a manner in which the cyber-infrastructure appears to be custom designed just for the particular co-production at hand. The processes can be one-of-a-kind since they are realized in the on-demand employment of the cyber-infrastructure, or, the virtual configurations commanded.

This thought model actually describes many e-commerce enterprises. A prime case is the ISP (Internet Service Provider) and ICP (Internet Content Provider) models. They, along with Portals and Search Engines, have thrived on sharing their digital resources among customized (virtual/non-consuming) uses – or, concurrent co-productions using the same cyber-infrastructure. Although their service products are not nearly as complicated as enterprise processes and professional consulting, they are still telling precedents.

The concept is illustrated in Figure 3. As shown, the notion of a "cyber-infrastructure application system" envisions that the common resources of societal/enterprise cyber-infrastructure is manageable for creating virtual configurations and supporting application sessions. Common reference models, open standards, and ontologies are incorporated.

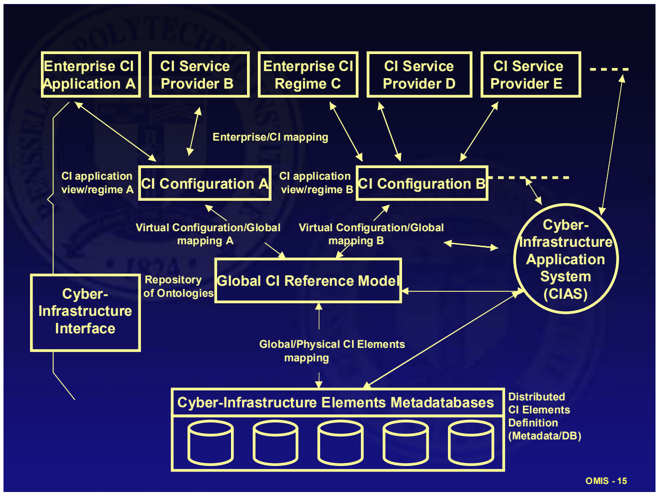


**Figure 3.** Cyber-Infrastructure Application System.

We submit that the above concept, if proven, promise to reduce the challenge of service productivity to that of cyber-infrastructure design, rather than to the standardization of co-productions (i.e.., the processes and the knowledge workers). The former can draw from the vast results in the fields of science, engineering, and management; while the latter may be both intractable and inappropriate.

## V. PRODUCTION BY EXTENDED FIRMS COLLABORATION

To help shed light on the intellectual nature of Connected Services using cyber-infrastructure, and thereby facilitate the analysis and design of their innovation, we propose a high level formulation of the micro-economic production functions for extended firms.

**Model of Production by Extended Frims**

Objective: maximization of utility - minimization of cost (C)

Decision Maker: users and providers of the output/product (collaboration through digital connection)

**C = h (I, D, F, K, Z)** where **I**: the institution; **D**: the digital connection/cyber-infrastructure; **F**: the non-digital production factors; **K**: the digital, knowledge production factors; and

**Z = f (A, R, P)** where **A**: the consumption activities or enterprise processes; **R**: the restrictions on the selection of A; and **P**: the market price for A. (The nature of constraints R defines goods vs. services)

$C^n = h^n (I, D, F, K \mid Z)$ if n = p (provider) or

$C^n = h^n (I, D, Z \mid F, K)$ if n = u (user)

($C^n$ is recursively expandable along the demand chain and the supply chain.)

The above model serves as a starting point to the formulation of some formal analysis of the productivity of Connected Services. On this basis, Services Innovation can also gain some formal grounding for analysis and design.

## VI. REMARK: NEW DOCTORAL PROGRAMS

The above sections provide a case for the need of a new science for services innovation, in support of the on-going industrial calls. The argument started with a discussion of the basic gaps in the scientific knowledge in the field, and elaborated into a postulation that recognizes digital connection by cyber-infrastructure as both the intellectual nature of a new class of services emerging in the society, and the means by which to gain productivity.

This argument inevitably leads to a conclusion that new doctoral programs are evidently required to anchor the new field, as the sustaining force of research and education for the new science. The doctoral research will likely feature new requirements and new structure, such as a problem-centric, industry-pull approach that actively involves industry in the educational process. Therefore, new paradigms of academia – industry collaboration seem to be necessary, too. Exploratory and forward looking research problems resulted from the industry-academia collaboration will help define the new doctoral programs.

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