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ON SERVICES RESEARCH AND EDUCATION

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Abstract

The importance of the services sector can not be overstated; it employs 82.1 percent of the U. S. workforce and 69 percent of graduates from an example technological university. Yet, university research and education have not followed suit. Clearly, services research and education deserve our critical attention and support since services – and services innovation – serve as an indispensable engine for global economic growth. The theme of this paper is that we can and should build services research and education on what has occurred in manufacturing research (especially in regard to customization and intellectual property) and education; indeed, services and manufactured goods become indistinguishable as they are jointly co-produced in real-time. Fortunately, inasmuch as manufacturing concepts, methodologies and technologies have been developed and refined over a long period of time (i.e., since the 1800s), the complementary set of concepts, methodologies and technologies for services are more obvious. However, while new technologies (e.g., the Internet) and globalization trends have served to enable, if not facilitate, services innovation, the same technologies (e.g., the Internet) and 21st Century realities (e.g., terrorism) are making services innovation a far more complex problem and, in fact, may be undermining previous innovations in both services and manufacturing. Finally, there is a need to define a "knowledge-adjusted" GDP metric that can more adequately measure the growing knowledge economy, one driven by intangible ideas and services innovation.

Keywords: Services, manufacturing, customization, innovation, education, intellectual property

1. Pertinent Background

The importance of the services sector can not be overstated (Tien, 2006); it employs a large and growing proportion of workers in the industrialized nations. As reflected in Table 1, the services sector includes a number of large industries; indeed, services employment in the U.S. is at 82.1 percent, while the remaining four economic sectors (i.e., manufacturing, agriculture, construction, and mining), which together can be considered to be the "goods" sector, employ the remaining 17.9 percent. Alternatively, one could look at the distribution of employers for graduates from such technological universities as Rensselaer Polytechnic Institute (RPI); not surprisingly, as indicated in Table 2, there has been a complete flip of employment statistics within the past twenty years – from 71 percent being hired into manufacturing jobs in 1984-1985 to 69 percent going into services in 2004-2005. Yet, university research and education have not followed suit; the majority of research is still manufacturing- or hardware-related and degree programs are still in those traditional disciplines that were established in the early 1900s. Clearly, services research and education deserve our critical attention and support in this 21st Century when the computer chip, the information technology, the Internet and the flattening of the world (Friedman, 2005) have all combined to make services – and services innovation – an indispensable engine for global economic growth.

Table 1 Scope and size of U.S. employment

Industries	**Employment (M)**	**Percent**
Trade, Transportation & Utilities	26.1M	19.0%
Professional & Business	17.2	12.6
Health Care	14.8	10.8
Leisure & Hospitality	13.0	9.5
Education	13.0	9.5
Government (Except Education)	11.7	8.5
Finance, Insurance & Real Estate	8.3	6.1
Information & Telecommunication	3.1	2.2
Other	5.4	3.9
SERVICES SECTOR	**112.6**	**82.1**
Manufacturing	14.3	10.3
Construction	7.5	5.5
Agriculture	2.2	1.6
Mining	0.7	0.5
GOODS SECTOR	**24.7**	**17.9**
TOTAL	**137.3**	**100.0**

Source: *Bureau of Labor Statistics,* April 2006

Table 2 Graduating students with reported jobs

Economic Sector	**1984-1985 Graduates**	**2004-2005 Graduates**
Services	29%	69%
Manufacturing	71	29
Agriculture	0	0
Construction	0	2
Mining	0	0
TOTAL	**100**	**100**

Source: *Career Development Center*, Rensselaer Polytechnic Institute

The focus of this paper is on services research and education. It draws extensively from what has happened at RPI's Department of Decision Sciences and Engineering Systems (DSES) in regard to services research and education. More specifically, DSES' Center for Services Research and Education (CSRE) – established in 1990 – has been responsible for our substantial activities in furthering services research and services education. Several factors have accounted for our progress in services research. First, the department, formally established in 1987, brought together faculty from science (in operations research), management (information systems and statistics) and engineering (industrial and systems engineering) – that is, from those disciplines that are coincidentally required for services research. Second, a majority of the DSES faculty has always had a research interest in services, especially public (including transportation and infrastructure) and financial services. Third and as detailed in Section 2, we have advanced services research by exploiting similarities, complementarities and differences between services and manufacturing and, then, by building on the extensive research in manufacturing. Fourth and as detailed in Section 3, the department's decision informatics (i.e., decision-driven, information-based, real-time, continuously- adaptive, customer-centric and computationally- intensive) approach to data analysis (e.g., fusion, mining), decision modeling (e.g., genetic algorithms, simulation), and systems engineering (e.g., Bayesian networks, distributed control) is especially appropriate for developing innovative and customized electronic services (Tien, 2006). Fifth and as detailed in Section 4, we have been particularly mindful of the intellectual property issues associated with services, especially in contrast to those associated with manufactured goods and products. Coincidentally, following the establishment of DSES in 1987 and based on our services research, we have revised our courses and curricula to be more services relevant, at both the undergraduate and graduate levels. As detailed in Section 5, we have revised and expanded our undergraduate program in Industrial and Management Engineering and inaugurated a Master's program in Services and Manufacturing Systems Engineering. Some concluding remarks are included in Section 6.

Before further addressing services research and education, it is helpful to provide some additional and pertinent background. In applying data surface mining (Berg and Einspruch, 2004) to the 50 companies with the largest sales volume in 2005, Table 3 indicates that 30 – or 60.0 percent of them – are service enterprises, and, by sales volume, it is 60.4 percent. Not surprisingly, the top 14 health care and financial service companies contribute 37.8 percent of the sales volume, while the top 6 energy companies contribute 23.0 percent of the sales volume. In practice, the delineation between the different economic sectors are blurred; this is especially true between the manufacturing and services sectors, which are highly interdependent (Tien and Berg, 1995; Berg et al., 2001). Clearly, the manufacturing sector provides critical products (e.g., autos, computers, aircrafts, telecommunications equipment, etc.) that enable the delivery of efficient and high-quality services; equally

Table 3 2005 top sales performers

SERVICES	COMPANY (BY RANK, BY SALES)	TOTAL NUMBER	SALES IN $B (%)
Health Care	Wellpoint (2, $45.1B), Caremark (3, $33.0B), United (4, $45.4B), Aetna (10, $22.5B), Coventry (38, $6.6B), CVS (39, $37.0B), McKesson (48, $85.9B)	7	$275.5 (19.2%)
Energy	Schlumberger (5, $14.3B), Halliburton (7, $21.0B), Weatherford (36, $4.3B)	3	39.6 (2.8%)
Retail	Lowe's (11, $43.2B), Best Buy (19, $29.4B), Coach (43, $1.9B), Staples (44, $16.1B), Home Depot (50, $81.5B)	5	172.1 (12.0%)
Transportation	Burlington (12, $13.0B), Fedex (40, $30.9B), Norfolk (46, $8.5B)	3	52.4 (3.6%)
Internet	Yahoo (14, $5.3B), eBay (37, $4.6B)	2	9.9 (0.7%)
Financial	Goldman (15, $43.4B), Lehman (16, $32.4B), JP Morgan (28, $79.9B), Merrill Lynch (29, $47.8B), Prudential (33, $31.7B), Franklin (41, $4.5B), Hartford (49, $27.1B)	7	266.8 (18.6%)
Leisure	Starbucks (24, $6.7B)	1	6.7 (0.4%)
Info Tech	Microsoft (34, $41.4B), Nvidia (45, $2.4B)	2	43.8 (3.1%)
	Sub-Total	**30**	**866.8 (60.4%)**
GOODS			
Technology	Apple (1, $16.2B), Jabil Circuit (18, $8.1B), EMC (20, $9.7B), TI (22, $13.4B), Cisco (23, $25.9B), Intel (25, $38.8B)	6	112.1 (7.8%)
Energy	Occidental (6, $15.2B), Baker Hughes (21, $7.2B), National Oilwell (27, $4.6B), Valero (30, $81.4B), Conoco (31, 162.4B), Marathon (32, $58.6B)	6	329.4 (23.0%)
Communications	Qualcomm (8, $6.0B), Motorola (13, $36.8B)	2	42.8 (3.0%)
Pharmaceuticals	Amgen (9, $12.4B), Gilead (17, $2.0B)	2	14.4 (1.0%)
Homebuilding	D.R.Horton (26, $14.2B), Lennar (42, $13.9B)	2	28.1 (1.9%)
Metals	Freeport (35, $4.2B)	1	4.2 (0.4%)
Machinery	Caterpillar (47, $36.3B)	1	36.3 (2.5%)
	Sub-Total	**20**	**567.3 (39.6%)**
	Total	**50**	**1,434.1 (100.0%)**

Source: Compiled from data in *Business Week*, April 3, 2006 clear, the services sector provides critical services (e.g., financial, transportation, design, supply chain, etc.) that enable the production, distribution and consumption of effective and high-quality products. Moreover, such traditional manufacturing powerhouses like GE and IBM have become more vertically integrated and are now earning an increasingly larger share of their income and profit through their services operation. For example, in 2005, IBM's pre-tax income was $12.2B (based on a total revenue stream of $91.1B) and it was divided into three parts: 28 percent from computer systems, 37 percent from software, and 35 percent from information technology services and consulting. Thus, IBM earned 28 and 72 percent of its profits from goods and services, respectively; as a result, IBM does not consider itself a computer company anymore – instead, it offers itself as a globally integrated innovation partner, one which is able to integrate expertise across industries, business processes and technologies.

What constitutes the services sector? It can be considered "to include all economic activities whose output is not a physical product or construction, is generally consumed at the time it is produced and provides added value in forms (such as convenience, amusement, timeliness, comfort or health) that are essentially intangible…" (Quinn et al., 1987). Implicit in this definition is the recognition that services production and services delivery are so integrated that they can be considered to be a single, combined stage in the services value chain, whereas the goods sector has a value chain that includes supplier, manufacturer, assembler, retailer, and customer. In fact, Tien and Berg (2003) call for viewing services as systems that require integration with other systems and processes, over both time and space; in fact, they make a case for further developing a branch of systems engineering that focuses on problems and issues which arise in the services sector. In this manner, they demonstrate how the traditional systems approach to analysis, control and optimization can be applied to a system of systems that are each within the province of a distinct service provider. They underscore this special focus not only because of the size and importance of the services sector but also because of the unique systems engineering opportunities that can be exploited in the design and joint production and delivery of services.

As we consider the future, it is perhaps more appropriate to focus on emerging electronic services. E(lectronic)-services are, of course, totally dependent on information technology; they include, as examples, financial services, banking, airline reservation systems, and consumer goods marketing. As discussed by Tien and Berg (2003), e-service enterprises interact or "co-produce" with their customers in a digital (including e-mail and Internet) medium, as compared to the physical environment in which traditional or bricks-and-mortar service enterprises interact with their customers. Similarly, in comparison to traditional services which include low-wage jobs, e-services typically employ high-wage earners – and such services are more demanding in their requirements for self-service, transaction speed, and computation. In regard to data sources that could be used to help make appropriate service decisions, both sets of services rely on multiple data sources; however, the traditional services require homogeneous (mostly quantitative) sources, while e-services require non-homogeneous (i.e., both quantitative and qualitative) sources. Paradoxically, the traditional service enterprises have been driven by data, although data availability and accuracy have been limited (especially before the pervasive use of the Universal Product Code); likewise, the emerging e-service enterprises have been driven by information (i.e., processed data), although information availability and accuracy have been limited, due to a data rich, information poor (DRIP) conundrum (Tien, 1986).

Consequently, while traditional services – like traditional manufacturing – are based on economies of scale and a standardized approach, electronic services – like electronic manufacturing – emphasize economies of expertise or knowledge and an adaptive approach. The result is a shift in focus from mass production to mass customization (whereby a service is produced and delivered in response to a customer's stated or imputed needs); it is intended to provide superior value to customers by meeting their unique needs. It is in this area of customization – where customer involvement is not only at the goods design stage but also at the manufacturing or production stage – that services and manufacturing are merging in concept. Another critical distinction between traditional and electronic services is that, although all services require decisions to be made, the former services are based on predetermined decision rules, while the latter would require real-time, adaptive decisions; that is why Tien (2003) has advanced a decision informatics paradigm that relies on both information and decision technologies from a real-time perspective. High-speed Internet access, low-cost computing, wireless networks, electronic sensors and ever-smarter software are the tools for building a global services economy. Thus, in e-commerce, sophisticated and integrated services are combining product (i.e., good or service) selection, order taking, payment processing, order fulfillment and delivery scheduling into a seamless system, all provided by distinct service providers.

Increasingly, customers or consumers want more than just traditional or electronic services; they are seeking experiences (Pine and Gilmore, 1999). Consumers walk around with their iPods, drink their coffee at Starbucks while listening to and downloading music, dine at such theme restaurants as the Hard Rock Cafe or Planet Hollywood, shop at such experiential destinations as Universal CityWalk in Los Angeles or Beursplien in Rotterdam, lose themselves in such virtual worlds as Second Life or World of Warcraft, and vacation at such theme parks as Disney World or the Dubai Ski Dome, all venues that stage a feast of engaging sensations that are provided by an integrated set of services and products or goods. There is, nevertheless, a distinction between services and experiences; a service includes a set of intangible activities carried out for the consumer, whereas an experience engages the consumer in a personal, memorable and holistic manner, one that tries to engage all of the consumer’s senses. Obviously, experiences have always been at the heart of entertainment, from plays and concerts to movies and television shows; however, the number of entertainment options has exploded with digitization and the Internet. Today, there is a vast array of new experiences, including interactive games, World Wide Web sites, motion-based simulators, 3D movies and virtual reality. Interestingly, the question may be asked: just as electronic services have accelerated the commoditization of goods, will experiences accelerate the commoditization of services?

2. Manufacturing Relationship

The interdependences, similarities and complementarities of services and manufacturing are significant (Cohen and Zyzman, 1987; Tien and Berg, 2003). Indeed, many of the recent innovations in manufacturing are relevant to the service industries. Concepts and processes such as cycle time, total quality management, quality circles, six-sigma, design for assembly, design for manufacturability, design for recycling, small-batch production, concurrent engineering, just-in-time manufacturing, rapid prototyping, flexible manufacturing, agile manufacturing, distributed manufacturing, and environmentally sound manufacturing can, for the most part, be recast in services-related terms. Thus, many of the engineering and management concepts and processes employed in manufacturing can likewise be used to deal with problems and issues arising in the services sector. As an example, the following statement – made before the U.S. Congress in 1993 – is still coherent and pertinent if the bracketed words are, respectively, substituted for the italicized words: "The changes in the global situation today are placing unprecedented demands – from customers and from increasing competition around the world – on our civilian industry to deliver low-cost, high-quality, differentiated, and even customized *products* (services). And at the same time, these forces demand that new, stronger relationships be forged between *suppliers* (service providers) and customers in the *manufacturing* (services) chain."

Tien and Berg (2003) provide a comparison between the goods and services sectors. The goods sector requires material as input, is physical in nature, involves the customer at the design stage, and employs mostly quantitative measures to assess its performance. On the other hand, the services sector requires information as input, is virtual in nature, involves the customer at the production/delivery stage, and employs mostly qualitative measures to assess its performance. Of course, even when there are similarities, it is critical that the co-producing nature of services be carefully taken into consideration. For example, in manufacturing, physical parameters, statistics of production and quality can be more precisely delineated; on the other hand, since a service operation depends on an interaction between the process of producing the service and the recipient, the characterization is necessarily more subjective and different. Consequently, a process orientation is required. Since services are to a large extent subject to customer satisfaction and since, as Tien and Cahn (1981) postulated and validated, "satisfaction is a function of expectation," service performance or satisfaction can be enhanced through the effective "management" of expectation. Parasuraman et al. (1998) employed the gap between expectation and actual service to evaluate service quality, as defined by reliability, tangibles, assurance, responsiveness and empathy.

A more insightful approach to understanding and advancing services research is to consider the differences between services and manufactured goods. As identified in Table 4, services are, by definition, co-produced; quite variable or heterogeneous in their production and delivery; physically intangible; perishable if not consumed as it is being produced or by a certain time (e.g., following a flight or train departure); focused on being personalizable; expectation-related in terms of customer satisfaction; and reusable in its entirety. On the other hand, manufactured goods are pre-produced; quite identical or substitutable in their production and use; physically tangible; "inventoryable" if not consumed; focused on being reliable; utility-related in terms of customer satisfaction; and recyclable in regard to its parts. Alternatively, in mnemonic terms and referring to Table 4, services can be considered to be "chipper", while manufactured goods are a "pitirur". Although the comparison between services and manufacturing highlights some obvious methodological differences, it is interesting to note that the physical manufactured assets depreciate with use and time, while the virtual service assets are generally reusable, and may in fact increase in value with repeated use and over time. The latter assets are predominantly processes and associated human resources that build on the skill and knowledge base accumulated by repeated interactions with the service receiver, who is involved in the co-production of the service. Thus, for example, a lecturer should get better over time, especially if the same lecture is repeated.

Table 4 Services versus manufactured goods

FOCUS	SERVICES	MANUFACTURED GOODS
Production	**C**o-Produced	**P**re-Produced
Variability	**H**eterogeneous	**I**dentical
Physicality	**I**ntangible	**T**angible
Product	**P**erishable	"**I**nventoryable"
Objective	**P**ersonalizable	**R**eliable
Satisfaction	**E**xpectation-Related	**U**tility-Related
Life Cycle	**R**eusable	**R**ecyclable
OVERALL	**CHIPPER**	**PITIRUR**

Automation – through software algorithms – has played a critical role in enhancing productivity in modern, electronic-based goods and services (including experiences). Thus, such algorithms have transformed inventory-laden, just-in-case supply chains to svelte, just-in-time manufacturing systems. In fact, productivity gains, together with increased output, have resulted in more efficient plant operations in the U. S. and throughout the world. Among the top 10 industrialized economies (i.e., U. S., Japan, Germany, China, Britain, France, Italy, Korea, Canada, and Mexico), which account for 75 percent of the world's manufacturing output, only Italy has managed not to lose factory jobs since 2000. Nevertheless, because of recent urban disruptions (e.g., 2001 9/11 tragedy, 2002 SARS – Severe Acute Respiratory Syndrome –

epidemic, 2004 South Asia Tsunami, and 2005 Hurricane Katrina), Tien (2005) suggests that we must trade off between productivity and security; between just-in-time interdependencies and just-in-case inventories; and between high-probability, low-risk life-as-usual and low-probability, high-risk catastrophes. Sheffi (2005) calls for a resilient enterprise that is able to gain competitive advantage through better risk management and more flexible supply chains.

In services, automation-driven software algorithms have transformed human resource-laden, co-producing service systems to software algorithm-laden, self-producing services. Thus, extensive manpower would be required to manually co-produce the services if automation were not available, a situation which would contribute to "Baumol's Disease". Baumol et al. (1989) recognized the connection between slow productivity growth and rising costs in certain stagnant industries within the services sector. Although automation has certainly improved productivity and decreased costs in some services (e.g., telecommunications, Internet commerce, etc.), it has not yet had a similar impact on other labor-intensive services (e.g., health care, education, etc.). However, with new technologies, some hospitals are beginning to treat their patients as customers, including the sharing of electronic records with their customers (Flower, 2006); with multimedia and broadband technologies, entire degree programs with just-in-time learning capabilities should be able to be accessed online (Tien, 2000); and, with new materials and production advances, personal fabrication systems are becoming a reality (Gershenfeld, 2005).

In addition to automation-related productivity gains, U. S. companies have also decreased its labor and overhead costs by outsourcing some of its activities, including "off shoring" manufacturing jobs to China and service jobs to India. However, a new trend is emerging, especially in regard to the "home shoring" of call-center type of service jobs. For example, all 1,400 of JetBlue Airways' reservation agents work from home. The home shore workers are typically well educated and well motivated stay-at-home spouses, seasoned retirees, disabled veterans, and part-time employees. Armed with personal computers and networked through the Internet, these workers are also more culturally sensitive than their counterparts in far away Asia. Home shoring also provides a flexible, just-in-time workforce whose performance can nevertheless still be monitored with the assistance of software agents and recording devices. While flexibility and control are the primary reasons for workers to accept home shoring assignments, the lack of fringe benefits may forestall future growth in this trend. Interestingly, the outsourcing of work to foreign, offshore companies is now being transformed to only an off shoring situation as U. S. companies gain control or invest in these foreign companies, eventually maybe even taking them over and making them wholly owned subsidiaries. For example, Electronic Data Systems (EDS) recently offered to buy 52 percent of MphasiS, a Bangalore software and back-office services company.

3. Towards Customization

Tien et al. (2004) provide a consistent approach to considering the customization of both goods and services – by first defining a value chain and then showing how it can be partitioned into a supply chain and a demand chain. The value chain consists of five logical components: the “supplier” of the raw material, the “manufacturer” of the product parts, the “assembler” of the product, the “retailer” – including the wholesaler – who stocks and sells the product, and the “customer” who purchases the product. The partitioning of the value chain into a supply and a demand chain depends on the customer order penetration point (COPP), sometimes referred to as the decoupling point or the point at which the customer order is received in the value chain. Thus, the supply chain begins with the supplier and includes all downstream components of the value chain, down to the COPP, and the demand chain begins with the customer and includes all upstream components of the value chain, up to the COPP. The manner in which these chains are managed, in turn, defines the underlying production approach.

While the COPP partitioning of the value chain has been recognized in the literature, its management and relationship to various production schemas is novel. In a make-to-stock (MTS) environment (where the COPP is at the retailer), the supply – and its chain – is somewhat given or fixed, while the demand chain can be managed (e.g., through discounting, advertising, etc.); that is, the supply chain is driven by material supply and all the products are finished before the customer order is received. The MTS supply chain is based on the principles of mass production, mass distribution and mass marketing; consequently, MTS allows for very limited product customization. In an assemble-to-order (ATO) environment (where the COPP is at the assembler), the demand – and its chain – is somewhat given or fixed, while the supply chain can be managed (e.g., through lean or just-in-time manufacturing); that is, the demand chain is driven by the arrival of a customer order, after which stocked components are assembled into a finished product. The ATO supply chain can thus be managed to allow for more customization; as examples, in addition to computer assemblers like Dell and Gateway, Nike offers a program called NikeiD that allows customers to choose the color, material, cushioning, and other attributes of their athletic shoe order, and Procter & Gamble allows women to create and order custom personal-care products such as cosmetics, fragrances, and shampoos. In a make-to-order (MTO) environment (where the COPP is at the manufacturer), the demand – and its chain – is somewhat given or fixed, while the supply chain can be managed (e.g., design-to-order); it is, like the ATO case, driven by the arrival of a customer order but, unlike the ATO case, all the components are made – and assembled – after the order arrives. The MTO supply chain can thus be totally managed to allow for full customization; however, as indicated earlier, except for special, one-time orders, neither mass customization nor real-time mass customization is a reality at this time.

Nevertheless, more advanced customization environments are being planned, although their customization capability is neither massive nor timely at this time. Customization of clothing, car seats, and other body-fitted products is being advanced through laser-based, 3-D body scanners that not only capture a “point cloud” of the targeted body surface (e.g., some 150,000 points are required to create a digital skin of the entire body) but also the software algorithms that integrate the points and extract the needed size measurements. For example, European shoe makers recently initiated a project called EUROShoE (www.euro-shoe.net), in which an individual's feet are laser scanned and the data are forwarded to a CAD/CAM computer that controls the manufacturing process. Likewise, electronics giant Toshiba wants to give Web surfers and walk-in customers new tools to view digital versions of themselves trying on clothes, accessories and make-up, and Paccar custom-builds large rigs or trucks to individual specifications. We can, of course, expect to see more and more applications of this kind in the future; they will serve to close the gap between products and services. Further, the upstream components of a demand chain (i.e., up to the COPP) are sometimes eliminated for cost reduction reasons; thus, for an ATO case, the "retailer" may be unnecessary in the demand chain, and for an MTO case, both the "retailer" and "assembler" may be unnecessary.

Not surprisingly and depending on where the COPP is located, different levels of customization can be defined. More specifically, when the COPP is at the customer, Pine and Gilmore (1997) call it adaptive customization, while Tien et al. (2004) call it mass production; similarly, when the COPP is at the retailer, the assembler, and the manufacturer, Pine and Gilmore (1997), respectively, call it cosmetic customization, transparent customization and collaborative customization, while Tien et al. (2004), respectively, call it minor customization, partial mass customization and mass customization. On the other hand, Pine and Gilmore (1997) do not consider the COPP at the supplier, while Tien et al. (2004) define it as real-time mass customization.

The key purpose for the management of supply and demand chains is to smooth-out the peaks and valleys commonly seen in many supply and demand patterns, respectively. Although supply chain management (SCM) can be carried out in both the ATO and MTO environments and demand chain management (DCM) can be carried out in the MTS environment, it is helpful to provide some background on SCM and DCM. SCM became known in the early 1980s when manufacturers tried to establish strategic partnerships with their immediate suppliers; since then, the concept has been gradually extended to include procurement, production, transportation, and inventory. It is still undergoing an evolutionary process as new trends – such as globalization, the Internet, and mass customization – continue to affect the business environment. Undoubtedly, this evolution in the business landscape has resulted in SCM being the most widely used – and "abused" – term. SCM continues to be an area of research focus. A critical new SCM technology is radio frequency identification (RFID), which tags (i.e., chips with transmitters) are placed on pallets or individual items passing through the supply chain. When activated by a reader, the tags can send or receive data. Wal-Mart and the U. S. Department of Defense are beginning to mandate the use of RFID in the supply chain. The real question is how companies can go beyond compliance and derive real value from RFID. It should be emphasized that the data content on an RFID must be carefully planned. The data should be defined based on what decisions are to be made, not vice-versa. Otherwise, like the unchecked growth of data warehouses, the RFID data will only serve to aggravate the data rich, information poor (DRIP) problem, initially predicted by Tien (1986). Indeed, the DRIP problem has not only highlighted the need to only collect decision-driven data but also the need to be consistent about data definitions and other data quality concerns, as well as the need to integrate or fuse the data before they are appropriately mined for relevant information that can support critical tactical and strategic decisions.

In contrast to SCM, DCM is an area of more recent focus; it assumes that demand can be managed – thus, it seeks to influence the level, timing, and type of demand. Like SCM, it is not surprising that, given the inconsistent definitions for demand chain, there is a confusing and overlapping set of definitions for DCM. DCM methods focus on maximizing revenue from the sale of products and services and on minimizing the potential loss due to inventory obsolescence; they serve to improve demand chain flexibility in order to better respond to the known or planned supply chain. DCM seeks answers to the question of how fluctuations in demand patterns can be optimized (i.e., minimized) to match a given amount or pattern of supply.

While the concepts of supply chain management (SCM) and demand chain management (DCM) are appropriately introduced above within the context of a value chain, it is important to consider the SCM and DCM from a methodological or research perspective (Tien et al., 2004). Although only depicting a simple two-by-two, supply versus demand matrix, Table 5 provides an insightful understanding of SCM (which can occur when demand is fixed and supply is flexible) and DCM (which can occur when supply is fixed and demand is flexible). The critical research area which is highlighted in Table 5 – real-time customized management (RTCM) – can occur only when both supply and demand are flexible and, as a consequence, be simultaneously managed in real-time. Note that when both supply and demand are fixed (i.e., at the top left quadrant in Table 5), then we are unable to manage either the supply or the demand chain, and, consistent with traditional economic theory, we can only fix the price where supply and demand are matched. SCM, DCM and RTCM are respectively considered in the remainder of this section. Table 5 provides several example SCM methods; they include inventory control (i.e., controlling the location, time, and amount of inventory levels), production scheduling (i.e., scheduling the timing and amount of production), distribution planning (i.e., planning the location, time, and amount of inventory movement), capacity revenue management (i.e., employing revenue management techniques to allocate capacity among products and, if appropriate, customers), and reverse auctions (i.e., providing price bids by sellers for items demanded by customers). Several comments should be made regarding SCM methods. First, it should be noted that most of the SCM methods are implemented in combination; indeed, the integration of these methods is one of the areas of extensive research in the SCM literature. Second, although revenue management is usually considered to be a demand chain management (DCM) tool (in which case, a fixed level of typically perishable products is consumed – and thereby revenue is enhanced – by managing the demand chain), it has also been employed as a capacity allocation tool; consequently, we refer to the DCM method as product revenue management and the SCM tool as capacity revenue management. Third, the taxonomy provided in Table 5 is both effective and insightful; thus, while reverse auction is typically considered to be a DCM method, it is appropriately identified as an SCM method since the supply chain is what is managed, while demand is assumed to be given.

Table 5 Research taxonomy for demand and supply chains

	Demand	
Supply	**Fixed**	**Flexible**
Fixed	**Unable To Manage** Price Established (At Point Where Fixed Demand Matches Fixed Supply)	**Demand Chain Management (DCM)** Product Revenue Management Dynamic Pricing Target Marketing Expectation Management Auctions
Flexible	**Supply Chain Management (SCM)** Inventory Control Production Scheduling Distribution Planning Capacity Revenue Management Reverse Auctions	**Real-Time Customized Management (RTCM)** Customized Bundling Customized Revenue Management Customized Pricing Customized Modularization Customized Co-Production Systems

Table 5 also provides several example DCM methods; they include product revenue management (e.g., overbooking or selling beyond capacity as a hedge against order cancellations; bumping or postponing an existing order subject to a possible discount; diverting or substituting a customer order subject to a possible discount; upgrading or allowing for, say, rush orders subject to a possible premium; and advance purchasing or requiring customers to purchase in advance of consumption), dynamic pricing (e.g., discounting or lowering price to stimulate demand; premium pricing or increasing price to lower demand), target marketing (i.e., marketing products to a targeted group of customers who are likely to respond positively), expectation management (i.e., managing customer expectation so that it is aligned with performance), and auctioning (i.e., customers offering price bids for a limited supply of items). Several comments should also be made regarding DCM methods. First, the DCM method of product revenue management has been applied to such products as seats on a flight, seats on a train, and rooms in a hotel – all items which, respectively, would expire or perish when the flight takes off, the train leaves the station, and night makes way for another day at the hotel. Second, due to the fact that price is the most natural mechanism for influencing demand, it is not surprising that dynamic pricing is the most widely used DCM method; they include the impact of pricing on production, lead-time, capacity selection, ordering, and tracking customer valuation curves (Yasar and Tien, 2003). Third, target marketing is becoming increasingly popular as a DCM tool for such Internet businesses as Amazon.com; however, it is not yet mass customizing since it is currently targeted at groups of customers or market segments – of course when it is targeted on an individual basis, then mass customization will become a reality. Current methods for target marketing aim to identify the similarity between a specific customer and a group of customers whose attributes are known. These methods would be ineffective in a mass customization environment due to the fact that the size of the customer segment is reduced to one. Fourth, the whole purpose of employing expectation management is to increase customer satisfaction, inasmuch as a customer's satisfaction with a service or product is a function of his/her expectation of how well the service might be rendered or the product may perform (i.e., greatly satisfied if performance is considerably above expectation and greatly dissatisfied if performance is considerably below expectation). Therefore, satisfaction can be enhanced through the effective management of expectation (Tien and Cahn, 1981).

Referring to Table 5, simultaneous and real-time management of supply and demand chains leads to real-time customized management (RTCM), which, in turn, constitutes the basis for real-time mass customization. It should be noted that, although relevant, the conduct of SCM and its corresponding impact on the demand chain – or the conduct of DCM and its corresponding impact on the supply chain – is not equivalent to RTCM. Moreover, the integration of the supply and demand chains is also not equivalent to undertaking RTCM; that is, while such efforts do serve to integrate the supply and demand parts of the value chain, they are not, however, equivalent to the simultaneous management of these two parts. On the other hand, in order to effectively and efficiently carry out RTCM, chain integration must also be a part of RTCM, following the simultaneous management of the chains.

Returning to Table 5, several points should be made regarding the RTCM. First, it is the quadrant where real-time mass customization is supported and where products and services are so complementary and overlapping that one can consider the resultant outcome to be a totally new product/service, one in which the resultant product and service are co-produced. Second, it is the quadrant where there are new opportunities for reengineering product structures and manufacturing technologies, opportunities that would be better suited for the co-production of highly customized products and services. The high degree of personalization would imply that each product/service that is provided to each customer is unique and that the product/service life cycle begins with customer order placement and ends with order fulfillment. Third, it is the quadrant where new analysis, modeling and decision making techniques are required to deal with real-time mass customization. Indeed, many of the existing mathematical programming based and queuing theory based methodologies for managing supply and demand chains would not be scalable, and possibly even not relevant in the highly dynamic environments of real-time mass customization. While such steady state techniques are known to be very useful in optimizing supply chain performance when demand is assumed to be fixed, and vice versa, they are of limited use in the presence of flexible supply and demand chains which never reach steady state, especially as product/service life cycles become increasingly shorter. Instead, as speed and flexibility become more critical, the time available for decision analysis and performance evaluation would be reduced and real-time decision support systems that are dynamic and adaptive, like decision informatics (Tien, 2003), would become essential. Fourth, it is the quadrant where not only are new technologies and techniques required but also where new products/services will abound. For example, the handful of differently constituted vitamin pills that is available on the market today will be displaced by almost an infinite number of differently constituted vitamin pills, each customized to a person's genetic make-up, weight, etc. In this regard, RTCM may well be considered to be the ultimate or most ideal demand-driven supply chain; it is clearly a rich area for research and development.

The question, however, remains: What methods are needed to move towards real-time mass customization? Interestingly, the taxonomy depicted in Table 5 suggests three approaches. First, we could extend the SCM methods in the bottom left quadrant to allow for flexible demand, thus yielding possible RTCM methods that are appropriate for the bottom right quadrant. Second, we could similarly extend the DCM methods in the upper right quadrant to allow for flexible supply, thus yielding possible RTCM methods that are appropriate for the bottom right quadrant. Third, we could develop RTCM that could explicitly address the simultaneous management of both the supply and demand chains. Possible methods could include customized bundling, customized revenue management, customized pricing, customized modularization, and customized co-production systems. Yasar (2005), for example, combines two SCM methods (i.e., capacity rationing and capacity extending) and two DCM methods (i.e., demand bumping and demand recapturing) to deal with the real-time customized management of, as examples, either a goods problem concerned with the rationing of equipment to produce classes of products or a services problem concerned with the rationing of consultants to co-produce classes of services. A number of findings and insights are identified, including the fact that the combined approach is considerably more profitable than sequencing the SCM and DCM methods. In sum, the benefits of real-time mass customization can not be over-stated as manufactured goods and services become indistinguishable and are co-produced in real-time, resulting in an overwhelming competitive economic advantage.

Finally, it should be noted that customization is both an enabler and a driver for services innovation. After a detailed review and analysis, Tien (2006) suggests that innovation in the services area – especially in e(lectronic)-services – are facilitated by nine major innovation enablers (i.e., decision informatics, software algorithms, automation, telecommunication, collaboration, standardization, customization, organization, and globalization) and motivated by four innovation drivers (i.e., collaboration, customization, integration and adaptation). Not surprisingly, all four drivers are directed at empowering the individual – that is, at recognizing that the individual can, respectively, contribute in a collaborative situation, receive customized or personalized attention, access an integrated system or process, and obtain adaptive real-time or just-in-time input.

4. Intellectual Property

Another critical difference between manufacturing and services concerns their intellectual property (Berg and Einspruch, 2006a). More specifically and in contrast to a manufactured product, services are based on intellectual property that is rarely protected by any patents belonging to the service provider. Usually the service provider uses physical technologies or products that belong to outside suppliers who protect their intellectual property by patents. However, the use of the intellectual property, either by product purchase or by license, is available non-exclusively to all competing service providers. Examples abound: the airline industry uses jet airplanes, which technology is protected by patents owned by the aircraft manufacturers and other suppliers; Wal-Mart, as part of its vaunted supply chain leadership, relies on point-of-sales cash registers developed and sold by IBM, which holds the intellectual property for those devices; and Citibank, the leader in employing the automated teller machine (ATM) innovation, does not hold the ATM-related patents – Diebold does.

Rather than the service processes being protected by intellectual property owned by the service provider itself, the service businesses often obtain competitive advantages in a different manner and by employing intangible assets. As examples, they use branding (e.g., Starbucks) to differentiate themselves from competitors; they use high switching costs (e.g., Microsoft) to make it difficult for customers to go over to other vendors; and they use supply chain cost advantages (e.g., Wal-Mart) or other organizational strengths. Another approach to creating competitive advantages or service value, not necessarily derived from intellectual property, is to utilize network externalities (e.g., eBay) for increasing the number of users. Admittedly, eBay and Microsoft also protect their intellectual property by patents and copyrights, but there is disproportionately more intellectual property protection in manufacturing than in services – that is, much more than 20 percent of the patents issued are in the goods sector, or conversely, much less than 80 percent of the patents issued are in the services sector, which, as indicated in Table 1, is now employing 82.1 percent of the U. S. workforce.

As a consequence and for the reasons enumerated above, services innovation focus on a knowledge-based understanding of technologies; they help to generate a new and valuable service and/or experience (which, like Starbucks, can be considered to be a closely integrated product and service). Therefore, the ability of service enterprises to readily understand, adapt, utilize, incorporate technologies and processes developed by others is essential for their commercial success. In particular, software algorithms make a computer operational and provide it with flexibility and intelligence. Moreover, with the introduction of personal computers, which have rapidly increased in power and performance, software has emerged as an important commercial product in its own right, one that can be marketed to individuals and small business as well as big business and the government. Interestingly, software may eventually be marketed and sold like an utility (e.g., water or electricity), on demand and as needed.

To the degree that services can be implemented through software algorithms, they can be considered, under the law, intellectual property and therefore entitled to protection from persons who seek to exploit it illegally. Software can be protected through the use of trade secrets, copyrights, patents, and trademarks. Trade secret protection may apply to unpublished works and the basic software instructions called source code. A person who works on developing a software considered to be a trade secret is required to sign a nondisclosure agreement; it is a contract that obligates the person signing it to keep the project a secret. Once software is developed and is ready to be sold, it can be copyrighted. Copyright protects the expression of an idea, not the idea itself. For example, a person could not copyright the idea of a computer database management system but could copyright the structure and content of a database software program that expresses the idea of a database system. However, court decisions appear to have limited copyright protection for some features of software. In Apple Computer v. Microsoft Corporation, 35 F.3d 1435 (9th Cir. 1994), the court held that Apple Computer could not copyright the graphical user interface (GUI) it had developed for its Macintosh computer. Microsoft Corporation's Windows software program contained a GUI nearly identical to Apple's. The court stated that Microsoft and other software developers were free to copy the "functional" elements of Apple's GUI because there are only a limited number of ways that the basic GUI can be implemented. Additionally, in Lotus Development Corp. v. Borland International, 49 F.3d 807 (1st Cir. 1995), Lotus alleged that Borland had copied the hierarchical menu system of the Lotus 1-2-3 spreadsheet program in its Quattro spreadsheet program. The court of appeals ruled that Borland had not infringed on Lotus's copyright because the menu’s command hierarchy was a "method of operation," which is not copyrightable under Federal copyright law (17 U.S.C.A. § 102(b)).

Patent law provides another means of protecting software. A patent protects the idea itself. It is, however, a difficult venue because it takes a significant amount of both time (usually two years) and money to obtain a patent from the U.S. Patent and Trademark Office (USPTO). The patent process is complicated and technical, with the applicant required to prove that a patent is deserved. Because the shelf life of a software program is often short, seeking a patent for the program is often impractical. Trademark law, on the other hand, protects the name of the software, not the software itself. Actually, protecting a name from being used by others can be more valuable than other forms of protection.

When software is leased or sold, the purchaser usually must agree to accept a software license, which details how the software is to be used and limits its distribution. A software license is an effective tool in preventing piracy. When consumers buy software from a software company or through a third-party business, they find in the packaging a software license. The license is typically on the sealed envelope that contains the software media, which itself is in a plastic wrapping. These "shrink-wrap licenses" describe contractual conditions regarding the purchaser's use of the software, and the opening of the shrink-wrap, according to the license, constitutes acceptance of all of the terms contained in the license agreement. The purchaser is informed that the software is licensed and not sold to the purchaser. By retaining title to the software, the software owner imposes conditions on the purchaser, or licensee, that are not otherwise permissible under Federal copyright law. The principal terms of the shrink-wrap license include prohibiting the unauthorized copying and renting of the software, prohibiting reverse engineering (i.e., figuring out how the software works) and modifications of the software, limiting the use of the software to one computer, disclaiming warranties, and limiting liabilities. The enforceability of shrink-wrap licenses has nevertheless been challenged in the courts. The prevailing view is that when mass-market prepackaged software is sold, the transaction is a sale of goods and not a true license agreement. The key issue is whether the license document is part of an enforceable contract. Defenders of shrink-wrap licenses argue that the purchaser agrees to the conditions of the license after breaking the packaging seal and therefore contract law must uphold the written terms of the contract. Opponents argue that the sequence of events in the typical software purchase transaction is skewed. The purchaser is not aware of the license agreement until after the sale is consummated. The purchaser's acceptance of the license agreement is inferred when he or she opens the package or uses the software. However, the purchaser does not sign the license agreement and may not even read the terms of the license agreement.

Obviously, software developers have legitimate concerns about software piracy. For example, piracy and counterfeiting account for billions of dollars in lost software sales each year in China alone. The Software Publishers Association (SPA) and the Business Software Alliance (BSA) are key organizations that combat software piracy. The SPA is the leading international trade association for the personal computer software industry. Both SPA and BSA have collected millions of dollars worldwide from companies that have used pirated software. Most companies with pirated software are usually reported by former – and most likely disgruntled – employees. In sum, the inability to appropriately safeguard the intellectual property of services remains a major obstacle to services innovation, especially as compared to manufacturing innovation.

Another approach to protecting the intellectual property of services is through business method patents. However, although there has been a growth of such patents granted by the USPTO, the Japan Patent Office (JPO) and the European Patent Office (EPO), the annual total number is still only in the hundreds and account for much less than one percent of all patents (OECD, 2005). In order to be patentable, a business method or process must be "useful" in the sense that it produces a useful result; furthermore, the result must yield a transformation of matter to produce a different state or thing (Wright, 2002). For example, a useful method for conducting an interview could be made transformative by adding to the claim a requirement that a computer program be used to transform an employment document into a pre-clearance rejection/acceptance letter. Similarly, a method for increasing traffic congestion could be rendered statutory by disclosing in the specification that the invention is actually useful for reducing traffic fatalities by forcing drivers to slow down. Imposing a requirement for some physical manifestation of a transformation separates abstract ideas from applied ideas. Thus, a method of operating on numbers according to steps that merely manipulate the numbers is not patentable because although the steps may transform numbers in a literal sense, there is no physical manifestation of the transformation. On the other hand, limiting the steps to execution in a digital computer does represent a physical manifestation of the transformation, inasmuch as the execution of computer instructions changes the physical state of the machine (i.e., it turns it into a different machine). As a consequence, by detailing a service in terms of a software algorithm makes it patentable, since the requirement for a transformation of matter is consistent with the "useful arts" limitation of the U.S. Constitution and the definition of "process" as interpreted by the Supreme Court. Future court decisions could help delineate the boundaries of what constitutes a sufficient transformation.

Not surprisingly, companies are fighting intellectual property theft by electronic means, with sophisticated software. However, when Sony BMG put anti-piracy or anti-copying software on their music CDs, they inadvertently opened the door for worms, viruses and other malware (Roush, 2006). Each Sony disc carried a digital rights management (DRM) software called XCP (eXtended Copy Protection), which is designed to control copying and thus limit acts of piracy. The problem was not the DRM software but a complementary rootkit program that hid the DRM from Sony customers; in so doing, it could have also been used to hide invasions by hackers with more sinister motives. The more egregious offense occurred when it was discovered that the installed software surreptitiously contacted Sony BMG via the Internet every time a customer played a copy-protected disc. When the anti-piracy attempt turned into an invasion of privacy, a class action suit ensued; Sony quickly settled the suit, claiming that the rootkit was deployed unintentionally. According to the Sony BMG website, the settlement allows "any person in possession of an XCP CD to exchange it for a replacement CD, an MP3 download of the same album, and either (a) cash payment of $7.50 and one (1) free album download from a list of 200 albums, or (b) three (3) free album downloads from that list, … (with) December 31, 2006 (being) the last day to submit a claim form". Clearly, this example demonstrates how interwoven the problems of intellectual property, damaging malware and personal privacy have become, especially as sophisticated software attempt to resolve these issues – in fact, one set of solutions can cause another set of unanticipated, if not unforeseen, problems.

5. Educational Considerations

Unfortunately, despite the tremendous growth of the services sector in the U.S. economy, the attention paid to services research and education by institutions of higher learning has been minimal. There are, of course, some notable exceptions – namely, the Fishman-Davidson Center for the Study of the Service Sector (established in 1984 at the University of Pennsylvania), the Center for Services Leadership (established in 1985 at Arizona State University), the Center for Services Research and Education (established in 1990 at Rensselaer Polytechnic Institute), and the Center for Excellence in Service (established in 2000 at the University of Maryland). Although minimal, most of the attention has been focused on services research and services courses. At Rensselaer, we have taken a two-prong approach to introducing services into our undergraduate and graduate courses; either by integrating service concepts and methods into our traditional industrial and management engineering courses or by developing new service-oriented courses like "Services Operations Management", "Information and Decision Technologies for Industrial and Service Systems", "Models for Production Control and Service Logistics", and "Global Strategic Management of Technological Innovation". In both cases and as discussed in the previous sections of this paper, we have built on or extended our manufacturing-related courses, highlighting service and manufacturing differences, interdependences, similarities, and complementarities. Not surprisingly, there is a dearth of textbooks on services – except for such noteworthy texts as Fitzsimmons and Fitzsimmons (2006) – and on the relationship between services and manufacturing.

In regard to services curricula or degree programs and except for what we have at Rensselaer, we are only aware of a few certificate programs, with each program being defined by 3-5 courses. Actually, it is not surprising that there is no undergraduate degree program in services, inasmuch as services is not a discipline – it is a multidiscipline or a combination of disciplines, including statistics, mathematics, computer science, management science, cognitive science, management, operations research, decision science, industrial engineering, systems engineering, electrical engineering, and man-machine systems. Moreover, because it– like manufacturing – is a multidiscipline, services can appropriately be the focus of a professional Master's degree. Indeed, at Rensselaer we have a Master's program in Services and Manufacturing Systems Engineering (SMSE). In the remainder of this section, our undergraduate degree in Industrial and Management Engineering (IME) and the above cited Master's degree are briefly described; again, both degrees have a focus on the services and manufacturing domains.

While certain objectives of an undergraduate education in engineering are common to all disciplinary programs, there are obvious differences that highlight the individual disciplinary fields of interest. In this regard, our baccalaureate program in IME seeks to educate students in the fundamental theories, principles, methodologies, and practices of industrial and management engineering and to develop in its graduates the ability:

- to apply a total integrated systems approach;
- to apply knowledge of manufacturing and service systems;
- to apply in-depth knowledge of computing;
- to manage people and systems;
- to design innovative products, services, facilities, equipment, processes, and systems;
- to identify, model, analyze, and solve challenging real-life problems;
- to possess a solid foundation in math and science;
- to possess strong communication skills, including in technical writing and interpersonal communications;
- to perform effectively on diverse teams, both as a leader and as a contributor;
- to be an informed member of society and broadly educated in the humanities and social sciences;
- to practice engineering in a socially responsible and ethical manner; and
- to be motivated and prepared for continued growth and learning.

As summarized in Table 6, the first two years of the IME program provide a strong foundation in basic science, engineering science, mathematics, and the humanities and social sciences. Computer-based methodologies, including simulation, modeling, and systems design, are emphasized. In the last two years of the program, students concentrate on building expertise in statistics, operations research, manufacturing, and service systems engineering. Through the appropriate choice of electives, students can gain additional depth in their selected areas of interest. Design projects span problems in both manufacturing and service systems, including information and public systems.

The SMSE Master's program actually evolved from our original program in Manufacturing Systems Engineering, which was established in 1992. As services content from our research activities began to be integrated into our manufacturing systems related courses, it became obvious that the entire degree program should be revised and, with the added introduction of a couple of services-specific courses, the program in Services and Manufacturing Systems Engineering was inaugurated in 2004. The SMSE reflects an integrated statistical, modeling, computational, design and management approach to service operations and manufacturing processes. It is a professional program, and the graduate is well versed and able to embark on a successful career in services and/or manufacturing. As detailed in Table 7, the Master's of Science (MS) degree in SMSE is a 30-credit-hour program of study. The prerequisite course – Operations Research I (or equivalent) – may be counted toward the 30-credit hour total if taken at Rensselaer and included in the Master's Plan of Study. In addition to the prerequisite course, a student's core course work includes 5 courses (i.e., Information Technology and Systems for E-Business, Systems Modeling and Decision Sciences, Discrete Event Simulation, Queuing Systems and Applications, and Knowledge Based Operations Management), leaving room for 4 to 5 courses selected from either the Service Operations or Manufacturing Processes concentrations.

Table 6 Undergraduate degree in industrial and management engineering

DSES recommends that students declare their intent to major in industrial and management engineering as early as possible in their academic career. Students are also urged to work closely with their assigned faculty advisers to ensure that all degree requirements are satisfied. This curriculum requires a minimum of 128 credit hours and completion of the course requirements shown in the typical four-year program presented below.

First Year: Fall Credit Hours	**First Year: Spring Credit Hours**
ENGR-1100 Introduction to Engineering Analysis 4	ENGR-1200 Engineering Graphics & CAD 1
ENGR-1300 Engineering Processes 1	MATH-1020 Calculus II 4
MATH-1010 Calculus I 4	PHYS-1100 Physics I 4
CHEM-1300 Chem. Principles for Engineers 4	Science Elective [1] ....…..................4
Hum. or Soc. Sci. Elective ....…..........4	Hum. or Soc. Sci. Elective ....…..................4
Second Year: Fall Credit Hours	**Second Year: Spring Credit Hours**
ENGR-2050 Introduction to Engineering Design 4	ENGR-2600 Modeling and Analysis of Uncertainty ...3
MATH-2400 Intro. to Differential Equations 4	CSCI-1190 C Programming 1
PHYS-1200 Physics II 4	DSES-2210 Prod. & Ops. Mgt. & Cost. Acctg.…….....4
Hum. or Soc. Sci. Elective 4	Multidisciplinary Engg Elective [2] 3-4
	Multidisciplinary Engg Elective [2] 3-4
Third Year: Fall Credit Hours	**Third Year: Spring Credit Hours**
DSES-4140 Statistical Analysis 4	DSES-4620 Operations Research II 3
DSES-4610 Operations Research I 3	DSES-4230 Quality Control 3
Management Elective [3] 4	ENGR-4760 Eng. Economics 3
Hum. or Soc. Sci. Elective 4	Hum. or Soc. Sci. Elective 4
Professional Development II [4] ....….........2	Free Elective 3-4
Fourth Year: Fall Credit Hours	**Fourth Year: Spring Credit Hours**
DSES-4530 Information Systems 4	DSES-4270 IME Design[6] 3
DSES-4962 Discrete Event Simulation 3	ENGR-4100 Professional Development III[6] 1
Technical Elective [5]........................ 3	DSES-4961 Supply Chain Management 3
Technical Elective [5] 3	Technical Elective [5] 3
Free Elective 3-4	Free Elective.................. 3-4

[1] Students are encouraged to select a life science course such as BIOL-1010.

[2] Students must select any two of the following approved multidisciplinary electives: ENGR-1600 Materials Science for Engineer, ENGR-2530 Strength of Materials, ENGR-2090 Engineering Dynamics, ENGR-2710 General Manufacturing Processes, ENGR-2250 Thermal and Fluid Engineering I, ENGR-4050 Mod. & Control of Dynamic Systems, ENGR-2350 Embedded Control, ENGR-4300 Electronic Instrumentation

[3] Students may select any one of the following courses to satisfy the management elective requirement: MGMT-1100 Introduction to Management, MGMT-4520 Technological Entrepreneurship, MGMT-2320 Accounting for Decision Making, MGMT-4530 Starting Up a New Venture, MGMT-4430 Marketing Principles, MGMT-4850 Managing the High Perf. Org I, MGMT-4510 Invention, Innovation & Entrepreneur, MGMT-4860 Managing the High Perf. Org II

[4] This course can be fulfilled by taking a 2-credit course from a list of courses published at the start of each semester.

[5] Students may select any three of the following courses to satisfy technical elective requirements:DSES-4200 Design and Analysis of Work Systems, DSES-4240 Engineering Project Management, DSES-4250 Facilities Design & Industrial Logistics, DSES-4260 Industrial Safety and Hygiene, DSES-4810 Computational Intelligence, DSES-4280 Dec. Focused Systems Engineering, Certain graduate level DSES courses can also serve as technical electives for eligible undergraduates with permission of the instructor and the adviser.

[6] May be taken in either fall or spring semester.

Source: *2005-2006 Catalog*, Rensselaer Polytechnic Institute

Table 7 Master's degree in services and manufacturing systems engineering

All students seeking the MS degree in Services and Manufacturing Systems Engineering (SMSE) must complete the following courses in their 30-credit-hour program of study. The prerequisite course – Operations Research I (or equivalent) – may be counted toward the 30-credit hour total if taken at Rensselaer and included in the Master's Plan of Study. In addition to the prerequisite course, a student's core course work will include:

- DSES-6570 Information Technology and Systems for E-Business
- DSES-6610 Systems Modeling and Decision Sciences
- DSES-6620 Discrete Event Simulation
- DSES-6820 Queuing Systems and Applications
- MGMT-6960 Knowledge Based Operations Management

Concentrations: Students must select the remaining 4 to 5 courses in the Plan of Study from either the Service Operations or Manufacturing Processes concentrations. The Service Operations concentration includes the following courses:

- DSES-6110 Introduction to Applied Statistics
- DSES-6140 Exploratory Data Analysis
- DSES-6180 Knowledge Discovery with Data Mining
- DSES-6470/MGMT-6610 Global Strategic Management of Technological Innovation
- DSES-6480/MGMT-6480 Services Operations Management
- DSES-6500 Information & Decision Technologies for Industrial and Service Systems
- DSES-6600 Models for Production Control & Service Logistics
- DSES-6630 Continuous Simulation and Financial Mathematics
- DSES-6640 Quantitative Analysis of Health Systems
- DSES-6860 Evaluation Methods for Decision Making
- DSES-6870 Introduction to Neural Networks
- DSES-6990/6980 Master's Project in Services System
- MATH-4740 Mathematics of Finance
- MGMT-6240 Financial Trading and Investing
- MGMT-6690 Supply Chain Management for E-Business

Source: *2005-2006 Catalog*, Rensselaer Polytechnic Institute

Finally, it should be noted that graduates from our IME undergraduate and SMSE Master's programs, as well as from our Ph.D. program in Decision Sciences and Engineering Systems (DSES), are in high demand and typically have several job offers. The types of offers, however, have changed over time as the hiring of Rensselaer graduates by employers in the goods sector began to decrease in favor of services employment; today, as indicated in Table 2, the majority of our graduates are entering the workforce as employees in the services sector. Indeed, while some of the same well-known goods companies (e.g., General Motors, Boeing) are still hiring large numbers of our graduates, it is their services divisions that are doing the hiring.

6. Concluding Remarks

The theme of this paper is that we can and should build services research and education on what has occurred in manufacturing research and education; indeed, as stated in Section 3, services and manufactured goods become indistinguishable as they are jointly co-produced in real-time. Fortunately, inasmuch as manufacturing concepts, methodologies and technologies have been developed and refined over a long period of time (i.e., since the 1800s), the complementary set of concepts, methodologies and technologies for services are more obvious. However, while new technologies (e.g., the Internet) and globalization trends (Friedman, 2005) have served to enable, if not facilitate, services innovation (Berg and Einspruch, 2006b), the same technologies (e.g., the Internet) and 21st Century realities (e.g., terrorism) are making services innovation a far more complex problem and, in fact, may be undermining previous innovations in both services and manufacturing (Tien, 2006).

A final remark relates to the economic measurement of services itself. Corrado et al. (2005) are concerned that while the government's decades-old system of data collection and statistical analysis are appropriate for capturing tangible investments in equipment, buildings and even software, they are inadequate in reflecting the growing knowledge economy, one driven by intangible ideas and innovation. In other words, the Bureau of Economic Analysis in Washington, D. C., is not tracking the billions of dollars that companies spend each year on innovation and product design, brand-building, employee training, or any of the other investments – not consumption costs – that are required to compete in today's global economy. As a result, services-oriented economies – like those of the U. S. and Japan – are probably much stronger than the official statistics indicate. Such an innovation in economic measurements may result in a "knowledge-adjusted" GDP metric which could, in turn, provide a greater motivation for focusing on services research and education.

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