



Science & Technology Value Creation (STVC) 2015 Panel Report

Innovative Services



Science and Engineering
Research Council

Contents

Executive Summary	ii
Chapter 1 Introduction to Innovative Services	1
1.1. Introduction – The demand for innovative services	1
1.2. Innovative Services as a sector.....	2
1.3. Key drivers and global trends.....	3
1.3.1. Demographic Trends	4
1.3.2. Business and Technology Trends.....	5
1.3.3. Environment and Individual Trends	5
Chapter 2 Vision	7
2.1. Impact of Innovative Services on economy	7
2.2. Services as a Sector	8
2.3. Key enabling technologies and platforms.....	9
2.4. High level economic potential and impact	9
2.4.1. Economic potential and impact in Healthcare	11
2.4.2. Economic potential and impact in Education	11
2.4.3. Economic potential and impact in Retail	12
2.4.4. Economic potential and impact in Transportation	12
Chapter 3 Proposed Programmes	14
3.1. Value-chain approach	14
3.1.1. Key user segments	14
3.1.2. 3-Dimensional Cube analysis	15
3.2. Description of Proposed Programmes.....	17
3.2.1. Programmes in the Healthcare Sector	17
3.2.2. Programmes in the Education Sector.....	20
3.2.3. Programmes in the Manufacturing Sector	24
3.2.4. Programmes in the Retail Sector	26
3.2.6. Summary of Programmes and Key Technologies	31
3.3. Recommended Programme Time Horizon	33
Chapter 4 Conclusions and Recommendations	34
Acknowledgements	35

Executive Summary

The global economy is currently transitioning from a goods-based economy to an economy in which value creation, employment and economic wealth depends on services. Services play an important role in the growth of Singapore's economy and development, contributing up to two-thirds of Singapore's GDP.

This report presents the findings of the Innovative Services panel, which is comprised of 11 members from all 7 Research Institutes of the Science and Engineering Research Council (SERC). The panel followed a picture-of-the-future approach and identified 11 research innovative services programmes under 5 clusters namely, Healthcare, Education, Manufacturing, Retail and Transportation that could most likely bring significant socio-economic impacts to Singapore given the capabilities of A*STAR.

It was clear that some capabilities crucial to advances innovations in services is lacking. These include software and IT, systems science and integration. The panel recommends that a sufficiently large, and adequately resourced, capability group is supported in one of the SERC Research Institutes that is dedicated to service related problems.

The evidence to support the programmes was gathered from public literature, and discussions with experts, on technological developments and economic trends. These findings were then validated through various engagements and dialogue with key government agencies and stakeholders.

Chapter 1 Introduction to Innovative Services

1.1. Introduction – The demand for innovative services

A service can be defined as a dynamic configuration of resources (people, technology, organizations and shared information) that creates and delivers value for the customer through the provider.

Services play a key sector in many developed economies. Industries that deliver help, utilities, experience, entertainment, information, or other intellectual content have expanded rapidly in recent decades and now account for more than 70% of total value added in the Organisation for Economic Co-operation and Development (OECD) countries¹. In Singapore, service competitiveness has become increasingly more important given that the dividing line between manufacturing and services is blurring and that the structure of Singapore's economy is one where services sectors are burgeoning. And one that plays an ever greater part in value creation.

Agriculture and manufacturing used to be the key drivers of the modern world's economies and for centuries Adam Smith's belief of the "non-fixed" value of services has been held firm. The world has changed significantly and now, services have emerged as the main source of job creation in most developed countries, often mitigating for job losses in manufacturing. Business services, such as computing, information services, and R&D services, generated more than half of all employment growth in many developed countries over the past few years. In addition, global markets are increasingly becoming service-based economies. Many manufacturing companies are now reinventing and reorganizing themselves as services companies while others have diversified their business into services sectors.

Figure 1 shows that services now represent 80 percent of the US economy and China's service sector has grown 191% during the last 25 years and now makes up about 35% of the nation's economy². Services also account for more than 50% of the economies in countries such as Brazil, Germany, Japan, Russia, and the United Kingdom. In Singapore alone, services sector account for more than two-thirds of the country's GDP.

¹ "Understanding Service Sector Innovation", Communications of the ACM, July 2006.

² Linda Dailey Paulson, Services Science: A new field for today's economy, IEEE computer society, Aug 2006.

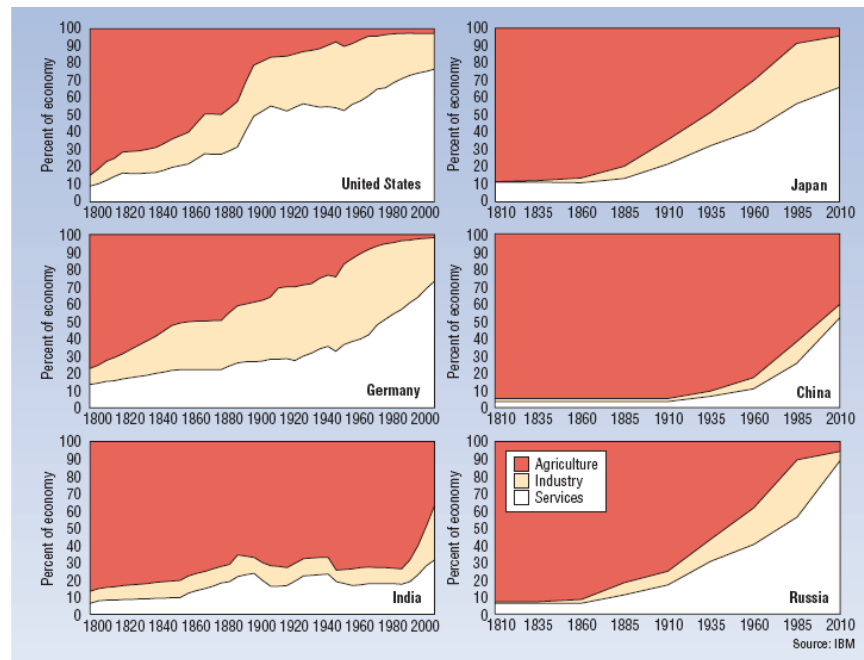


Figure 1: Services represent a growing segment of the developed and developing world's economies

1.2. Innovative Services as a sector

In the US, the National Academy of Engineering (2003)³ argued: “*service industries represent a significant source of opportunity for university-industry interaction.... Nevertheless, the academic research enterprise has not focused on or been organized to meet the needs of service businesses*”

Innovative services mean a sector comprising of various sub-sectors e.g. retail, transport, education, healthcare, manufacturing. As a sector, services can be directly attributed to measured economic outputs and is inherently multidisciplinary.

Innovation has long been recognized as the key to economic growth and development, but its role in the service sector has been underappreciated. Research funding can play an important role in stimulating service-sector innovation for economic benefits. Plans can be organized for each sub sector to develop R&D strategy for selected focus areas. For example, research could explore the challenges associated with the application of Information Technology

³ National Academy of Engineering (2003) “The impact of academic research on industrial performance”, National Academic Press, Washington D.C.

(IT) to innovative service industries, such as health care and education⁴. The focus of such research task would not be the development of specific software applications for these domains, but rather is a platform solution for complex systems that demand multidisciplinary expertise like management, IT, automation, security, system architectures, vision systems and database science. Placing a greater emphasis on technology adoption and diffusion would enable higher productivity and offer specialized services to consumers⁵. A classic example of an innovation that has helped transformed an industry is the use of bar codes in retail. This technology is now pervasive in retail as it links together information and communication. Having a greater emphasis on technology diffusion would enable advances in productivity and help to spread innovative approaches throughout the highly fragmented service sector⁶.

1.3. Key drivers and global trends

The growing importance of services in the economy implies that efforts to improve standards of living, boost productivity, and create jobs must focus increasingly on the service sector. Knowledge-intensive services, whose value added is intangible rather than incorporated into physical products is increasingly playing a dynamic and pivotal role in the economy today, contributing to innovation in all economic sectors. When deciding on the areas to develop in the services sector, it is crucial to review global trends that entail services innovation as well important domains that challenge sustainable improvement efforts.

The panel brainstormed on the various global trends which are relevant to the innovative services theme. By taking into account the impact to the Singapore economy and the likelihood of occurrence, the panel identified several key trends. See Figure 2 for details.

⁴ CSTB. Making IT Better: Expanding Information Technology Research to Meet Society's Needs. National Academy Press, Washington, DC., 2000.

⁵ Alic, J. Postindustrial technology policy. Research Policy 30 (2001), 873–889.

⁶ Alic, J. Postindustrial technology policy. Research Policy 30 (2001), 873–889.

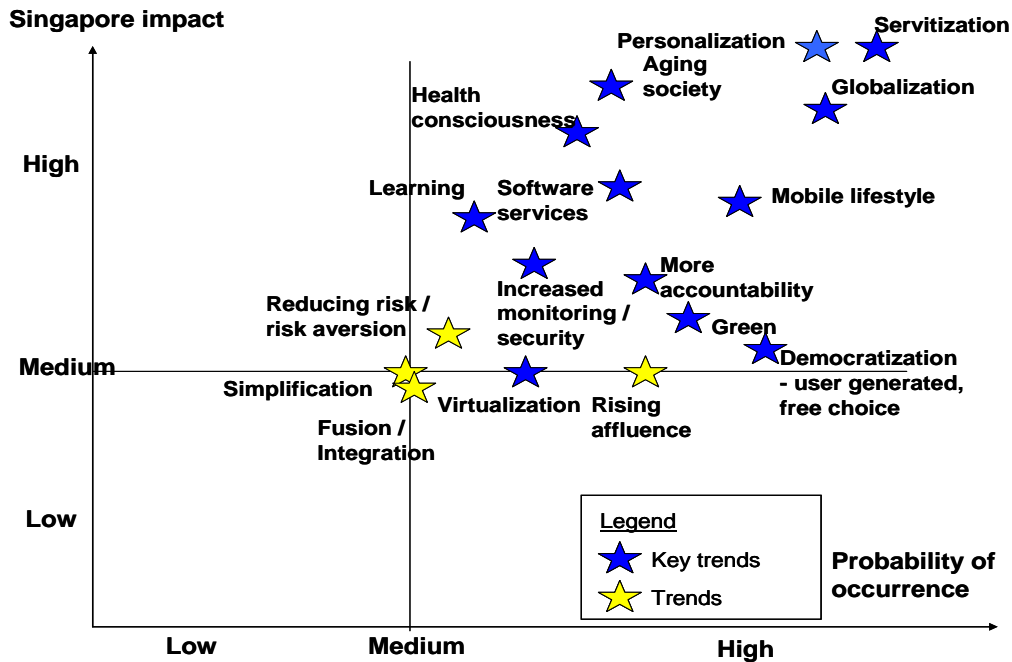


Figure 2: Key Trends relevant to the Innovative Services theme

1.3.1. Demographic Trends

Demographic trends (aging society) and sustainability concerns (health consciousness and green technologies) will drive the demand for innovation in service activities

Demographic trends point towards a more aged, more educated and wealthier population in many of today’s developed countries and this is expected to continue to drive the demand for healthcare, education, transportation, retail and manufacturing.

The society is changing and the middle class market segments in developing countries are growing rapidly. Over the next several decades, the number of people considered to be in the “global middle class” is projected to swell from 440 million to 1.2 billion or from 7.6 % of the world’s population to 16.1 %, according to the World Bank⁷. Most of the entrants will come from China and India, and there would be rising expectation for service quality.

⁷ Global Trends 2025: A transformed world, pp 8, Nov 2008.

In the developed countries, the period of most rapid growth in the ratio of seniors (aged 65 and above) to the working-age population will occur during the next twenty years (2010 – 2030). This period will provide many opportunities for the healthcare and wellness industries.

Different demographic segments will demand different levels of service, be it low-cost service or premium high-cost high value service and the design of the service experience will need to take into account the individual needs and cultural differences.

1.3.2. Business and Technology Trends

Trends in business and technology (globalization, “servitisation” of manufacturing and mobile lifestyle) will further drive the demand for business transformation service activities and innovations.

The rise of the globally integrated enterprises will continue to drive demand for information and communication technology (ICT) infrastructure services and improvements. These improvements will allow the focus to migrate to the more knowledge-intensive business activities built around the infrastructure service providers.

1.3.3. Environment and Individual Trends

Trends in empowerment of the individual (personalization, and democratization – user generated content) are particularly important to service activity growth (learning, virtualization, software services, increased monitoring and security) and more service-oriented research is needed to understand the evolution of user demands.

New information technologies have constituted a technological and industrial revolution in service provisioning that challenges many to consider redesigning their usual work flow and living patterns in unprecedented ways. Coupled with the empowerment of the individual, this has created a whole new sector in which innovation in services is necessary to create and address the needs of a new lifestyle.

As an example, the growth of the internet together with the contribution by millions of users has enabled the creation of Wikipedia (single largest encyclopedia ever assembled) which today is considered as a valuable resource for knowledge. Instead of relying on Encyclopedia Britannica as in the past,

people today use a computer terminal and "google" or search for their required info through Wikipedia which in itself is a form of software service.

Chapter 2 Vision

2.1. Impact of Innovative Services on economy

Innovative services is an enabler which provides an opportunity for transforming enterprises and for organisations to serve their customers more effectively and efficiently. With the continuation of the current supply of goods and the gradual decline in prices, the differentiation between hardware products based solely on low prices and good quality has become more blurred and products have become increasingly less competitive in the global marketplace. Many manufacturing firms do not only provide physical products but also package accompanying services with them.

In order to survive in this tough environment, it is becoming increasingly crucial that companies not only constantly improve product development capacity and productivity, but at the same time increase the differentiation of their products from their competitors by adding relevant services to meet the needs of their customers. In this way, innovation in services is becoming a more and more prominent factor for a company's competitiveness and eventual survival.

Furthermore, a deep understanding of services is not limited to the service industries but in manufacturing and other industries as well. As information technology (IT) and internet technologies develop rapidly and the Internet moves towards open platforms, there is a growing opportunity for various innovative services to be developed from this progress. Examples of IT-driven services are numerous. For instance, SaaS—Software as a Service—is a recently emerging trend where companies provide their independently developed software application through network systems.

Services over the Internet are still in their infancy, and the global economy is in the starting phases of translating existing services onto the Internet. As these services mature, it is anticipated that the openness and extensiveness of the services available will grow far beyond current levels, which will inspire an increasing number of businesses to shift their focus from products to services.

One arena in which this shift can be seen is in information technology (IT). In the past, IT providers offered IT services as a tool to carry out client companies' operations. However, as IT advances, it has grown beyond the supportive roles into one which creates new business models and processes.

With sensors and computers now available and installed in a host of locations, there is a massive flow and usage of data and information. As a result, many services that were previously treated as “mass services” are now customized to offer individual and personalized services.

In order to achieve “personalisation”, some form of decision-making systems incorporating expertise in data mining, software learning, mathematical modelling and prediction tools are needed. All of which provide rich areas for research opportunities and is similar to the capabilities built over decades in many science and engineering domains.

2.2. Services as a Sector

Many services are embedded in industry sectors in electronics, info-comms and media, chemicals, engineering and bio-medical sciences (see Figure 3). However, the panel recommends that in order to apply focus and effectively grow services R&D capabilities, it should be treated as a standalone cluster where specific R&D roadmap deliverables designed and integrated teams brought together to drive and develop programmes.

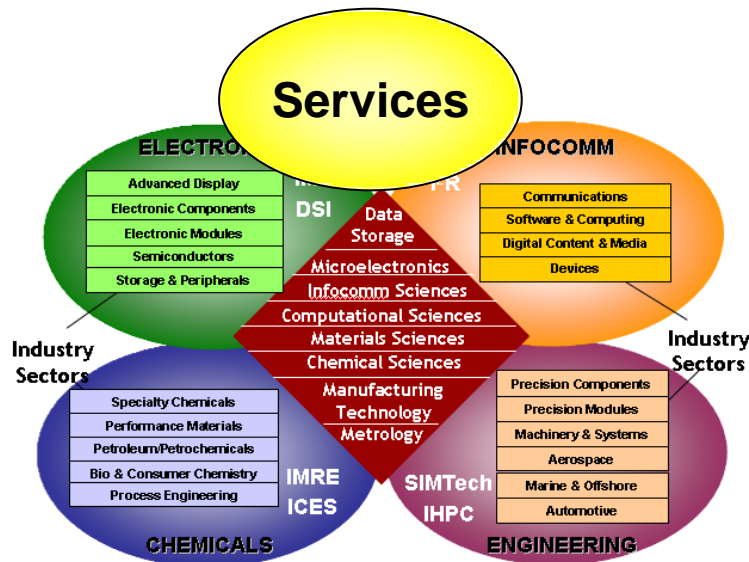


Figure 3: Growing Services as a stand-alone sector

In addition, the Services cluster can investigate opportunities for innovations in the non-traditional manufacturing arenas and into sectors such as retail, healthcare, education and transportation (see Figure 4).

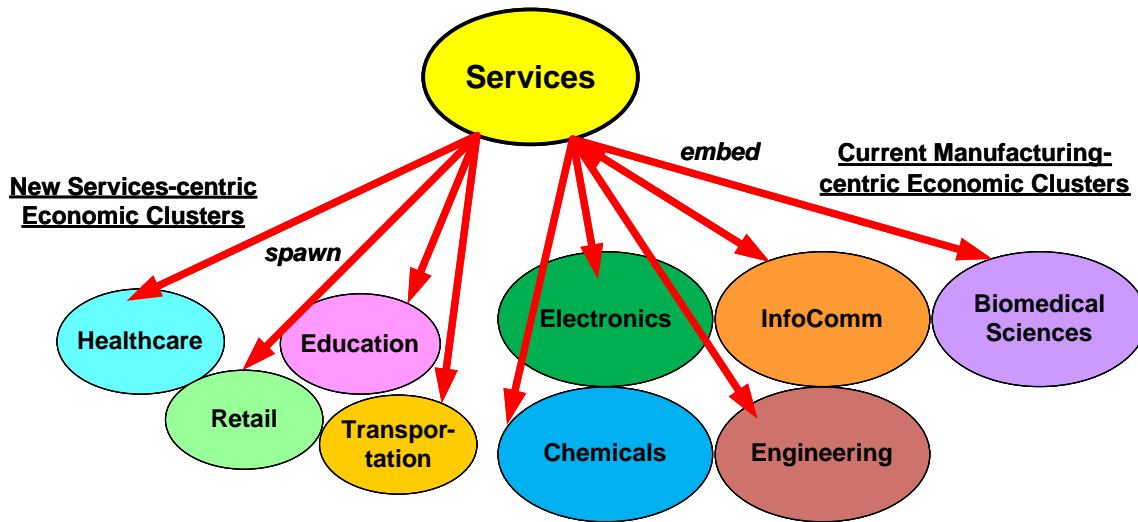


Figure 4: Services are embedded in manufacturing -centric clusters and spawn new services-centric clusters

2.3. Key enabling technologies and platforms

The service-based economy is inherently a multi-disciplinary one requiring expertise in many areas. Some of the basic capabilities would include IT and computing, ubiquitous sensing, communications, security, vision, intelligent systems and data mining. These capabilities must be tightly coupled with a services-oriented approach to solutions and a capacity to integrate elements from like computer science, manufacturing, business and management engineering.

2.4. High level economic potential and impact

Over the years, the services component has assumed greater importance in our economy. The share of services in Singapore's Gross Domestic Product (GDP) and employment has been on the rise since the mid-1980s. This is a phenomenon that is not unique to Singapore. Many developed countries such as the US, UK, France, Germany and Japan have also experienced a rising share of services as a proportion of GDP and employment as their economies matured.

In the late 1980s, to diversify Singapore's sectoral and market dependency, reduce vulnerability, and promote a broader base for the economy, services were promoted together with manufacturing as twin pillars of the economy.

Services is now one of the key pillars of the Singapore economy, it contributed 65.9 per cent of the nominal GDP and 67.7 per cent of total employment in 2007⁸ (see Figure 5). In 2006, there were 138,000 establishments in the services sector, employing a total of 1,128,000 workers, or an average of 8 workers per establishment.

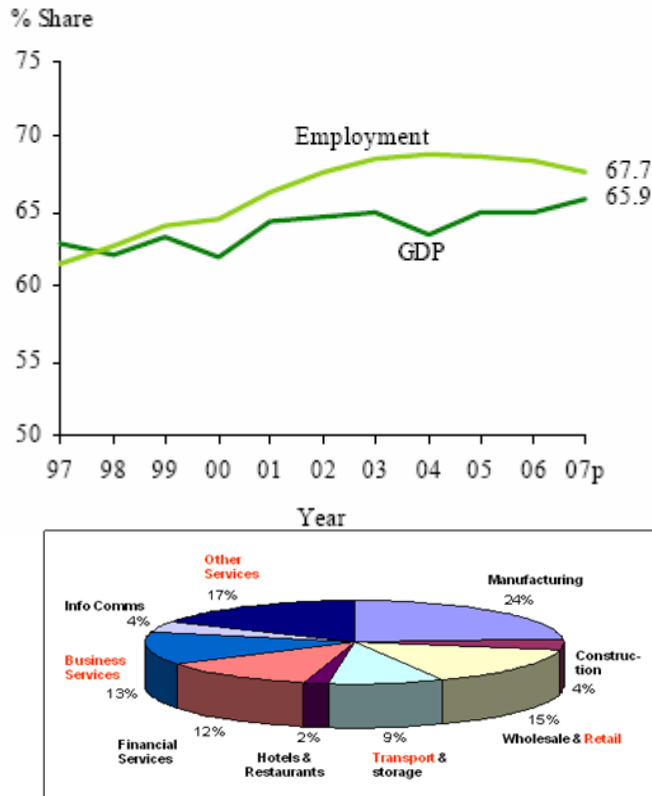


Figure 5: Services share of GDP and employment in Singapore, 1997 - 2007

Although manufacturing has been and will continue to be a key growth engine, Singapore needs to promote our service sector more actively as a second growth engine. As China, India and Greater Asia markets become increasingly sophisticated, their markets will seek better quality services in education, healthcare, transportation or retail.

There are many opportunities for our indigenous technological innovations to capitalise on these opportunities. Singapore is well placed to meet part of this

⁸ Economic survey series 2006: The services sector, published Aug 2008 by Department of statistics.

demand and be a regional services hub. In the Economic Review Committee (ERC) report⁹, one vision is to make Singapore, Asia's leading provider of world-class services. The following sections contain excerpts on the economic potential and impact from the ERC report in the healthcare, education, retail and transportation.

2.4.1. Economic potential and impact in Healthcare

Healthcare demand is inherently related to population size and purchasing power. Using this as a basis, there is a large growth potential in the regional demand for healthcare services.

Asia's population is expected to expand from 3.2 billion in 2002 to 5.6 billion in 2050 which would comprise of 60% of the World's population¹⁰. Also, consumer expenditure on healthcare services and healthcare goods for Asia is expected to double from US\$90 billion in 1999 to US\$188 billion in 2013¹¹.

2.4.2. Economic potential and impact in Education

Singapore has several compelling advantages that position it well as a global education hub. These include having a strategic geographical location, a good reputation for educational excellence and a safe cosmopolitan environment.¹²

The global educational market is estimated at US\$2.2 trillion and Singapore can capture a larger share of this and increase the educational services' contribution to GDP. The education industry is estimated to contribute S\$3.0 billion to the Singapore economy, which is 1.9% of the GDP (Department of Statistics, 2000). The sector employs 47,000 people and enrolls 50,000¹³ foreign students in Singapore in both public and private institutions.

Moreover, Education tends to be a counter-cyclical industry where the unemployed seek to retrain and upgrade themselves in times of economic downturns. This counter-cyclical characteristic of Education can help to cushion the economy during dips in the business cycle and diversify the economic base.

⁹ Economic Review Committee report, Feb 2003 (<http://app.mti.gov.sg/default.asp?id=507>).

¹⁰ Human Population: Fundamentals of Growth, Population Reference Bureau 2002.

¹¹ Euromonitor International Marketing Forecasts 2001.

¹² Economic Review sub committee report on Education.

¹³ Singapore Immigration & Registration, 2001.

2.4.3. Economic potential and impact in Retail

The wholesale and retail trade sector accounts for 40.1 per cent of the total establishments in the services sector. It employs 30.3 per cent of the services sector's total workforce¹⁴ (see Figure 6). Retail supports the Singapore economy by providing an important anchor as it is more resilient to external and internal economic shocks. It also provides a hotbed for entrepreneurs due to low barriers for entry (low complexity level and low financial investment).

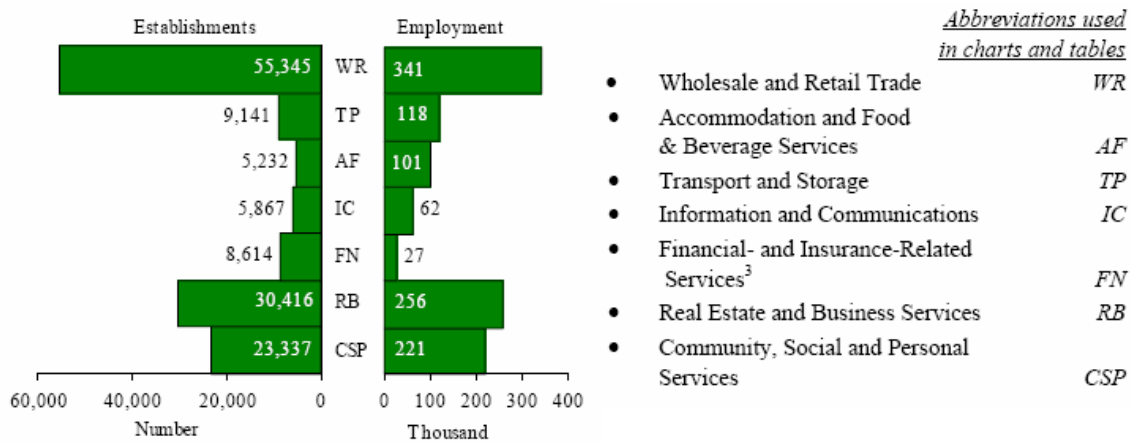


Figure 6: Establishments and employment

2.4.4. Economic potential and impact in Transportation

The transport and logistics sector is a sizeable growth market worldwide and is expected to grow at an annual rate of 3-10%. As the pace of global outsourcing gathers momentum, transportation is likely to enjoy continued growth, especially via services in specialised areas.

Compared to the US and Europe, Asian shippers are in the process of outsourcing their logistic functions. Also, there is strong interest in Asian companies in revamping their supply chains and integrating them with operations worldwide. This provides much propensity for growth within the Asia region.

¹⁴ Economic survey series 2006: The services sector, published Aug 2008 by Department of statistics.

In land transportation, we expect that the travel demand would increase from the current 8.9 million journeys a day to about 14.3 million journeys a day by year 2020¹⁵. Apart from the infrastructure to cater to the demand, there is also a need to address the principal problems of long waiting times, long journey times. Services can be exploited to increase the efficiency of road operations and optimise the capacity of the road network, thus enhancing travel experience and safety.

¹⁵ Land transport masterplan 2008, March 2008.

Chapter 3 Proposed Programmes

3.1. Value-chain approach

The panel devised a value chain approach to provide a framework to identify possible research programs for developing R&D activities in the innovative services space. The value chain approach categorizes the generic value-adding activities associated with a process and provides a means to capture the economic relevance and impact at each stage. Products go through each of the activity of the value chain in a subsequent fashion, one stage after the next and at each stage, some value-add activity is performed. The panel has broken down the value chain for innovative services into 5 generic stages: development process, production method, delivery channel, consumption by the user and recycling process (see Figure 7).



Figure 7: Value chain approach for innovative services

3.1.1. Key user segments

The panel also identified the key user segments which would enjoy the potential benefits arising from the outcomes of the research initiatives in the innovative services space. The following eight services sectors were identified to be of relevance to Singapore:

1. Retail
2. Healthcare
3. Education
4. Transportation
5. Manufacturing
6. Finance
7. Entertainment
8. Tourism

In order to provide a more in-depth analysis of some of these service sectors, the following set of criteria was taken into consideration in the deliberation process (list is not in order of importance):

1. High economic impact;
2. Representation of a major segment which is already well-defined;
3. Brings significant benefits to society;
4. Driven by or reflects an obvious trend;
5. Evidence of growing local and global trends;
6. Singapore's present position with respect to the segment;
7. Major contribution to Singapore's GDP;
8. Level of knowledge and expertise on the segment;
9. Segment which is receptive to technology; and
10. Importance of segment to Singapore's economy.

Based on this, the following five key service sectors were selected for a more in-depth analysis:

- **Healthcare**
- **Education**
- **Manufacturing**
- **Retail**
- **Transportation**

For the purposes of this report, the analysis and programme recommendations are made with considerations given mainly to these FIVE service sectors which have been identified. Notwithstanding this, the panel also recognized that there are research opportunities provided by the other THREE service sectors.

3.1.2 3-Dimensional Cube analysis

A 3-dimensional cube approach was used to anticipate future end-user needs and identify key programmes and technological breakthroughs which have high growth potential and relevant for the innovative services theme in a systematic and sustained manner. The value chain and the service sectors come together to form two of the axis, defining the space associated with an activity in a particular service sector. The other axis of the cube composed of the functionality which the innovative services (i.e. security aspects, connectivity aspects, productivity aspects, etc) (see Figure 8).

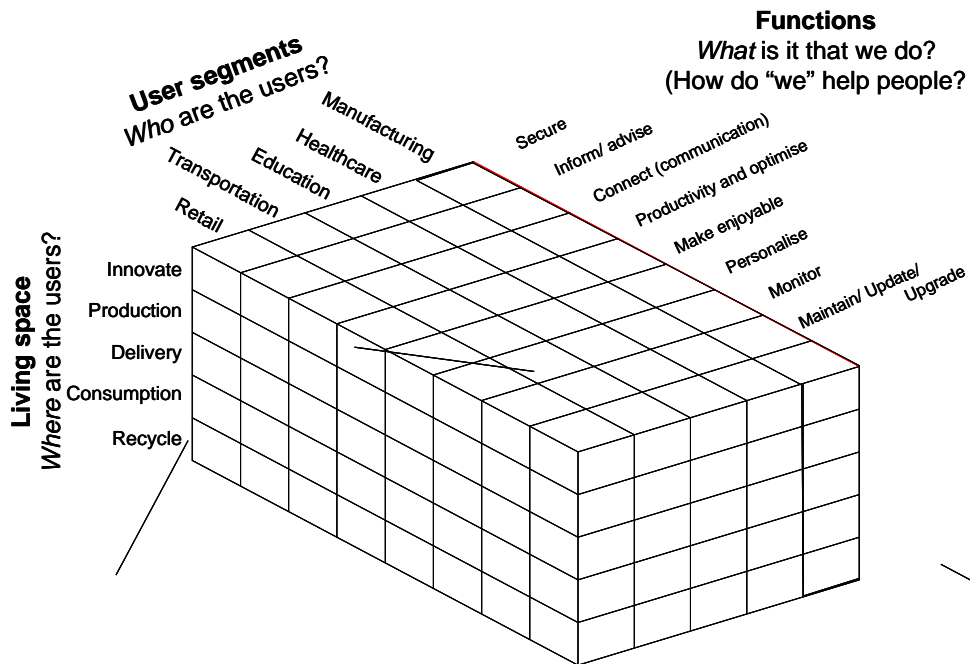


Figure 8: 3-Dimensional Cube Analysis of the Innovative Services

The outcome of the panel's discussion and deliberations on the potential programmes to be developed (see Figure 9) are captured in the following sections.

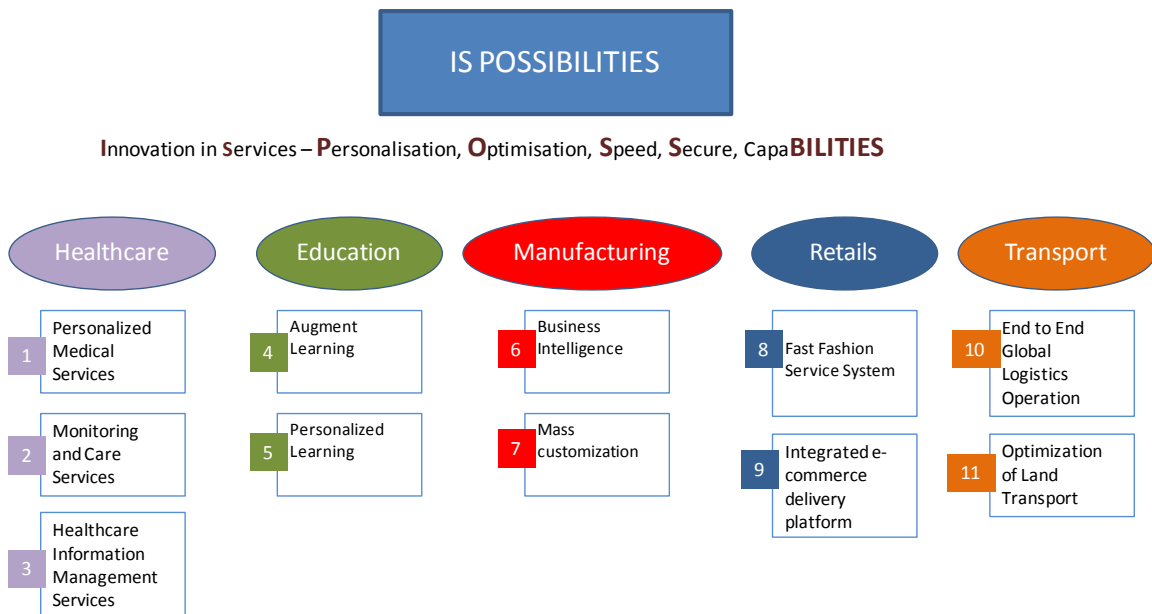


Figure 9: Overview of the Proposed Programmes of Innovative Services

3.2. Description of Proposed Programmes

3.2.1. Programmes in the Healthcare Sector

Programme 1: Personalized Medical Service

Overview

The proposed personalized medical service seeks to develop innovative technologies and services that have the potential to transform healthcare services to be more proactive, preventative, participatory, and personalized. Through technological advances, the proposed programme aims to develop medical services which can be made available anywhere and anytime to the general population. Some of the possible services include:

- Validation of genome-based medication (personalised medication) for the emerging Asian market.
- New pervasive and non-intrusive technologies which can be used potentially for monitoring lifestyle-related data, i.e. sleeping or smoking habits with incorporation of environmental and genetic factors.
- Biobanking services in providing data (genetic, medical and lifestyle) and samples (i.e. cord blood and other biological tissues).

Key Impact

The proposed personalized medical service program is expected to improve the well-being of the individual and address the growing healthcare-related issues with a rapidly aging population. It is expected to help develop Singapore into a technologically advanced medical hub. In addition, it provides a more precise diagnostic capability and provides better patient mobility and reduces the frequency to visit the healthcare provider through the provision of personalized medical services (remotely).

Key Technologies:

- Data mining / Bioinformatics
- Computer networks / Data storage / Information securities
- Digitization technologies for health records
- Monitoring technologies for pervasive but non-intrusive tracking

Programme 2 : Monitoring and Care Services

Overview

This program seeks to develop a comprehensive set of healthcare and wellness-related monitoring and care services. Possible services are:

- Automated gathering and analysis of vital signs (i.e. heart rate, blood pressure, respiration etc.) and human behaviours using wearable and environment-based or ambient sensors. The wearable sensors are expected to be comfortable and fashionable. These will be supported through home or office-based data storage and information processing mobile devices or applications running on mobile phones.
- Monitoring alone is not sufficient and there should be an avenue to make it possible for the caregiver to intervene (either determined automatically by an expert system or by a qualified medical doctor) and provide the care (e.g. administer medication remotely). This aspect is currently lacking and it is one of the main reasons which are restricting the widespread adoption of the health monitoring system.

Key Impact

Driven by an aging population and a shortage of nursing staff, the proposed monitoring and care program is definitely a key development to improving the healthcare system. Some important information to note:

- Forecasted Market size for US home healthcare monitoring in 2011: US\$130.5m.
- Forecasted Market size for US hospital wireless healthcare monitoring in 2011: US\$435m.
- Growth rate for remote monitoring device in US for 2007 was 20.4 percent.

(Source: A mirror to healthcare current trends and the economic impact concerning remote monitoring. Frost and Sullivan, Feb 2009)

Key Technologies:

- Automated identity authentication
- Privacy protection and data anonymization
- Secure content transmission and interactive feedback

- Robust scalable audio-video communication with intelligent routing to achieve the lowest cost at highest possible quality
- Converged data, voice and video communication system to allow the individual constant access to medical support and advice

Programme 3: Healthcare Information Management Services

Overview

This program focuses on the provision of available care and treatment options for the doctor and patient to make a more informed choice. The information can include records in all media format (i.e. text, audio, image and video) both in-house and external (i.e. internet and blogs), discussion on medical case studies, cost benefit analysis of treatment options, collated statistics on previous medical cases and electronic medical and health records from the healthcare providers that have been anonymized.

The Healthcare Information Management System can be used to “mine” real-time information flows and provide an early alert on the possible onset of an epidemic, the spread of diseases and the rate of spreading. This information is critical for healthcare providers to implement preventive measures early to mitigate the spread of potential outbreaks of diseases.

Key Impact

Driven by potential savings from increased productivity and the need to manage the usage of preventive medicine, the Healthcare Information Management System will become a necessity. It provides the following advantages:

- Increase the awareness of patients on inaccurate medical information available on the internet.
- Encourage patients whom are more web savvy to be more proactive to check online on their medical symptoms by providing a secure and anonymous avenue.
- Increase public awareness and market opportunities for alternative or traditional medicines like Traditional Chinese Medicines (TCM).

Key Technologies

- Data aggregation, extraction and information mining from multimedia content (encompassing various modalities such as x-ray, computed

tomography (CT), magnetic resonance imaging (MRI), functional-MRI, Positron emission tomography (PET), etc)

- Information extraction and mining of new media
- Information assurance (validity and verification of information)
- Rich media communication
- Automatic discovery of new patterns or behaviour
- Robust automated identity authentication

3.2.2. Programmes in the Education Sector

Programme 4: Augmented Learning

Overview

Augmented learning refers to the enhancement of traditional learning environment using technology such as mixed reality, haptics feedback, IT-based simulation amongst others. Services can play a major role in the exploitation of technologies towards building responsive environments that motivate, engage, and inspire learners, and which are embedded in the business processes and human resource management systems of organizations. While various technology pieces are there, the current capabilities fall short of various expectations such as flexibility in configuration and ability to provide meaningful feedback to the users.

In augmented learning programme, there are three main focus areas: behavioural-based learning, skill-based learning and concept-based learning:

- **Behavioural-based learning** refers to the learning of social skills such as teamwork, communication and presentation skills and inter-personal skills. The trends here gears towards role-based games in a community-oriented setting where technologies for creation and delivery of realistic and high-fidelity contents are needed. This platform must be able to adapt to developing situations on the fly and project a believable interactive environment. Also, educators desire flexibility in configuring the platform to achieve different desired outcomes. Thus, software engineering paradigms will need to evolve to address such requirements.
- **Skill-based learning** refers to the learning of techniques through the process of mimicry. There are two main categories, namely mechanical related skills

such as playing golf and badminton and verbal skills such as learning a foreign language and singing. Numerous technology gaps can be addressed here. For instance, lab-based language learning is still pretty rudimentary and does not provide sufficient qualitative and quantitative feedback to the learners. Also, technologies for learning sports are still not portable and cost-effective enough.

- **Concept-based learning** refers to the understanding and comprehension of key concepts such as gravity and the application to solve real-world problems. It can be segregated into 2 main areas: (a) physical science and engineering and (b) humanities. In the former, there is clear limitation in structured and follow-the-instruction pedagogy. Simulation-based and model-driven education systems must allow students to truly experiment in unstructured ways. They must be intelligent enough to track what the students are doing and to provide feedback to them to enhance the understanding.

Key Impact

Innovative educational services and flexible learning environments driven primarily through the use of infocomm technology seek to deliver a more engaging learning experience to meet the diverse needs of learners. It does so by enabling access to the latest knowledge and new learning resources, making learning come-to-life with multimedia and interactive elements. This will enable learners to achieve higher levels of engagement and learning experience.

Key Technologies

- Improved sensor and smart space technologies that can provide real-time monitoring and feedback of the dynamics during the learning process.
- Online rapid prototyping tools to quickly create concepts and models for experimentation.
- Adaptive physical science based simulations and highly customizable virtual experimentation. Quasi-simulation models might also be needed to provide near real-time interaction instead of having to wait for hours for a physically based simulations to complete.
- Real-time interactive technology platform for quicker monitoring, analysis and response to students' learning process and ability.
- High-fidelity visualization and immersive environment.

- Analytical tools for understanding the collated feedback and responses from the users.
- Agent-based coaching methodologies and tools.
- More effective human-computer interaction techniques.

Program 5: Personalized Learning

Overview

Personalised learning is about tailoring teaching and learning to meet individual need and is essential in creating a unique experience in helping children and adults achieve the best possible progress and outcomes. At the heart of personalized learning is the understanding that the learning environments comprise factors with which the learners interact, including people, spaces and resources. It is an interactive process in which both the learner and their environment respond flexibly to constant change in interaction with each other.

Different people learn better in different settings and learning in appropriate contexts allows the learner to have a better learning experience. Services is key in creating the personalised learning environments in which learners can create a coherent experience of learning in diverse locations, collaborate with experts in areas of personal interest, track and review their own learning across different sites and stages of education, have access to resources in forms and media that are best suited to their current skills, abilities and personal preferences.

In a personalised learning system, the individual is able to learn at his own pace, anywhere he prefers with tailored personalised content. The system would necessary need to run through an iterative cycle of observation and assessment, analyse the data and then make the appropriate adaptation in terms of the learning pace, contents, transmission rate and the mode of delivery. For example, when the system detects that the user is in a home environment with sufficient bandwidth, the system can deliver its educational components with a full range of multimedia-enhanced effects for an immersive experience. In another setting, say when the user is on the move with his portable display device with limited bandwidth, the system should be able to adapt and deliver the educational components with minimal multimedia elements to conserve bandwidth. Also, it is critical for the system to be user friendly for psychologists and sociologists to incorporate their feedback and inputs (see figure 10).

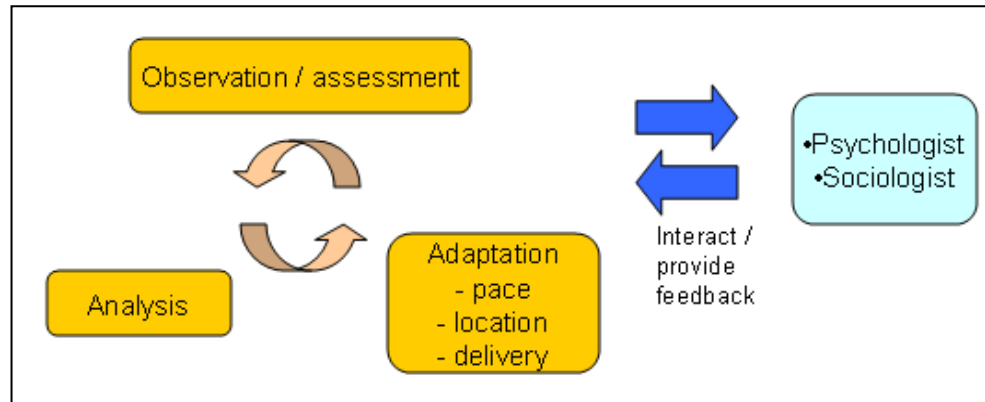


Figure 10: Schematic showing the interactions between various components for the personalised system

Key Impact

Much has been talked about the desired transition from structured education to personalized learning. After all, people learn at different paces and are motivated in different ways. There are schools in the USA that pace the learning of a student based on his or her ability¹⁶. Researchers are also pushing for electronic-portfolios as a means to help student track and reflect upon their learning journey¹⁷. This project also strives to understand the complex interplay between affective and cognitive process. Can the same approach be elevated to the next level in teaching more complicated concepts and theories?

Researchers at the Ministry of Education (MOE) lamented the drawback of current technology that lacks the autonomy to configure and realize adaptable contents on the fly in an intuitive manner. This calls for a very adaptive content creation framework and tools. Countries such as the USA look at the bigger picture of cradle-to-grave learning lifecycle. This is probably where commercial opportunities abound, as it appeals to the needs of a larger community. Focusing on learning-based services could also position Singapore as an international hub capable of providing such services to the global community.

¹⁶ <http://www.schooloftomorrow.com>

¹⁷ Electronic Portfolios: a Path to the Future of Learning. The Chronicle of Higher Education. 18 March 2009.

Key Technologies

- Technologies enabling ubiquitous access to learning contents and adaptation to different end devices.
- Multi-mode sensors (video, audio, physical interactions with devices) and software tools (physical movement, tone/pitch, emotions etc.) to accurately capture and analyze students' responses to the learning contents and process.
- Machine-learning and cognitive methods to understand and adapt contents and delivery approach to students' mood and learning capability. This includes social cognitive techniques to model and act on the states of mind during the interaction. Knowledge-based and semantic technologies which allow for the understanding, sharing and reasoning between the system and user at execution time would also be required.
- Data analytics tools to help users gain insight from data on the web.
- More effective human-computer interaction techniques.

3.2.3. Programmes in the Manufacturing Sector

Program 6: Business Intelligence for Manufacturing Services

Overview

In the knowledge economy of the 21st century, the access to information for production, market demand analysis and resource planning will enable manufacturers build services that offer business intelligence to enable timely and market appropriate services to their customers. Business intelligence can take on the form of knowledge systems among employees for innovation of new products or provide information on lead indicators on raw material supplies or manage capacity planning as a result of demand fluctuations. Intelligence could also be gathered through predictive services that can predict and avoid unplanned failures in equipment and enable real-time inventory control, manage production throughput and increase visibility of manufacturing operations at local plant and global operations levels.

Key Impact

Production shop floors can then better manage their resources of equipment, manpower and material if information can be updated through systems that can inform and advise with sufficient accuracy in a relatively short time. The impact of having intelligence be it in raw material availability, equipment downtime

prediction, energy prices can bring significant savings in getting things right the first time or having sufficient confidence in planning to deliver products or components in a timely and efficient manner. The risks can be significantly lowered and outcome made more predictable. Production capacity will be better managed with increasing reliable intelligence on uptime availability of resources.

The ability to forecast demand strongly depends on timely update of all intelligence data that can be accessed easily by users such as operators, line managers, maintenance personnel and production managers.

Key Technologies

- Service oriented architecture
- Grid computing
- Agent technology
- Web services
- Computational intelligence

Program 7: Mass Customization for Manufacturing Services

Overview

Mass customization as opposed to mass manufacturing is the ability of a manufacturer to meet the changing demands of her customers by having adaptive manufacturing practices coupled with equipment that can be reconfigured. It is opposed to customised manufacturing practiced by the early years of cottage industry in 19th century. There is an increasing market for custom configure services, though this could normally be done at the expense of price. Mass customization captures the imagination of delivering personalized manufactured products to suit the needs of 1 person without incurring cost penalties. Mass customization can be adopted at all value chain of manufacturing of goods, covering assembly, delivery, fabrication and design customization.

Key Impact

This programme in mass customization services would be most suitable in meeting the needs of manufacturing in small volumes as a result of high product diversity. The twin trends of new generation of consumers becoming increasingly individualistic and production cycles becoming shorter with the rapid advancement of technologies have become contributory factors to creating the

need to rapidly customize a production outfit for a new process or new customer. The diversification of businesses also enables manufacturers to survive spikes in demand due to fluctuations of the world's economy and the fast-paced dynamics of just-in-time manufacturing balanced against increased pressure to outsource.

Key Technologies

There are several technologies that would need to be developed that would bring mass customization nearer to reality, such as interactive virtual manufacturing and reconfigurable systems.

3.2.4. Programmes in the Retail Sector

Program 8: Fast Fashion Service System

Overview

This program aims to produce fashion in a much shorter time compared to the traditional manufacturing which takes at least 21 days to meet the demands of the modern era retailers. The targeted customers are mainly tourists and overseas shoppers who want a quick fit and personalization touch on the finishing and final design of their fashion. The proposed program, known as "Fast Fashion Service System", requires the following services:

- Database of 3D measurement of customers, clothes, design elements, customer purchase information, electronic supply chain.
- High-throughput mobile and broadband transfers for quick previews and review before manufacture.
- New materials for fabricating clothes on demand and able to be tailored to different thickness and permeability.
- Cloth fabricator to print cloth speedy using multiple material feed sources, size and capacity.
- Artwork imprinter for printing long lasting design and colours onto the new materials.
- Multi-environment tagging for flexible substrate based information tagging.

Key Impact

The key impact of a 3D Fast Fashion Service System will help develop Singapore into a high tech fast fashion hub for the modern generation of shoppers.

Key Technologies

- Flexible substrate-based information tagging technology
- Database development
- Nano-material - low-power multi-coloured light-emitting nano-materials, nano-wire, carbon-nanotube-based texture material
- Recommendation engine
- Microfluidics printers
- Rapid manufacturing system from 3D to actual clothes
- High throughputs mobile and broadband transfer technology

Program 9: Integrated e-commerce delivery platform**Overview**

With the success of electronic-commerce websites such as E-Bay and Amazon, consumers no longer need to be present at the shops or going down to the mall. On-line shopping and TV shopping have become more prevalent in developed countries such as the US and Europe. The next step is expected to be the convergence of on-line shopping with interactive TV through portable devices such as PDAs and handphones.

An Integrated E-commerce Delivery Platform (IEDP) that enables businesses to publish their product listings and push their advertisements through these channels will open up a new paradigm for e-commerce. This will lead to the convenience of shopping at anytime, anywhere and on any devices a reality.

This platform will be able to adapt and inter-operate with various devices including different screen sizes, operating systems and supported features. Such a system when developed, may be offered as a software-as-a-service business model which retailers can use to market their products.

Key Impact

This programme is expected to optimize end-to-end service delivery for multiple platforms thus improving the retailer's time-to-market for online stores and the user's experience and usability.

Key Technology

- Programming expertise in mobile applications, 4G communication systems, Asynchronous JavaScript and XML (AJAX) - Expertise in the interfaces and communication channels are necessary to ensure that the IEDP can support the various systems in place.
- Intelligent content adaptation – Presentation of the same set of content in different fashion and on different delivery channels which is customized to the specific feature of the end-user devices. This refers to the size of the display screen, the input methods available on devices such as PC, mobile phones, PDA and TV. The content must also be user friendly for the various delivery channels to allow intuitive interactive applications.
- Data mining and personalisation engine – The platform must be able to intelligently personalise the end-user's preference based on the user's profile to present to them items which would fulfil their needs.
- User profiling – This refers to the set of attributes and information on the user which is derived from the user's browsing history, past purchases and purchases of other shoppers. The information is stored and retrieved to make “smart” recommendations. One particularly useful example is Amazon. Recommendation engine technology is now still in its infancy, however, this critical component for online shopping system should be developed.

3.2.5. Programmes in the Transport Sector

Programme 10: Innovative Services for end-to-end global logistics operations

Overview

This program will focus on R&D in the technologies needed to enable, support and create innovative services for end-to-end global logistics operations. In terms of the “value-chain” aspect (reference Figure 8), it will cover all three modes (land, sea and air) transportation and logistics infrastructure. Specifically, the program will focus on:

- Services creation, discovery & composition for end-to-end global logistics operations.
- Enabling and optimising end-to-end global logistics operations.

- Identifying the gaps and providing a comprehensive system for planning purposes and to track and monitor goods across different modes of transport.
- Improving Supply Chain Management (SCM) efficiency through new innovative services that address the problems caused by the fragmented logistics chain from manufacturing to retail.

Key Impacts

The beneficiaries of the R&D output from this programme include port operators, shipping lines, manufacturers, third party logistics providers, wholesalers and retailers. Fully integrated end-to-end logistics management systems would enable advanced value-added and seamless services. These services may include personalised packing, tracking, tracing, and secured transfer which will improve efficiency, reduce costs and enhance the sense of security for the ultimate consumers.

Validation discussions with local port authorities and operators had revealed that there are several challenges in the area of container movements and port operations. For example, presently, disparate information systems are maintained across various stakeholders. These systems are not fully integrated thus resulting in the need for multiple data entries of the same information. Amid rising wages, there is a shortage of port workers, especially, local workers. The problem will become more acute as the port plans to double its capacity over the next 10-15 years. Thus, improving operational efficiency and deriving new values through innovative services have become imperative.

Inputs from the industry also unveiled that the logistics chain from manufacturing to warehousing to goods movements to the retail shop fronts is still fragmented. The above challenges present an opportunity for conducting R&D in new and innovative services that can create or extract value by improving end-to-end global logistics and container terminal operations. Based on the R&D outputs of this programmes, these companies may have the opportunity to leverage on highly knowledge-based logistics systems and innovative services. This in turn will help to grow the local transportation and logistics sectors as the new services would help fuel the growth of global markets.

Key Technologies

This programme could leverage on existing capabilities available or being developed by research institutes and local universities. These capabilities include knowledge and experience in design of service oriented architecture, platform; data mining; cryptography and security systems; networking protocols; complex simulations of large scale transactions; sensor networks; etc.

To complement the existing capabilities, more capabilities will need to be developed. These may include:

- Supply chain operations
- Risk assessment
- Compliance and regulatory requirements
- Transportation industry structural and business dynamics
- Business-to-Business and Business-to-Consumer business relationships
- Analytical/simulation models for goods movement patterns
- Metadata discovery
- Reuse and management
- Secured access and delivery system
- Datamining; route optimization
- Data latency minimization from creation to consumption

Programme 11: Optimisation of Land Transport Capacity

Overview

The programme will focus on the monitoring and optimisation of land transport capacity and infrastructure by allowing commuters and motorists to plan their journeys in advance or on the go. Land transport comprises of road infrastructure (roads, parking, refuelling stations) and all forms of transport including cars, buses and trains.

Key Impacts

Through this programme, there is an opportunity to develop a holistic and intelligent transport management system. The system could be realised through sensor and communications networks to provide real-time adjustment to local traffic flow and overall traffic conditions. It would also give the transport authority and commuters a bird's eye view of the traffic situation, anytime, anywhere and by any means. Such a system would allow commuters and goods (through logistics channels) to travel from point A to point B in the most efficient manner, thus reducing time and energy wastage. This in turn will translate to higher productivity and more efficient energy usage; both of which will improve our competitive edge and impact the economy positively.

Key Technologies

To embark on this programme, it would require:

- data mining
- pattern recognition
- predictive tools
- sensors

- wireless communication
- complex transport system simulation
- cognitive systems to model and predict crowd behaviour

3.2.6. Summary of Programmes and Key Technologies

No.	Programmes	Key Technology
Healthcare		
1	Personalized Medical Service	<ul style="list-style-type: none"> ▪ Data mining / Bioinformatics ▪ Computer networks / Data storage / Information securities ▪ Digitization technologies ▪ Monitoring technologies
2	Monitoring and Care Services	<ul style="list-style-type: none"> ▪ Automated identity authentication ▪ Privacy protection and data anonymization ▪ Secure content transmission and interactive feedback ▪ Robust scalable audio-video communication
3	Health Care Information Management Services	<ul style="list-style-type: none"> ▪ Data mining ▪ Information validation and verification system ▪ Media communication techniques ▪ Automatic discovery of new patterns or behaviour ▪ Robust automated identity authentication
Education		
4	Augmented Learning	<ul style="list-style-type: none"> ▪ Multi-mode sensor ▪ Online rapid prototyping tools ▪ Simulations and highly customizable virtual experimentation. Quasi-simulation models ▪ Real-time interactive technology ▪ High-fidelity visualization technology ▪ Analytical tools ▪ Agent-based coaching methodologies and tools ▪ Human-computer interaction techniques
5	Personalized Learning	<ul style="list-style-type: none"> ▪ Multi-mode sensors ▪ Machine-learning and cognitive ▪ Data analytics tools ▪ Human-computer interaction techniques

Manufacturing		
6	Business Intelligence for Manufacturing Services	<ul style="list-style-type: none"> ▪ Data processing ▪ Grid computing ▪ Intelligent agents ▪ Web services ▪ Computational intelligence
7	Mass Customization for Manufacturing Services	<ul style="list-style-type: none"> ▪ Interactive virtual manufacturing ▪ Reconfigurable systems
Retail		
8	Fast Fashion Service System	<ul style="list-style-type: none"> ▪ Flexible substrate-based information tagging technology ▪ Database ▪ Nano material ▪ Recommendation engine ▪ Microfluidics printers ▪ Rapid manufacturing system ▪ High throughputs mobile and broadband transfer technology
9	Integrated e-commerce delivery platform	<ul style="list-style-type: none"> ▪ Programming expertise in mobile applications, 4G communication systems, Asynchronous JavaScript and XML (AJAX) ▪ Intelligent content adaptation ▪ Data mining and personalisation engine
Transportation		
10	Innovative Services for end-to-end global logistics operations	<ul style="list-style-type: none"> ▪ Supply chain management ▪ Metadata discovery technology ▪ Reuse management ▪ Secured access and delivery system ▪ Datamining; route optimization
11	Optimisation of Land Transport Capacity	<ul style="list-style-type: none"> ▪ Data mining ▪ Pattern recognition ▪ Predictive tools ▪ Sensors ▪ Cognitive systems

Table 1. Summary of Proposed Programmes and Key Technologies

3.3. Recommended Programme Time Horizon

The roadmap for the 11 proposed programmes is shown in Figure 11. It is envisioned that the 11 proposed programmes will face different challenges in gaining adoption and as such, they will attain different levels of maturity. Given the current global trends and the current capabilities of A*STAR, it is highly likely to see the following programmes reach maturity in technology readiness within 3-5 years:

- Monitoring and care services
- Healthcare management information
- Augmented learning
- Secure real-time inventory management for retail
- End-to-end global logistics operations
- Integrated e-commerce delivery platform

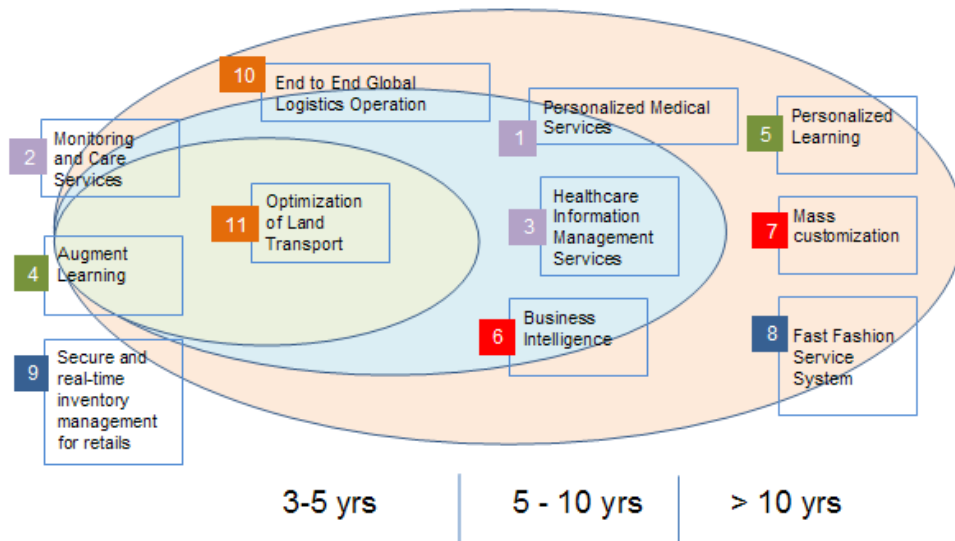


Figure 11: Time horizon of the Proposed Programmes of Innovative Services

Chapter 4 Conclusions and Recommendations

The continual transformation of the world's and Singapore's economy from a goods-based to a service-based economy points to a strong need for A*STAR to make major efforts to adapt its research and development efforts to create technologies pertinent to this new industry. This transformation is a result of the increased competition and global trends of globalization, ageing population, increasing urbanization, rising energy costs and increased mobile workforce.

A total of 11 research programmes under innovative services have been proposed by the panel. These research programmes will enable A*STAR to steer towards the creation of a pipeline of technologies, the training of human capital and the development of new business models. This effort will ultimately set the stage for the formation of a strong and sustainable services industry.

The panel recommends that to make real progress, services be viewed as one cluster (comprising different sectors) and driven as a specialised domain. This is to ensure focus is applied to grow relationships in the different sectors and the appropriate technological innovations are made in Services where approach to innovation may differ across sectors. Over time, as successful relations and R&D collaborations grow in Services, responsibility for advancing Services can be devolved to each of the traditional manufacturing sectors.

It must be recognised that innovation Services, by its nature, is best driven through a strong relationship between the public and the private sector where technological solutions and new ideas are generated by experts in collaboration with those that have a deep domain knowledge.

A critical mass of capabilities and talent in computer science, software development, systems- science and integration are urgently needed.

Hence, a capability group should be grown from the Institute for Infocomm Research to develop the know-how and set the directions to advance innovation in services. Talent, in particular, must be specially developed of people capable in their home discipline but with the skills to scan across areas to spot opportunities to apply their expertise.

Recommended programmes in healthcare services (section 3.2.1) should be incorporated into the broader set of recommendations of the **Healthcare and Wellness** theme. Recommended programmes in education services be integrated into the portfolio of R&D efforts at the learning laboratories resident in NIE. The panel recommends that the proposed research topics be co-lead by A*STAR and NIE.

Acknowledgement

Panel Composition

Chair

- Dr Raj Thampuran
Institute of High Performance Computing

Co-Chairs

- A/P Tham Chen Khong
Institute for Infocomm Research
- Ms Angeline Poh
Economic Development Board

Panel Members

- Dr Wilson Wang Yong Hong
Data Storage Institute
- Dr Yeo You Huan
Data Storage Institute
- Mr Walter Lee
Exploit Technologies Pte Ltd
- Dr Ng See Kiong
Institute for Infocomm Research
- Dr Yau Wei Yun
Institute for Infocomm Research
- Mr Cheah Kok Beng
Institute for Infocomm Research
- Dr Bao Feng
Institute for Infocomm Research
- Dr Terence Hung
Institute of High Performance Computing
- Mr Hoang Du'c
Science and Engineering Research Council, A*STAR

- Prof Chua Soo Jin
Institute of Materials Research and Engineering
- Dr Lee Eng Wah
Singapore Institute of Manufacturing Technology
- Ms Jenny Ang
Singapore Institute of Manufacturing Technology
- Mr Kee Thian Seng
Infocomm Development Authority of Singapore
- Mr Dennis Sng Cheng Hong
Media Development Authority
- Mr Too York Lou
SPRING Singapore
- Mr. Soh Kok Hoe
Science and Engineering Research Council, A*STAR
- Dr. Ian Chan Hian Leng
Singapore Institute of Manufacturing Technology

In preparing this work, the Innovative Services panel consulted numerous domain experts and would like to acknowledge them for their contributions.

Education

S/N	Name	Designation	Organisation
1	Mdm Low Khah Gek	Director (Curriculum Planning & Development)	Ministry of Education (MOE)
2	Prof S. Gopinathan	Associate Dean, Office of Education Research (OER)	National Institute of Education (NIE)
3	Dr Chen Der-Thang Victor	Associate Professor, Learning Sciences Laboratory (LSL)	National Institute of Education (NIE)
4	Ms Moo Woan Shing, Eva	COTF Manager, Academic Computing & Information Services (ACIS)	National Institute of Education (NIE)

Retail

S/N	Name	Designation	Organisation
1	Ms. Callia Chua	Dep Director / LEAD Manager	Textile and Fashion Federation (Singapore) (TaFf)
2	Ms. Fong Loo Fern	Managing Director	CYC Shanghai
3	Ms. Angeline Hoon	Marketing Manager	CYC Shanghai
4	Mr. John Hirst	Asst Director, Industry and International Affairs	Singapore Retailers Association (SRA)

Transport

S/N	Name	Designation	Organisation
1	Toh Ah Cheong	Director (Technology)	Maritime & Port Authority of Singapore
2	Goh Kwong Heng	Deputy Director (Research & Technology Development), Chief	Maritime & Port Authority of Singapore

		Information Officer	
3	Oh Bee Lock	Senior VP (Corporate Planning)	Port of Singapore Authority (PSA)
4	Tey Yoh Huat	VP, Technical Services	APL
5	Goh Gin Howe	Deputy Director, IT Planning & Quality Assurance, Innovation & InfoComm Technology	Land Transport Authority (LTA)
6	Rosina Howe-Teo	Group Director & Chief Innovation Officer, Innovation & InfoComm Technology	Land Transport Authority (LTA)

Healthcare

S/N	Name	Designation	Organisation
1	Dr Jong Hee Sen	President & Executive Director	Healthway Medical Corporation Limited
2	Dr Paul Wang	Director, PMO	Integrated Health Information Systems Pte Ltd (IHIS)
3	Dr Ting Choon Meng	Chairman & CEO	HealthSTATS Int'l Pte Ltd
4	Dr John C W Lim	Chief Executive Officer	Health Sciences Authority (HSA)
5	Dr Gregory Leong	General Practitioner	Parkway Shenton Medical Pte Ltd

Manufacturing

S/N	Name	Designation	Organisation
1	Esmond KC Lim	Managing Director	PLC Industries Pte Ltd
2	Poon Cher Heng	Managing Director	Unigold International Pte Ltd
3	ST Lim	Director	Riso Seiki (S) Pte Ltd
4	Leong YF	Engineering Manager	Windsor Airmotive Asia Pte Ltd
5	Kwan Lok Suen	Director	CKE Manufacturing Pte Ltd
6	Eric Tan HH	Director	JEP Precision

			Engineering Pte Ltd
7	Low Hwee Hwa	Director, Business Development	Advance Tech Precision Pte Ltd
8	Vincent Leo	Associate Director	Disk Precision Industries Pte Ltd
9	Lam Keng Yew	General Manager	Onn Wah Precision Engineering Pte Ltd
10	William Kuek	Operations Manager	Sky Engineering Pte Ltd
11	Sieow Sok Peng	General Manager	II-VI Singapore Pte Ltd
12	Ron Mao	Director	SPEQS Manufacturing Pte Ltd
13	Michael Anthony Oxborrow	Chief Executive Officer	ACP Metal Finishing Pte Ltd
14	Leong Kwok Choon	Chief Operating Officer	ETLA Ltd
15	Kenny Lim	General Manager	Crafts Precision Engineering Pte Ltd