

1

Introduction

1.1 Differentiating Technology and Engineering Innovation

This book is about technology and engineering analysed in the context of the impact of invention and innovation on the political, social and economic dynamics of the global telecommunications industry, tracing the transition and transformation that has occurred particularly since fixed and mobile broadband has become such a dominant deliverable. The occasional unapologetic excursion is made into the more distant past as and when relevant and valid.

The subject focus is technical but the ambition is to make the content relevant and accessible to as wide an audience as possible. It is common to find engineers who have an absorbing interest in the humanities. It is less common to find managers with a humanities background developing a similar passion for engineering. This is possibly because some engineering books can be dull to read. Our mission is to try and remedy this disconnect between two disciplines that in reality are closely interrelated.

Another myth that we attempt to dispel is the notion that somehow technology change is occurring faster today than in the past. This is a false flattery. Technology change viewed through the prism of the present appears to be tumultuous but is more accurately considered as part of a continuing process of transition. The past remains surprisingly relevant, can inform present judgement and should be used to help forecast the future. This is our excuse or rather, our reason for raiding the Science Museum archives and picture collection that are referenced in most subsequent chapters.

The derivation of the word science is from the Latin 'Scientia' meaning knowledge. The word physics is from the Greek 'Physis' meaning nature. A recurring narrative of this book is that informed decision making is contingent on studying knowledge and well-evidenced opinion from the past. However, any decision taken has to obey the fundamental laws of physics. Our understanding of those laws changes over time. A present example is the science of the very small, how the behaviour of materials change when constructed at molecular scale. The ability to understand the potential usefulness of a physical property is a skill that can transform the world. Newcomen's observation of steam and Edison's observation of the behaviour of a carbon filament in a vacuum are two prior examples. Paul Dirac's work on quantum mechanics is a near contemporary example and the work of Stephen Hawking on string and particle theory a contemporary example. The study of 'prior art' is often today the

job of the patent attorney, but would be more beneficially encompassed as an engineering rather than legalistic discipline.

The discipline of economics has always been the fundamental tool of analysis used to quantify and qualify business risk and opportunity. Our argument is that technology economics and engineering economics are a discrete subset of economic analysis, individually deserving of independent analysis and often overlooked or underappreciated.

Frustratingly, technology and engineering are often considered as interchangeable terms. Although closely coupled they are in practice distinct and separate entities. The word 'technology' is derived from the Greek word '*techne*' meaning craft, which the ancient Greeks considered represented the mechanical arts. 'Engineering' comes from the Latin word '*ingeniare*', from which modern English derives the word '*ingenious*'.

The difference in practical terms can be illustrated by considering how Archimedes fortified his adopted home town in the Siege of Syracuse in 214 to 212 BC. Under attack from the Romans, Archimedes had a number of enabling *technologies* available to him including ropes and pulleys. These technologies were then combined together with *ingenuity* into throwing machines known as ballistas, from which the term ballistics is derived. Engineering in effect was the process through which usefulness or value was realised from several separate component technologies. More prosaically, Bran Ferren, the computer scientist, hit the nail on the head by defining technology as 'stuff that doesn't work yet'.¹

1.2 Differentiating Invention and Innovation

Similarly, the words invention and innovation are often used interchangeably but are also distinct and separate though closely linked. An invention will typically be an outcome from a 'mechanical art' and will result in an enabling technology. An innovation will generally be a novel use of that enabling technology and can therefore be categorised as engineering.

In the modern world the words technology and invention can be correctly and broadly applied to almost any type of mechanical component. The specification and performance of these components is usually described and prescribed in a technical standard. For example a modern mobile phone is a collection of component technologies, each with a discrete purpose but a common objective, to send or receive voice or data over a radio channel. Each component technology will have had engineering (ingenuity) applied to it to ensure the component behaves as expected and required.

1.3 The Role of Standards, Regulation and Competition Policy

The standards documents describe the expected performance and behaviour of the functions of the complete product. Engineering is applied to ensure the complete product behaves in accordance with these standards.

The cost and realisable value of a wireless network is heavily influenced by the characteristics of the radio channels used for communication. This is because wireless communications have a unique ability to interfere with one another. In the US in the 1920s for example, competing radio broadcasters progressively increased transmitted power close to the point where no

¹ <http://qotd.me/q2007-01-29.html>.

one could receive anything clearly. The Federal Communications Commission was established in 1934 to impose order on chaos and the basic principles of radio and TV regulation became established in national and later international law. As a result, spectral policy today has a direct impact on radio engineering cost and complexity.

If standards making and spectral policy are focused on achieving improvements in technical efficiency then the result will generally be an improvement in commercial efficiency. An improvement in commercial efficiency can be translated into improved returns to shareholders and/or some form of associated social gain. This topic would fill several books on its own but it is useful to reflect on two important trends.

Harmonised and mandatory standards have been crucial in delivering R and D scale efficiency more or less across the whole history of telecommunications. Within mobile communications for example, the rapid expansion of GSM over the past twenty years would almost certainly not have happened without robust pan-European and later global standards support. More recent experiments with technology neutrality in which an assumption is made that 'the market can decide' have been less successful. Markets are determined by short-term financial pressures. These are inconsistent with the longer-term goals that are or should be implicit in the standards-making process.

1.4 Mobile Broadband Auction Values – Spectral Costs and Liabilities and Impact on Operator Balance Sheets

In parallel, spectral policy has been increasingly determined by an assumption that the market is capable of making a rational assessment of spectral value with that value realisable through an auction process. Superficially that process would have appeared to be significantly successful, but in practice the 1995/1996 US PCS auctions produced the world's first cellular bankruptcies (Next Wave and Pocket Communications), the 2002 UMTS auctions emasculated BT, left France Telecom excessively geared and brought Sonera and KPN to the brink of financial collapse.

The UK UMTS auction in 2002 is an example of this law of unintended consequences. The auction raised £22.5 billion none of which was spent on anything relevant to ICT. It was assumed that the investment would be treated as a sunk cost and not be passed on to the customer but in practice the licenses have added £1.56 to every bill for every month for 20 years. Digital Britain is being financed from old ladies' telephone bills.²

The impact on operator balance sheets was equally catastrophic. Taking T Mobile and Orange together their *pro forma* return on investment including spectral license cost shows cumulative investment increasing from 70 billion euros in 2001 to just under \$100 billion in 2008 with a cumulative cash flow of \$20 billion euros. The merger of the two entities into Everything Everywhere may delay the point at which a write down is made but does not disguise the net destruction of industry value that has occurred.

This translates in the relatively short term into a destruction of shareholder value. In the longer term the impact is more insidious. One of the easiest and fastest ways to cut costs either with or without a merger is to reduce research and development spending. The problem with this

² My thanks to John Tysoe of The Mobile World for these insights, which as always are both colourful and acutely observed.

is that it becomes harder to realise value from present and future spectral and network assets. Thus, a short-term three- to five-month gain for a national treasury translates into a longer-term loss of industrial capability that may have a negative impact lasting thirty to fifty years.

In the US, the 700-MHz auctions between 2005 and 2007 allowed the two largest incumbent operators to squeeze out smaller competitors and resulted in a payment to the US Treasury of \$20 billion dollars. The band plan is, however, technically inefficient. In particular, it is proving difficult to achieve the scale economy needed to develop products that can access all channels within the band. As a result, companies have paid for spectrum and built networks and then been frustrated by a lack of market competitive performance competitive user equipment. Some entities have not even got as far as building networks because no one can supply the filters needed to mitigate interference created by or suffered by spectrally adjacent user communities, in this example TV at the bottom of the band and public safety radio at the top of the band.

In theory the regulatory process exists to anticipate and avoid this type of problem but in practice a doctrine of *caveat emptor* has been applied. If entities are prepared to bid billions of dollars for unusable spectrum, so be it. It is up to those entities to have performed sufficient technical due diligence to arrive at an informed view as to whether the spectrum being auctioned is an asset or a liability. However, a failure to bid and win spectrum typically results in a short term-hit on the share value of the bidding entity. Therefore, there is a perverse incentive to bid and win spectrum. In the US case the opportunity to return the US market to a duopoly was an associated incentive but resulted in an outcome directly contrary to US competition policy.

1.5 TV and Broadcasting and Mobile Broadband Regulation

Regulatory objectives have changed over time. TV and broadcasting regulation may have its origins in spectral management but competition policy and the policing of content have become progressively more dominant. In telecommunications the original purpose of regulation was to act as a proxy for competition, protecting consumers from the potential use of market power by landline monopolies or later by their privatised equivalents.

Cellular operators in the 1980s had to meet spectral mask requirements in terms of output power and occupied radio bandwidth, but were otherwise largely unregulated. The assumption was that market regulation would inhibit network investment during a period in which return on investment was largely an unknown quantity.

Over the past thirty years this has changed substantially and regulatory powers now extend across pricing, service quality and increasingly social and environmental responsibility, potentially the first step towards more universal service obligations. This is in some ways an understandable response to a profitable industry enjoying revenue growth that significantly outpaced increases in operational cost. Whether this will continue to be the case depends on future technology and engineering innovation.

There is also arguably a need for a closer coupling of standards and regulatory policy across previously separate technology sectors. The transition to digital technologies both in terms of the mechanisms used to encode and decode voice, image and data, the storage of that information and the transmission of that information across a communications channel has resulted in a degree of technology convergence that has not as yet been fully realised as a commercial opportunity or reflected adequately in the standards and regulatory domain.

For example, the same encoding and decoding schemes are used irrespective of whether the end product is moved across a two-way radio network, a cellular network, a broadcast

network, a geostationary or medium or low-earth orbit network and/or across cable, copper or fibre terrestrial networks. Similarly cable, copper, fibre and all forms of wireless communication increasingly use common multiplexing methods that get information onto the carrier using a mix of orthogonal³ or semiorthogonal phase, amplitude- and frequency-modulation techniques.

1.6 Technology Convergence as a Precursor of Market Convergence?

Despite the scale of this technology convergence, these industry sectors remain singularly independent of each other despite being increasingly interdependent. This is a curious anomaly, probably best explained by the observation that commercial exigency drives commercial convergence rather than technology opportunity. The adoption of neutral host networks covered in the third part of this book is an example of this process at work.

The technology case for a neutral network managed by one entity but accessed by many has been obvious for some time. It is simply an extension of the fundamental principle of multiplexing gain. The concept is, however, only recently gaining market traction.

The reason for this is that data demand is increasing faster than technology capacity. Technology capacity is substantially different from network capacity. As demand increases across any delivery domain, wireless, cable, copper or fibre, it is technically possible to increase network capacity simply by building more infrastructure. Existing capacity may also be underutilised, in which case life is even easier. However, if infrastructure is fully loaded additional capacity is only financially justifiable if revenues are growing at least as fast as demand or at least growing sufficiently fast to cover increased operational cost and provide a return on capital investment.

Technology can of course change this equation by increasing bandwidth efficiency. The transition to digital for example yielded a step function gain in bandwidth efficiency that translated into profitability, but as systems are run ever closer to fundamental noise floors it becomes progressively harder to realise additional efficiency gain.

This is problematic for all sectors of the industry but particularly challenging for wireless where noise floors are determined by a combination of propagation loss and user to user interference. Present mobile broadband networks provide a dramatic illustration.

1.7 Mobile Broadband Traffic Growth Forecasts and the Related Impact on Industry Profitability

In a study undertaken last year⁴ we forecast that over the next five years traffic volumes would grow by a factor of 30, from 3 to 90 exabytes.⁵ On present tariff trends we projected revenue to grow by a factor of 3. On the basis of the data available since then, particularly the faster

³ Mathematically expressed, orthogonality is when the inner product of two functions within the signal is zero. An orthogonal signal is one in which the phase of the signal is arranged to ensure that, in theory at least, no interference is created into an adjacent signal.

⁴ LTE User equipment, network efficiency and value Published 1 September 2010 available as a free download from <http://www.makingtelecomswork.com/resources.html>.

⁵ An exabyte is a million terabytes. These forecasts including tariff trends are drawn from industry sources and modelling and forecasting undertaken by RTT and The Mobile World.

than expected uptake of smart phones, we have revised our 2015 figure to 144 exabytes (see graphs in Chapter 4).

Irrespective of whether the final figure is 90 exabytes or 150 exabytes or some larger number, the projected efficiency savings from new technology such as LTE are insufficient to bridge the gap between volume growth and value growth.

New solutions and/or new income streams are therefore required in order to enable the sustainable growth of the mobile broadband industry. This includes technology and engineering innovation and specifically for wireless, a combination of materials innovation, RF component innovation, algorithmic innovation and radio engineering innovation. Market innovation to date seems to have been focused on producing ever more impenetrable tariffs and selling smart-phone insurance that users may or may not need.

1.8 Radio versus Copper, Cable and Fibre – Comparative Economics

Radio engineering is a fascinating discipline but is best analysed in a broader context in which technical and commercial viability is benchmarked against other delivery options, copper, cable and fibre. The comparative economics are complex and can yield idiosyncratic and counterintuitive results. For example, if a large file is not time sensitive then the most efficient delivery method, at least in terms of cost, may be to put the data on a memory stick and post it.

In fact, the mechanics of the postal service are quite relevant when analysing network economics and the end-to-end economics of delivering voice and data over wireless, fibre, cable and copper networks.

Part of the efficiency gain in telecommunications has traditionally been achieved by multiplexing users over either single or multiple delivery channels to achieve what is commonly known as ‘trunking gain’. Telephone lines for example started using frequency multiplexing experimentally in the 1920s and time division multiplexing became increasingly prevalent from the 1960s onwards. Trunked radio systems and first-generation cellular radio in the 1980s and 1990s were frequency multiplexed, second-generation cellular radio systems were frequency and time multiplexed, third-generation cellular systems can also be spatially multiplexed over the radio part of the end-to-end channel. Optical systems today can also be frequency and/or time multiplexed.

Simplistically, trunking gain is achieved because most users only need resources for a relatively short time and therefore have no need for a dedicated channel. However, conversational voice is sensitive to delay and delay variability. Historically these end-to-end channels have therefore been deterministic with known and closely controlled end-to-end delay and delay variability characteristics. The transition from voice-dominant communication to a mix of voice and data, some of which is not time sensitive has allowed for additional multiplexing in which traffic is segregated into typically four traffic classes, conversational (voice and video calling), streaming, interactive and best effort. In theory at least, this allows for a significant increase in radio and network bandwidth utilisation that should translate into lower cost per bit delivered. This is the basis on which IP network efficiency gain assumptions are traditionally based.

However, reference to our post-office analogy suggests the cost/efficiency equation is more complex. A letter or packet posted first class stands at least a chance of arriving the next day. A

second-class letter will take longer to arrive as it will be stored at any point where there is not enough delivery bandwidth, lorries, aeroplanes or bicycles, for the onward journey. In theory, this means that the delivery bandwidth can be loaded at a point closer to 100% utilisation, thus reducing cost.

This is true but fails to take into account the real-estate cost of storing those letters and packets in some dark corner of a sorting office and managing their timely reintroduction in to the delivery path. Depending on how these costs are calculated it can be argued that a second-class letter or packet probably costs the postal service rather more to deliver than a first-class letter or packet with of course less revenue to cover the extra cost. An end-to-end packetised channel is the post-office equivalent of having first-, second-, third- and fourth-class stamps on every letter and packet. The routers have to inspect each packet to determine priority and store lower priority packets as needed. Packet storage needs fast memory, which is expensive and energy hungry and constitutes a directly associated cost that needs to be factored in to the end-to-end cost equation. If there is insufficient storage bandwidth available the packets will have to be discarded or other time-sensitive offered traffic will need to be throttled back at source. This introduces additional signalling load that in itself absorbs available bandwidth and may compromise end-user experience. As end-user experience degrades, churn rates and customer support costs increase.

On the radio part of the network, the additional address overhead needed to discriminate between delay-tolerant and delay-sensitive traffic combined with the signalling bandwidth needed to maintain a reasonably optimum trade off between storage bandwidth and delivery bandwidth utilisation comes directly off the radio link budget and will therefore show up as a capacity loss or coverage loss, effectively a network density capital and operational cost. The user's data duty cycle (time between battery recharge) will reduce as well.

These caveats aside, multiplexing in its many forms does produce an efficiency gain, but this will not always be quite as much as claimed by the vendor community. The efficiency gain can be substantial if we are tolerant to delay and delay variability or can access delivery bandwidth in periods of low demand. For example our business offices are situated in a residential area from which most people commute every day. Day-time contention rates on our ADSL lines are low, evening contention rates are high, which suits us just fine.

1.9 Standardised Description Frameworks – OSI Seven-Layer Model as a Market and Business Descriptor

All of the above suggests a need for a standardised description framework that can be used as the basis for analysing how different functions in a network interact together and the coupled effects that determined delivery cost and delivery value.

Such a framework already exists and has been in use since 1983.⁶ Known as the Open Systems Interconnection Model, this seven-layer structure remains as relevant today as it has ever been and encapsulates the topics addressed in all subsequent parts and chapters in this book. (See Table 1.1.)

There are two immediately obvious ways to approach an analysis using this model, to start at the top and work downwards or to start at the bottom and work upwards. Most industry

⁶ http://www.tcpipguide.com/free/t_HistoryoftheOSIReferenceModel.htm.

Table 1.1 OSI seven-layer model

Description	Example protocol or layer function	
Layer 7	Application Layer	Windows or Android
Layer 6	Presentation Layer	HTML or XML
Layer 5	Session Layer	Reservation protocols
Layer 4	Transport Layer	TCP prioritisation protocols
Layer 3	Network Layer	IP address protocols
Layer 2	Data Link Layer	ATM and Ethernet Medium Access Control
Layer 1	Physical layer	Fibre, cable, copper, wireless including free-space optical, infrared, ultraviolet and radio frequency

analysts would err towards starting at the top and working down on the basis that the application layer has the most direct impact on the customer experience and therefore should be regarded as the prime enabler. This assumes that we are working in an industry that is customer led rather than technology led, but this is at odds with historical evidence that suggests that the economics of telecommunications supply and demand are directly dependent on fundamental innovations and inventions at the physical-layer level. The innovations in the lower layers are generally, though not exclusively, hardware innovations, the innovations in the upper layers are generally, though not exclusively, software innovations.

This functional separation determines the structure of this book, with Part 1 reviewing user equipment hardware, Part 2 reviewing user equipment software, Part 3 reviewing network equipment hardware and Part 4 reviewing network equipment software. In terms of analysis methodology we are firmly in the bottom-up brigade.

Readers with long memories might recall that this is uncannily similar to the structure used in ‘3G Handset and Network Design’ and we would point out that this is entirely deliberate.

The business of technology forecasting should in practice be a relatively precise science, but even if imperfect can be used to calibrate future efforts. ‘3 G Handset and Network Design’ still provides a perfectly adequate primer to many of today’s technology trends but lacked an ambition to integrate the technology and engineering story with economic analysis.

1.10 Technology and Engineering Economics – Regional Shifts and Related Influence on the Design and Supply Chain, RF Component Suppliers and the Operator Community

Which brings us back towards our start point in which we said that we aim to make the case that technology and engineering economics are separate disciplines that deserve separate analysis. In this context we will find that technology and engineering capacity is also determined by the gravitational effect of large emerging markets that absorb R and D bandwidth that would previously have been available elsewhere.

Ten years ago Jim O Neill, a partner at Goldman Sachs, wrote a paper entitled Building Better Global Economics and coined the term BRIC identifying the four countries, Brazil, Russia, India and China that combined large internal markets with high growth potential.

Over subsequent years these countries have not only been tracked as an entity by analysts but have also developed political and economic links that aim to leverage their combined economic power. In 2010 China invited South Africa to become a member so the acronym is now officially BRICS.

The BRICS are benchmarked in terms of geography and demography and economic growth rate. All are markets in which large telecommunication investments are presently being made, but of the four China stands out as having the largest number of internet users and the largest number of mobile phones that combined together suggest that China is already by far the world's largest single potential market for mobile broadband access. In terms of mobile connections China and India together are now five times the size of the US market. China's present dominance is illustrated in Figure 1.1.⁷

Figure 1.2 shows China Mobile's particular leverage.

In turn, this has had a dramatic effect on the local vendor community. Over a five-year period between 2006 and 2011, Huawei has moved from being a subscale (in relative terms) infrastructure provider with an \$8.5 billion turnover to being number two globally with \$28 billion dollars of revenue and 110 000 employees across 150 nationalities.⁸ A similar pull-through effect has created a local development and manufacturing community both in China and Taiwan that has challenged and will continue to challenge Nokia both at the lower, mid and upper end of the user equipment market. HTC in Taiwan, for example, at the time of

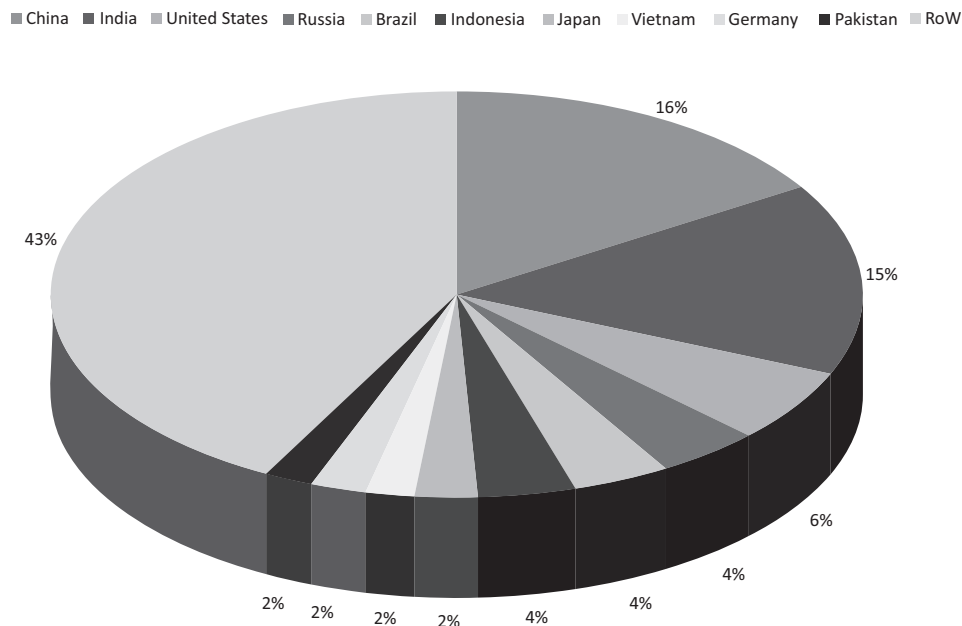


Figure 1.1 Mobile connections by country Q1 2011. Reproduced by permission of The Mobile World.

⁷ All market statistics and modelling in this book are sourced from *The Mobile World*.

⁸ http://www.cambridgewireless.co.uk/docs/FWIC%202011_Edward%20Zhou.pdf.

and more than as much again in associated 700-MHz network hardware and software – a \$50 billion investment. The band requires a unique mix of RF components, filters, switches, oscillators, RF amplifiers, low-noise amplifiers and RF amplifiers and associated matching components.

These are typically 50 cent devices. The RF component industry is highly fragmented and works on margins that are significantly lower than other component sectors. Servicing a subscale customer therefore implies an insupportable opportunity cost. The end result is that a \$50 billion investment can be compromised and/or invalidated by an inability to source a few 50 cent components.

The critical enablers for RF performance both in user equipment and radio network equipment can be summarised as materials innovation, for example gallium arsenide, or more recently gallium nitride, in RF power amplifiers, component innovation, for example SAW or FBAR filters, and algorithmic innovation, for example adaptive matching techniques or at higher layers of the OSI model adaptive traffic management and scheduling.

Historically, these inventions and innovations have tended to originate from the West Coast of the US or Japan or Germany or Sweden or Finland or the UK or France to a greater or lesser extent.

China, however, is producing 450 000 university graduate engineers a year with India not far behind. India already has a major footprint in global ICT and China has an increasingly global footprint in the provision of telecommunications equipment. Companies such as Huawei and ZTE have large internal markets and can increasingly exploit local intellectual resources to develop in-house intellectual property value that can be leveraged into external markets.

A CTO from a European vendor pointed out that partly because of present exchange-rate anomalies, average engineering wage rates in mainland China are one tenth of European levels with a second level of subcontractors earning an order of magnitude less again. Combine this with preferential access to capital and it becomes obvious that Chinese vendors are well positioned to take market share from the European and US vendor community.

In the past, Europe and the US may have been able to realise a measure of market protection through aggressive management of the standards process and associated use of litigation to defend intellectual property value

However, this incurs a cost that at a practical engineering level translates into hundreds of engineers attending hundreds of international standards meetings that generate thousands of pages of standards documents that only the authors can interpret. This is probably no longer a sustainable business model. The progressively more active engagement of Chinese and Indian vendors in telecommunication standards work is a symptom of this transition in present progress.

And that summarises the underlying narrative that will be explored in the next twenty chapters. Technology economics and engineering economics are distinct and separate disciplines that are amenable to analysis and can yield significant insight into future competitive differentiation and competitive advantage opportunities. Accurate historic data sets are available that can be used to measure the rate of technology change. These can be used to underpin forward forecasts, but have to be qualified against any external factors that have undergone significant change.

So, for example, it could be argued that the spectral auction process has taken probably at least \$200 billion dollars of cash out of the mobile telecommunications sector of the telecommunications industry. This has resulted in a decrease in available R and D resource.

In parallel, new markets have emerged, specifically China. These are having a gravitational effect on already diminished and diluted global technology and engineering capability. This will create a vacuum that will increasingly become filled by locally sourced resource. China's present investment in telecommunications engineering education and training closely mirrors the educational policy adopted by the Finnish government in the late 1980s and 1990s. The availability of well-trained highly competent hardware and software engineers was an essential ingredient in Nokia's transition from small niche player to global market leader in mobile phones, a position now increasingly under threat.

1.11 Apple as an Example of Technology-Led Market Innovation

Some of the ebb and flow of competitive advantage and opportunity can be directly ascribed to technology innovation. The Apple iPod proposition is built on the availability of low-cost solid-state memory, the Apple iPhone and iPad proposition is based on capacitive touch-screen interactive display technology. Both are examples of component-level innovation transforming user behaviour, a technology opportunity that Nokia failed to capitalise on early enough.

Apple also successfully managed to add content value and software value to the hardware proposition. Quite who has done what when and who owns what is, however, always subject to legal interpretation. Nokia sued Apple for patent infringement and won a royalty agreement in June 2011 worth just under 5% of the value of each iPhone sold plus a one-off payment of 800 million euros.

This corroborates our thesis that a technology and engineering opportunity analysis and ownership analysis should be the starting point not the end point of the strategic planning process.

And fortuitously, the methodology is beguilingly simple. To forecast three to five months ahead look three to five months behind, to forecast three to five years ahead look three to five years behind, to forecast thirty to fifty years ahead look thirty to fifty years behind.

It might seem absurd to contemplate a thirty- to fifty-year planning cycle, but in reality many technology cycles in telecommunications are of this order of magnitude. This is why standards or regulatory policy if determined by short-term three- to five-year political interest can destroy shareholder, stakeholder and social value. This is why short-term return on investment expectations, three- to five-year or three- to five-month or three- to five-day horizons can destroy longer term competitive capability.

Additionally, it is an inescapable fact that global scale is now more or less an exclusive precondition of commercial success in the telecommunications sector. Arguably only one country is large enough to have sufficient economies of scale to sustain any kind of nationally specific telecommunications technology policy. Previous attempts to protect local markets have, however, proved disastrous, the impact of nationally specific Japanese standards on the Japanese vendor community being a relatively recent example.

'Making Telecoms Work – from technical innovation to commercial success' is an all embracing title for an all-embracing attempt to bridge the traditional gap between engineering and the business planning process.

It is an absolute truth that hugely ambitious commercial plans can be invalidated by apparently trivial technical details. This brings us to Chapter 2.