Engineering and Services

George Bugliarello
University Professor and Chancellor
Polytechnic University

Abstract

The goal of this paper is to show the role that engineering and engineering schools can play in the service sector, identify some of the major challenges and present the experience of Polytechnic University's involvement in the areas of finance and supply chains, merchandising and retail. The service sector is very large and in an advanced economy like the United States constitutes the largest portion of the Gross National Product. Services are ever more dependent on technology and are being revolutionized by it. However, engineering schools have focused to a much lesser extent on services than on manufacturing, and virtually not at all on the areas of retail and finance that dominate the service sector. The very large role and scope of technology in services present major engineering challenges, ranging from systems architecture to a focus on the customer that is unprecedented in engineering curricula. Graduate curricula in financial engineering and in supply chain and retail, as well as targeted undergraduate internship programs in the retail industry at Polytechnic University exemplify a response to these challenges.

Introduction

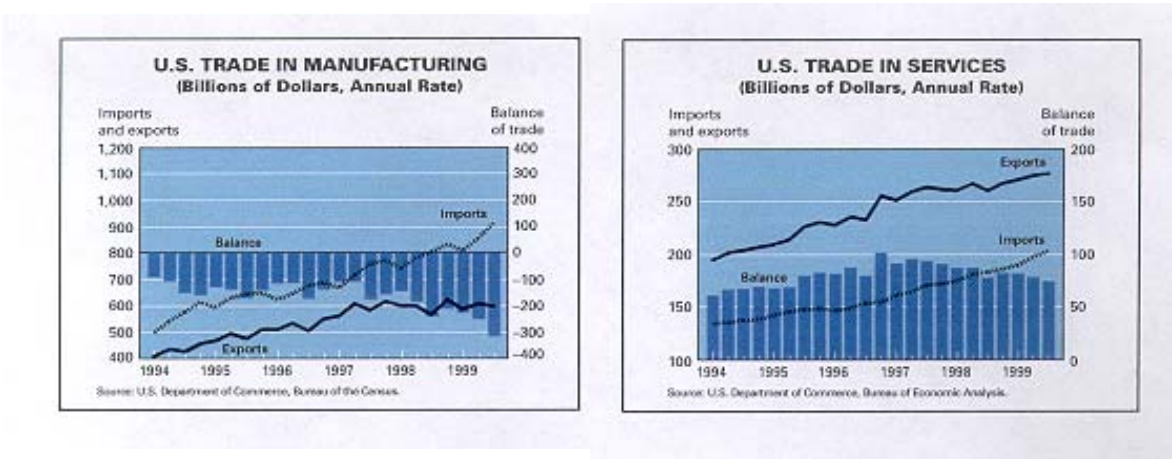
The service sector is very broad, as shown by the activities classified under it in the U.S. Industry and Trade Outlook[1] (Fig. 1). In advanced economies, the sector represents the largest segment of their Gross Domestic National Product. In the United States, unlike the manufacturing sector, it has a positive balance of payment, with exports more than double the imports (Fig. 2).

Services are ever more dependent on technology and are being revolutionized by it. From algorithms, to automation, physical/mechanical systems, information systems, and telecommunications, technology is pervasive in virtually all aspects of services, with far-reaching impacts transforming not only the efficiency, but also the content and process of business. Technology has become essential to the survival of many players in the service field, from the very large to the very small.

An example of the importance of technology in services is the field of finance. Financial markets have been growing at an exponential rate. Trillions of dollars flow between countries and the leading financial markets are supported by a robust information infrastructure. New financial

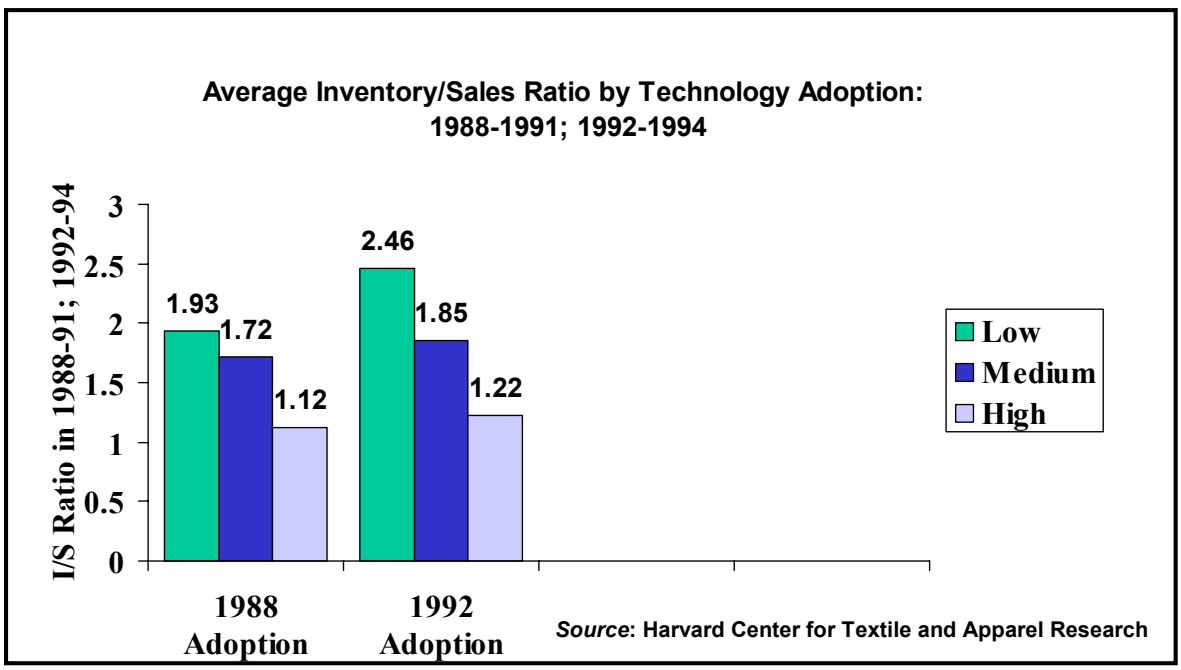
products are made possible by new technologies and new quantitative methods. The very nature of the financial industry is rapidly changing, the risks associated with new technology-based financial products are escalating and the boundaries between financial institutions and other industries handling information are becoming ever less defined.

Fig. 1. The Field of Services



Source: ***U.S. Industry and Trade Outlook 2000***

Fig. 2. U.S. Trade



***Source*: F.H. Abernathy et al./*Technology in Society* 22 (2000) 5-31**

Fig. 3. The Importance of Technology in Retail

The importance of technology in services is also exemplified by the field of retail, where a telling indicator is the declining ratio of average inventories to sales[2]—and hence, other factors being equal, the increase in profitability, with increasing intensity of technology (Fig. 3). The technological needs and opportunities in this field involve potentially all engineering disciplines[3]. Information technology obviously requires the involvement of computer engineering, computer science and electrical engineering. Integration of warehouses, storage and distribution involves operations research, mechanical engineering, and computer science, as well as electrical engineering. Packaging involves mechanical, chemical and environmental engineering, and so does recycling. Increasing the efficiency of suppliers calls, among other engineering disciplines, for industrial engineering, and the design of environments where the service is delivered, from stores to offices, calls for civil engineering.

Engineering Schools

Engineering schools have been involved in sectors of services that traditionally employ engineers, such as transportation, logistics, maintenance and building construction, and aspects of health care. But they have not been involved in sectors such as financial services, retail, and hospitality/entertainment. One reason is that there have been no government programs supporting the training of engineers for careers in these very important but less traditional areas of services. In general, engineering schools are not knowledgeable of the service sector, do not have many contacts with it, or faculty or students interested in it (demonstrated, for example, in the case of undergraduate engineering students at Polytechnic University, by the lack of interest encountered in focus groups). Although technical suppliers to the service sector have no difficulty in attracting engineers, they need to train them to understand the sector so that they can be more effective in responding to its needs and opportunities. As a result, the service sector has not developed the kind of dialogue with engineering schools that has been so beneficial in other sectors, such as manufacturing.

Elements in Common of Many Services

Most services have many elements in common:

- They have the customer as the focal point. The customer demands cheaper, faster, more convenient, customized services with quality, reliability, and privacy, as well as safety.
- They possess a supply chain or net characterized by product flows (broadly defined to include also patients, tourists, and so on), information loops, and control loops.
- They are complex, as they involve a combination of technologies (embodied, e.g., in products, clinical devices, information systems) and human factors (the customer, the client, the personnel) involved in delivering the service.
- They are affected by the economic costs of inventories, be they goods or unoccupied beds in hotels or hospitals.

- They critically depend on customers data in order to be able to more effectively respond to their needs.
- They often are characterized by the confluence of multiple services at the point of sale, as when in a supermarket the customer pays with a credit card issued by a financial institution.

The scope of technology in services ranges from *products*, such as manufacturing and packaging of goods for retail markets to *supply chains*, encompassing transportation, warehousing, distribution, delivery, recycling, and remanufacturing (increasingly important in order to reduce the environmental impact of what the customer discards after use or returns), to the *point of intersection between the customers and the service*, where technology is needed to display, inform, and guide, to the *customer at home* where the technology could be the Internet or the very architecture of the home.

Engineering Challenges

Within the very large role and scope of technology in services there are major and distinctive engineering challenges. Among them:

Systems Architecture. The first challenge is in this area and involves a wide range of issues:

- technologies and organizational designs as critical elements for deciding whether to develop centralized *versus* distributed systems (e.g., services delivered at the hospital versus at the doctor's office);
- hard- *versus* software solutions;
- materials *versus* information solutions (e.g., the possessing of enough information to reduce wastage by having only necessary supplies reaching the point of sale, or just enough beds at hospitals, or inventories just sufficient to supply the demand);
- interconnections for inter-operability, both of information and material flow systems. Interoperability can enable different branches to operate effectively by having compatible information systems or by being able to move goods along a supply chain without having to change containers or packaging.
- cross-connections between information and material flow, to make information about material flow constantly available to the management of a service enterprise. They can be achieved through the use, for example, of bar codes or electronic tags. Both have reached very small dimensions and have grown very rapidly in number over the years.

Production. The production of goods conveyed to the customer by the service industries challenges the engineer to provide flexibility, customization, quality control, environmental sensitivity, recyclability, appropriate packaging (to respond, for example to the need of an increasingly aging U.S. population to have information more visibly conveyed and containers more easily openable), value added processes—whether that value is added in transit, through customization, or through desktop manufacturing—and value added designs, that is, designs that

provide multiple functions, such as a telephone that can also function as an e-mail terminal or a bar code reader.

Point of Contact Challenges. A need of many services is for locational technology to provide information as to where an individual customer is located, e.g., in a store, and to enable, in turn, that customer to communicate or be communicated with in any given position, for instance, by the means of specialized local area networks, or by "piped" voice, etc. Another point of contact challenge is the psycho-engineering design of the service environment, be it a store, a mall, a hospital or a school, by providing the customer with images, olfactory signals and acoustic signals, that convey information or guide, deter, or encourage. For instance, there are certain olfactory signals that attract and others that repel. Similarly, with acoustic signals, frequencies of half a cycle per second generally instill a sense of dread and are considered to be a deterrent.

Information Extraction About the Customer. Most services depend vitally on knowing their customer and, hence, on the ability to extract information from their contacts with the customers. To be successful and perform effectively, most services need to have, as much as possible, behavioral information about the habits, the preferences, purchasing power and the *modus operandi* of the customer. Point of contact manufacturing offers increasing opportunities to respond with immediacy to the needs of the customers, as in the case of financial products, medical procedures, desktop publishing, and, eventually, also clothes.

The Home. An increasingly important and promising frontier in the area of service, is a direct connection between home and supply chain that may involve the whole range of technologies, from Blue-tooth technology to PANs, to supply chain LANs, to WANs. This will demand increasing development of other in-home point of contact technologies.

Observations

In responding to these technical challenges, it is worth observing that:

1. *The technical best is not necessarily the economic best.* Sometimes features of a technological system or device may need to be added or removed to make it easier to reach a certain group of customers, to facilitate their payments, etc.
2. *There is often a gap between the speed of innovation and societal, that is, cultural, acceptance.* To make a trivial example, it took some time before the umbrella or the wristwatch would be accepted, or for that matter, before the wealthier segment of the population would accept to reside in apartments rather than in individual houses.
3. *Not all technologies in a given sector advance at the same speed*. For example, automotive technology has advanced faster than the ability to guide and control traffic on highways and to create intelligent highways.
4. *Opportunities arise from societal concerns*, such as safety, security of information, privacy, environmental preservation, or, as in the wake of the events of September 11, 2001, individual and collective protection.
5. *In general, a competitive advantage goes to the entity with greater information*

capabilities. For instance, considering the point of sale, there is a question as to whether the store or the financial company that provides the credit card will dominate. A good information backbone facilitates the expansion of a business and the acquisition of other businesses, while a weak information backbone often becomes an insuperable handicap.

6. *Virtuality is rapidly growing in importance.* Outsourcing and contract manufacturing are transforming a number of companies to "pure service providers" (as AT&T has indicated it intends to become) and category management—a well established kind of virtuality—gives suppliers the ownership and management of a range of products in a store.
7. *The changing technological environment will have an increasing impact on the service sector*. It ranges from ubiquitous MEMs to a situation of computational plenty made possible by mega teraflop machines, to holographic data storage, smart, ubiquitous and cheap dust web servers, reconfigurable chips, recyclable software, web wireless telephony which is changing the information architecture within a store or a hospital, encryption and the move from data collection to knowledge extraction, to agent-based computation to keep track of a myriad of interactions between a service and its customers.
8. *There are a number of powerful factors of technological change*. They range from the development of disruptive technologies that change the way a service is being delivered, for example by telephone and the Internet, to the synergies of technologies, such as the bar code and the computer. There are also synergies of technology and new business needs or opportunities, as in the case of e-commerce, and synergies of technologies and social trends, as in the combination of information technology and entertainment. There is also an urgent quest for technologies to enhance security. Emergencies are a powerful factor of technological change and show how rapidly the demand for new technology can arise.
9. *The involvement of engineering in services is a two-way street*. It impacts not only services but also engineering itself. If engineering is to become more involved in the area of services, it needs to develop a focus on the individual—the user of services—a focus on logistics, and also on special technologies such as psycho-engineering.

The Polytechnic University Experience

As an example of a university involvement in the area of services, the case of Polytechnic University is illuminating. Polytechnic, an independent technological university, has in recent years developed programs in technology for financial services and for retail and supply chains. The path of evolution of those programs started with the creation of Metrotech, a university-industry park surrounding the University's Brooklyn campus, focused primarily on the information and telecommunications needs in financial services[4]. (Today with some 25,000 jobs, Metrotech is the largest *urban* university-industry park in the United States.) The creation of Metrotech was followed by that of a graduate academic program in financial engineering. This resulted in the creation in 1994, with a grant from the Sloan Foundation, of a graduate program

of technology in finance. The program in financial engineering is currently leading to a Master of Science in financial engineering with two tracks, one in capital markets that involves computer sciences, financial engineering and mathematics, and another in financial technology. The program currently has some hundred graduate students.

This first venture of Polytechnic in the area of services led to considering other areas of services in which technology is playing an increasingly important role. Thus the program in technology in retail and supply chains started in 1997 with an exploration, sponsored by the Sloan Foundation, of the requirements in distribution and merchandising for personnel with technical background[5]. The main conclusions of the study are worth noting, as they exemplify issues that are bound to be relevant also to other areas of services.

1. The pace of technological change creates an imbalance in the skills of the merchandising and retail industry. Technical professionals need to know more about merchandising and retail, whether they work in merchandising and retail firms, or in technology supply firms. Non-technical personnel, too, need to better understand technology and its implications: strategic possibilities, risks, costs, personnel requirements and business impacts.
2. The merchandising and retail industry has serious difficulty in attracting the engineers and computer scientists it needs to fully benefit from technological advances. This conclusion was buttressed by the results of several focus groups at Polytechnic. They showed that students from various engineering and computer and information science departments initially had no interest in seeking careers in the retail and supply chain industry. However, after a brief description of that industry and of the technological challenges it faces, the students became more interested in it, although still not with the same intensity with which they were looking at other industries. Jobs in the retail and supply chains industry remain the last choice for science and engineering students, a serious challenge for the industry and for a university interested in fostering technological innovation in the service sector.

To respond to the challenge, Polytechnic University has established, with industry support, a Center for Technology in Supply Chains and Merchandising, which is at various stages of development, ranging from undergraduate courses to internships in the retail/supply chains industry for high school students interested in pursuing technical careers in that industry, after they graduate from Polytechnic, to the creation of an Executive Master's in Technology Management focused on innovation in retailing (MOTIR) which started in September 2002, to the creation of a Technology Laboratory. In Fall 2002, Polytechnic also received a 3-year National Science Foundation grant for a pilot endeavor to introduce technology (computerized scanning) to bodegas in the Bronx – a complex socio-technological project. The Center is guided by a Policy Board chaired by a leading exponent of the retail industry and composed of retailers and suppliers.

Conclusion

The ultimate goal of technology in services is to increase through technology the effectiveness of a sector of the economy of overriding importance. The key issues that need to be addressed are: 1) human resources, and, therefore, university curricula and programs; 2) research and innovation, considering, e.g., that pre-competitive research has been very successful in the manufacturing sector; 3) the creation of clusters, such as Metrotech, that encourage with a critical mass of co-located companies the development of innovation and the attraction of professionals; 4) industry-university interactions; 5) a science policy that focuses government attention and resources on the sector; and, equally important, 6) a concerted focus by businesses in the service sector on mechanisms whereby technology-knowledgeable human resources can be developed in that sector, as the essential prerequisite for technological innovation.

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GEORGE BUGLIARELLO is University Professor and Chancellor of Polytechnic University, of which he was previously president. He catalyzed the creation in Brooklyn, NY, of Metrotech, the nation's largest urban university-industry park. He holds a doctor of science degree from MIT and is a member of the National Academy of Engineering and a Fellow of the ASEE.