ENGINEERS AND SERVICES INNOVATION

Manufacturers in the UK have to develop new and innovative ways to maintain hard-won market positions to protect proprietary technology or compete with low-cost economies. One approach is through services-led competitive strategies. In this first of two articles the authors deal with the need to prepare engineers for a manufacturing industry built around services. The second article (on page 36) examines the threats and opportunities facing manufacturers who move into services.

The contribution of engineers to innovation in the service industry is not always immediately obvious. However, engineers bring a specialised set of skills that often enable the development of cheaper, better and more personalised services. Mark Dodgson, David Gann and Irving Wladawsky-Berger explain how education can help engineers further develop the service economy.

When Apple sells an iPhone, it has sold much more than a piece of hardware. It has drawn the buyer into a 'service economy', providing access, at a cost, to a vast array of information services. There are currently over 220,000 third-party applications available for the iPhone, offering a bewildering array of services, and creating a great deal of new wealth.

This is just one example of innovation in services, innovations that differ in many ways from those found in the industrial economy. It is important to analyse the changing pattern of innovation, and engineers need to appreciate the differences to acquire and develop the capabilities they will need if they are to make a bigger contribution to a new wave of economic growth.

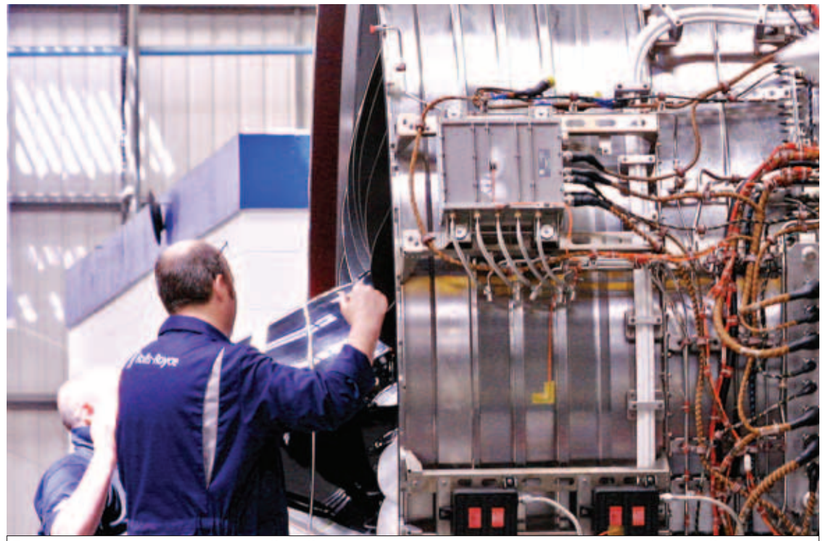
Employment in services, such as healthcare, finance and communications, comprise the largest component of global economic activity, accounting for the majority of jobs in most developed economies. Recent data from the Organisation for Economic Co-operation and Development shows that in the USA, manufacturing accounts for 14% of GDP and services for 76%. In the UK, the figures were 13% and 75% respectively. Even in China, the powerhouse of much global manufacturing, a third of GDP was from manufacturing while services accounted for 40%.

The emergence of services as the dominant activity in advanced economies has led to speculation on how science, technology, engineering and mathematics (STEM) contribute to their development. Innovation in manufacturing depends on the skills, tools and processes of engineers. The contribution of engineering to services is similarly profound but less immediately obvious.

STEM CONTRIBUTIONS

Engineering's biggest contribution to services innovation is probably through the education of people who apply scientific approaches in their work, and through the development and use of the digital technologies that underpin service delivery and innovation. These are the more visible roles of engineering in services innovation. Other contributions are obscured by the difficulties in distinguishing between services and other activities, a reflection of the blurring of boundaries as different disciplines, professions and organisations come together to solve complex problems.

Examples of how STEM contributes to services innovation include the internet, the algorithms that brought Google its success, and the complex



The service concept is so important to Rolls-Royce that the company has registered trademarks for both Power-by-the-Hour and TotalCare. Under these contracts, Rolls-Royce provides airlines with a predictable service cost for engine operations. The vast majority of airlines operating the latest Rolls-Royce civil engine have signed Totalcare deals. Defence customers often sign MissionCare contracts for equipment availability. Overall, services account for half of the company's revenues.

engineering systems that deliver energy, transport, and healthcare services. Engineering's contribution to services often appears to be disconnected from the education of future generations of engineers, and indeed from the research base more generally.

The recent report from the Royal Society, *Hidden wealth: the contribution of science to service sector innovation*, suggests that it is too easy to take STEM for granted. For example, STEM is embedded in the algorithms that drive logistic systems and in human capital. The report shows that service organisations are the largest employers of STEM graduates, with 82% working in the services sector in the UK.

If engineering graduates are to make a greater contribution to innovation in services, then it is important to provide them with appropriate education and training in four broad capabilities. These are: the traditional engineer's knowledge of a specific domain; analytical skills; the ability to collaborate with people from other disciplines; and knowledge of organisational systems and processes.

KEY SKILLS

Analytical skills are required for decision-making in complex and unpredictable social systems, such as urban environments, healthcare and financial systems. These skills need to be strongly mathematical and should utilise the massive increase in the amount of data available from sensors and computing. Analytical skills also require expertise in simulation and modelling of these systems, complex control theory, real-time information analysis, and design and optimisation, all of which can be found in traditional engineering skills.

From the business perspective, analytical expertise is also important in market and user analysis, modelling value creation in business, and measuring and managing risk and performance. Examples of how analytics contribute here include the use of Monte Carlo and Markov simulations in data security, transportation and logistics. These skills are widely used in such companies as PayPal, Tesco and Rolls-Royce. When Rolls-Royce combined selling aero engines with a service offering, providing TotalCare, it depended on the company's analytics expertise and its deep knowledge in engine design and capability to assess engine performance and schedule maintenance. As a result the company's revenue from services has tripled between 1998 and 2007.

Companies profit from new approaches to organising their processes, logistics and customer experiences: so-called 'business model innovation.' Service firms that have been very successful at business model innovation – such as Amazon, Google and EasyJet – are often underpinned by deep mathematical modelling capabilities.

The transformation of the services economy also changes the context in which engineers contribute to innovation where traditional engineering concentrates on the design and manufacture of high quality products at competitive prices, innovation in services focuses first and foremost on consumers and their experiences. In this way, service innovation focuses directly on appreciating and meeting human needs and market demands. In services, innovation requires greater emphasis on understanding and adapting systems made up of information, people and organisations. This is why we believe that innovation in services also requires engineers to have knowledge of business systems and processes.

Service innovation also changes the culture and organisation of the innovation process itself. While conventional engineering draws on engineers working in isolation with a deep 'vertical' knowledge of specific disciplines, knowledge that is still crucial to the development of services, innovation in services also draws on many different disciplines working together.

COMBINING SKILL SETS

Services are often highly interconnected. Innovations in the insurance industry, for example, are related to changes in the medical system, the design of safer buildings and the building of better roads.

Understanding these connections requires knowledge of what happens at boundaries between disciplines and professions. Interdisciplinary and collaborative skills are therefore often critical. This is why we see the ability to collaborate with people from other disciplines as one of the four broad capabilities that engineers will need to participate fully in service innovation.

Innovation in services needs teams that bring different skills to bear on the design, development and management of systems and processes. This requires 'horizontal' expertise and an understanding of the behaviour of individuals, groups and organisations in related fields. Such expertise requires the development of professionals with deep knowledge in one or two fields and who also have a broad knowledge of other fields that are critical to solving complex challenges.

Collaboration is especially important as services are not produced in the laboratories and factories of the industrial R&D arena where they can be fully tested and optimised. Services are usually produced at the point at which they are consumed: the act of consumption rather than invention is the focal point for innovation. New services are therefore developed using a 'market-facing' approach, often connected to people and organisations that articulate and express their requirements and demands as they use the innovation. For example, companies like Amazon and Google, or online gaming and entertainment businesses, typically conduct hundreds of experiments a day, using different versions of web pages to test consumer preferences.

This emphasises the importance of prototypes and shared experiments with users in real time, including with employees, partners, clients and the public at large. These high levels of collaboration are symptomatic of what has become known as 'open' innovation.

The nature of services innovation implies that answers to technical problems will not lie exclusively within research institutions or companies with proprietary R&D cultures. Instead, they will emerge through integration of ideas from a wide range of organisations with which they have had little or no previous experience. Furthermore, the delivery of cheaper, better and more personalised services will require a multi-disciplinary framework for collaboration, involving STEM alongside the social sciences and humanities.

FUTURE PROOFING

Technologies, such as virtual prototyping, simulation and modelling, can assist collaboration by drawing on multiple perspectives and expertise. These technologies have profound consequences for the role of engineers in the organisation and management of services innovation. They hold the possibility of major productivity improvements in services themselves, comparable to the advent of machine tools in the 1850s or lean production in the 1980s.

Research organisations are already responding to these changes. This is seen in the development of large university teams researching the interdisciplinary problems of transportation, healthcare, energy, the environment and new digital media. It is seen in new education programmes that build on interdisciplinarity and use the new supportive technologies. Examples of such developments include joint programmes between the engineering and business schools at Imperial College London and MIT.

These activities include Design London and MIT's System Design and Management Program. Design London, an initiative of Imperial College and the Royal College of Art, is a multi-disciplinary centre that offers postgraduate programmes with a common course on Innovation, Entrepreneurship and Design. Students use an Innovation Technology Centre supporting the virtual design of services. MIT's programme combines courses from its Sloan School of Management and School of Engineering, which jointly grant the resulting Master of Science degree.

The pace of change in services is not likely to slow down. Indeed, there is the potential for a new wave of innovation, based on rapidly expanding markets for personalised services, and taking advantage of the availability of massive amounts of data from ubiquitous sensors and devices and the availability of hardware and software to analyse this data flood. Realising this potential depends on the capabilities we have identified, developing and using the emerging technological infrastructure to support innovation. These skills and technologies will also be essential if we are to deal with the intractable social and economic problems we face in health, energy and environment.

The changing pattern of innovation has implications for the way in which we conduct R&D. The private and public sectors invest around $1 trillion a year in the production of knowledge. This investment inevitably affects innovation in services, raising questions about how we choose where and how to spend that money.

Engineering's influence in these opportunities and challenges will rise when its contribution is less hidden than it has been. Engineers need to learn to engage effectively with people and organisations with which they have little contact in the past. This requires the ability to cross traditional boundaries and a new approach to the education of scientists and engineers.

BIOGRAPHIES

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