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Analyzing technological threats and opportunities in wireless data services

Gert T. du Preez[a], Carl W.I. Pistorius[b,*]

[a]*Deloitte Consulting,Johannesburg,South Africa*
[b]*University of Pretoria, Pretoria 0002, South Africa*

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Abstract

The ability to assess the threat and opportunity that technological innovations pose to an organisation's profitability, growth and survival has become one of the key elements in the development of offensive and defensive innovation strategies. Central to this process of assessing technological threats and opportunities is the need to analyze various aspects of identified technological developments. A range of analysis techniques exists, and a number of these are discussed and simultaneously applied to a specific technological development. While threat and opportunity assessment is relevant to almost any company in any industry, it is especially relevant to industries characterised by high rates of volatility such as the communications industry. The technological development, which has been chosen to apply these analysis techniques to, is the offering of 2.5/3G wireless data services, which is currently of great significance in the communications industry. The point of view that is taken is that of a European mobile network operator (MNO) that needs to assess the threats and opportunities that this development poses to its business. The result shows that the analysis process leads to a better understanding of not only the identified developments, their driving forces and enablers, but also their possible impacts on the organisation. This greatly enables the extent to which developments represent a threat or opportunity for a specific organisation to be assessed. In the framework of the overall technological threat and

* Corresponding author.
E-mail address: pistorius@ee.up.ac.za (C.W.I. Pistorius).

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opportunity assessment methodology, the results of the analysis process will feed into the strategy formulation process where possible organisational responses can be developed.

Keywords: Technology forecasting; Technological threat and opportunity assessment; Innovation strategies; Wireless data services; 2.5G wireless; 3G wireless

1. Introduction and overview

In an age where technology itself is becoming an increasingly important component of the ability of companies to compete and even to survive, the capacity to identify emerging technologies and manage them are vitally important issues. This is confirmed by Ashton et al. [1], who state that "Companies that want to survive the increasingly sophisticated and competitive global marketplace will be required more and more to follow technical developments worldwide." The authors have proposed the notion of technological threat and opportunity assessment as a useful framework for anticipating technological change [2]. One of the core components of this framework is an analysis of identified technological developments and their potential impacts on the organisation.

In this paper, the fast growing area of wireless data communications is analysed from a technological threat and opportunity assessment viewpoint. The high levels of volatility and uncertainty in this industry sector make the ability to assess technological threats and opportunities extremely relevant and important. The analysis in this paper focuses on the impending substitution of the so-called second-generation (2G) wireless telephony technology by third generation (3G) technology. The technology battle is complicated by the emergence of the hybrid 2.5G technology, which is anticipated to significantly influence the substitution process.

In Section 2, the notion of technological threat and opportunity assessment is briefly described within the context of a model that has been proposed previously [2]. Section 3 presents an overview of the technologies and some market considerations that pertain to wireless data services. In Section 4, the threat and opportunity assessment approach is applied to wireless data services from the point of view of a European mobile network operator (MNO). Section 5 contains some conclusions.

2. Assessment of technological threats and opportunities

There is a growing realisation among companies that technological innovation is a powerful source of competitive advantage. As such, technological innovations present both threats and opportunities not only to companies' short- and medium-term profitability, but also to the longer-term growth and survival. This is true of all technology-based organisations, i.e., those organizations where technology can have an effect on the bottom line in one way or another—and we have yet to be convinced that there is any organisation in which this is not the case. There are many examples of companies that were market leaders and

financially very strong, but failed or came to serious grief because they misjudged the impact that technological innovations can have on their business (see, for example, Refs. [3,4]). The ability to develop and deploy offensive and defensive innovation strategies has become a necessary element of companies' strategy portfolio, and a framework to assess technological threats and opportunities is an essential component of these strategy.

The framework for assessing technological threats and opportunities that was previously proposed is shown in Fig. 1. It follows a two-pronged approach. Firstly, a rapidly changing global technological landscape necessitates keeping track of technological developments. Since the focus here is on innovation (as opposed to mere invention), the market implications are as important as the technological ones and have to be considered as well. One must assess developments not only in the technology field or the market, but rather the interaction in the technology–market domain. Also, although the emphasis is on *technological* threats and opportunities, social, economic and political issues tend to affect technological diffusion acutely, and hence any methodology for keeping track of technological developments should be able to translate these trends into technological impacts. It is essential to monitor and scan broadly, since industry-shattering and paradigm-shifting innovations very often originate in an entirely different industry than the one that they eventually have the greatest impact on [3].

Secondly, as was pointed out above, *any* organisation could be considered to be technology-based to some or other degree, and the second core element of the framework is thus to

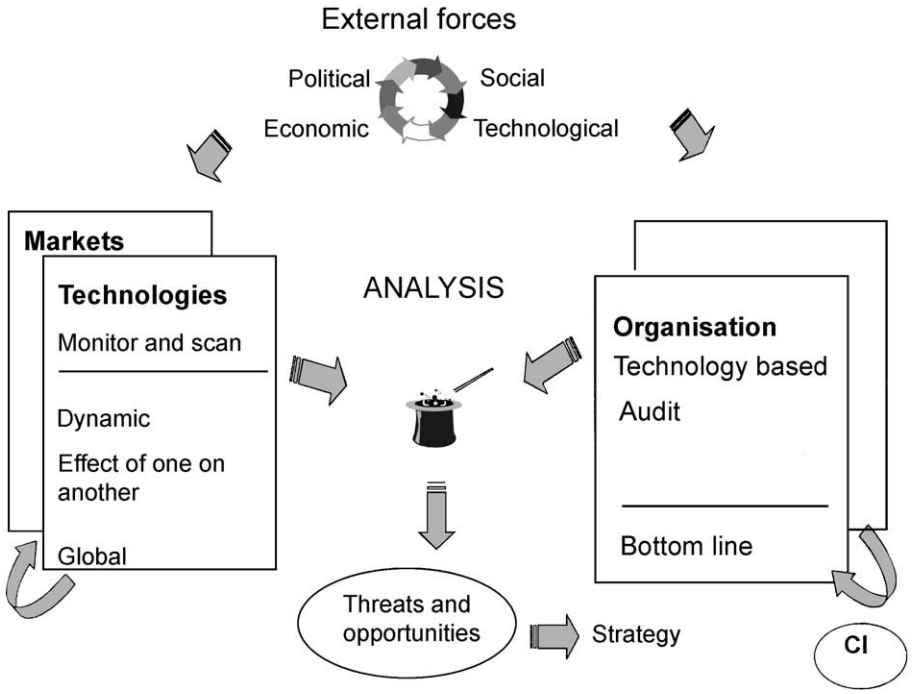

Fig. 1. Technological threat and opportunity assessment (after du Preez and Pistorius [2]).

assess which of the technological developments could potentially impact the organisation, typically through a technology or innovation audit. Also, no organisation operates in a vacuum, and therefore other entities that interact with the organisation in question needs to be identified, be they partners, competitors, suppliers or distributors. Some competitive intelligence practices are thus highly applicable for this activity.

The purpose of the analysis component of the threat and opportunity assessment framework, which is focused in Section 4, is to develop a better understanding of the nature of those developments that could potentially impact the organisation. This will enable these developments to be cast into a framework of threats and opportunities. The results will integrate into the corporate strategy formulation process where appropriate offensive and defensive innovation strategies can be developed.

3. Overview of wireless data services

The objective of this section of the paper is to provide a brief overview and background of wireless data services, some of the technologies that enable it and selected issues with regards to the state of the wireless communications industry for readers who are not familiar with recent developments in this industry segment. The background information will demonstrate why this industry sector was chosen as an example for the illustrative application of analysis techniques in Section 4 and will enable more value to be derived from that section.

Wireless data services refer to a wide range of value-added services that could be offered to wireless telephony users. Typical examples of possible services are shown in Table 1. These services can be accessed not only via mobile phones but also other access devices such as personal digital assistants (PDAs), laptop computers and autonomous devices (those devices involved in the delivery of telemetry type services such as a vending machine sending stock level information to a central controller). The e-booking and ticketing example can be taken as illustration: a user can access information about the latest movies showing at a specific theatre and their starting times from his or her phone anytime and anywhere; select seats and pay for these tickets via a number of options (e.g., charging the cost to his or her mobile phone bill, to a credit card or using customer loyalty scheme points). Arriving at the theatre, the user could scan the phone at a printing device that will authenticate the user and print the tickets.

A large number of European MNOs are currently operating 2G Global System for Mobile Communications (GSM) networks. Some operators are currently offering certain of the data services listed in Table 1 on the GSM network, making use of such data transfer protocols as wireless application protocol (WAP) and short message service (SMS). However, the take-up of the services offered has not been very high due to mainly three factors.

Firstly, the typical data transfer rate achievable on a GSM network is 9.6 kbps (kilobits per second), which leads to user frustration with long download times. The low transfer rate also severely limits the richness of information and complexity of the wireless data services and applications that can be offered—as an example, the data transfer rate required for streaming audio to a mobile device is around 32 kbps and for video services around 128 kbps.

Table 1
Examples of wireless data services and applications that could be offered

Market segment	Service categories	Specific services
Consumer	Information services	News headlines; market and financial information; new movie releases; "what's on"
	Personal information management (PIM)	E-mail; contact lists; shared scheduling; customised alerts for stock market prices or auction bids
	Location-based services	Directions from current position to a specified location; queries for various facilities (e.g., hospital and restaurant) in the user's vicinity
	Entertainment	Video and audio on demand; mobile betting and gaming
	M-commerce	Mobile banking, shopping and stock trading; mobile auctions; e-booking and ticketing
	Interactive communications	One-to-one or multiple participant text-based chat; video telephony and conferencing; interactive games. Remote control of appliances (e.g., alarm/VCR setting)
Business	Remote access to information	Sales force automation through access to stock, product and customer information; remote access to intranet or other corporate repositories; e-mail; online telephone directories
	Job and information dispatches	Informing field staff of their next assignment (e.g., plumbers, electricians and technical support staff). Sending of information to multiple recipients (e.g., notifications of meetings). Focused/personalised advertising
	Remote transactions	Remote control of processes and devices; placing and processing customer orders
	Telemetry/device-to-device	Price changes being sent from a central controller to all vending machines; meter readings; remote vehicle diagnostics

Secondly, data transmission on GSM is circuit-switched, meaning that a circuit connection is dedicated to a specific user for the entire length of the call, even when no information is being transmitted (and hence the user pays for the entire connection time instead of for the amount of data accessed or transferred during that time). A user also needs to dial up the service centre every time a service or application is accessed; with call and connection set-up times in the region of 50 s, this contributes to a frustrating user experience.

Lastly, most operators offering data services on a GSM network have billed for these services in the same way as for voice service, i.e., duration-based billing (per minute or in more advanced cases per second). There are several more appropriate billing mechanisms for

data services, such as volume-based billing (per packet or kilobit of information downloaded or accessed).

The combination of these factors resulted in the fact that accessing wireless data services on the GSM network has been both frustratingly slow and prohibitively expensive. However, advances in network technologies such as General Packet Radio Service (GPRS) and Universal Mobile Telecommunications System (UMTS) are forecasted to trigger an explosion in wireless data services over the next 5 years.

3.1. GPRS and UMTS

GPRS is often referred to as a 2.5G (second-and-a-half) generation network technology, envisaged as a 'stepping stone' between the current 2G GSM networks and 3G networks discussed in following paragraphs. Data transmission on GPRS is packet-switched, which means that information is split into "packets" of data that are transmitted and received in bursts rather than through a continuously open or dedicated radio channel [5]. This is more attractive for wireless access than circuit-switched GSM transmission because radio spectrum is used only when data is actually being transmitted. This also enables a user to be billed only for the volume of information that is accessed or downloaded and not for the duration of the connection.

Another valuable feature of GPRS is the fact that it is "always-on," eliminating the need for call and connection set-up every time a service or application is accessed. The theoretical data transfer rate achievable on GPRS is 114 kbps, which is a significant improvement over GSM's 9.6 kbps.

UMTS is a 3G wireless technology. It is based on the Code Division Multiple Access (CDMA) radio access protocol, and also features packet switching and always-on functionality similar to GPRS. The data transfer rate for a stationary user is forecasted to be 2 Mbps (megabits per second). This will truly enable information rich, complex applications such as videoconferencing to be offered.

3.2. The wireless telephony industry

In this subsection, some of the current characteristics of the wireless telephony industry will be highlighted, so that the impact that wireless data will have on the industry is better understood.

The wireless industry is currently characterised by rapid rates of change and high levels of volatility. A recent Forrester Research report on European MNOs forecasts that, although the usage of voice services will increase by 41% over the next 5 years (2001–2006), price competition will cause the average revenue per user (ARPU) for voice services to drop by 45% over the same period [6]. Also, regulatory authorities have various methods of issuing licenses to operators to offer 3G services. In the majority of countries, this has been and is done by way of an auction and, in some cases, staggering amounts have been spent on acquiring licences. Deutshe Telekom, France Télécom, Vodafone, Spain's Telefonica and others have spent more than $95 billion on 3G licenses and will need to invest another $125

billion on technology infrastructure [7]. It is expected to take a quite a long time to recoup these costs. The problem can be complicated significantly by the extent to which 2.5G can distort the technology and market trajectories.

Other challenges operators face include high levels of customer churn and the lack of MNO's intelligence on customers' usage patterns. Churn refers to customers switching to another MNO. This is being exacerbated by trends such as shorter contract lifecycles (12 months instead of 24) and number portability, where a customer keeps their number when they switch to another operator. Customer intelligence currently focuses on aspects such as monthly spending, income and related factors, whereas lifestyle segmentation features will be important for data services. Also, a large portion of a typical operator's client base is prepaid or noncontract clients (typically between 65% and 80%) with even less information available about these clients, their needs and preferences.

Since data services will be able to address these challenges that operators are facing in varying degrees (this will be shortly described in the following paragraph), the importance of wireless data services for an operator is confirmed.

Data services are seen as a source of additional revenue opportunities, which could slow the current trend of falling ARPU and support the recovery of 3G license costs. The same Forrester report mentioned above reports that operators expect data services to boost average revenue per user by 25% in 5 years. It is also expected that data services could reduce customer churn through the "stickiness" of services (a customer's e-mail address could, for example, be johnsmith@name-of-the-operator.com, which locks in the customer to some degree). With regards to customer intelligence, data services will enable information about customers to be gathered since they will need to sign-up for these services at which time a range of information can be requested. A possible strategy could be to offer services at no cost for a limited period, provided that customers complete a questionnaire. This free period also provides a marketing and customer education opportunity.

It is clear that the technological development of 2.5G and 3G wireless data services and applications are potentially significant for a MNO. In Section 4, a number of analysis techniques are discussed and applied to this development.

4. The analysis component of threat and opportunity assessment

The first objective of this component of the framework is to gain a better understanding of the nature of the developments that could potentially impact the organisation, the forces driving and enabling it as well as possible changes that might occur in the development over time. The second objective is to make an assessment of the development in the context of the organisation's internal and external environment so that a greater awareness of the impacts the development could have on a specific organisation is obtained.

In the remainder of this section, some of the analysis techniques that have been proposed will be discussed and applied to the development of 2.5/3G wireless data.

4.1. Causal models

The term "causal models" as used in this article refers to models that relate technological change to the factors that cause or drive it, rather than to statistical model or econometric analysis.

Instead of immediately focussing on the trend or development itself, the forces that produce the change or drive the trend are examined. The rationale is that this is a more reliable way of analysing the dynamics of technological change since the factors that cause change are normally not themselves volatile over the short term. The Institute for Prospective Technological Studies (IPTS) of the Joint Research Centre (JRC) of the European Commission (EC) has utilised this principle in some of its efforts (see, for example, their report on production technologies [8]).

These models are of great value for any company in any industry since they provide a macro view of both short-term technological change and longer-term driving forces causing the change. This is felt to be the best way of initiating the analysis effort in as much as it provides a structure or framework for portraying change related to a specific technological development from where other methods and techniques can be utilised to analyse specific issues in greater detail.

Table 2 shows a causal model compiled for the 2.5/3G wireless data development. Two specific issues listed in Table 2 will be briefly discussed here for the sake of comprehensiveness. *Bluetooth* is a low-cost technology using short-range radio links (up to 10 m) to provide cable-free connectivity between various devices such as between mobile phones, PDAs and PCs. If a PDA is Bluetooth-enabled, it would, for example, automatically synchronise with a PC that is within 10 m of it. Colleagues working with laptop computers at a client could set up their own network for file sharing using Bluetooth technology. *Pervasive computing* refers to the presence of technology in everyday objects such as refrigerator. The refrigerator will, for example, automatically order items from an on-line grocer as goods are consumed.

As can be seen, one of the greatest strengths of the causal model is the fact that it provides a cohesive view of technological, social, political/regulatory and economic/market forces that affect a specific technological development.

4.2. Correlation methods

Correlation methods refer to any situation where some relationship between an instance of technological change and some other factor may exist. This other factor could, for example, be an experimental employment of the technology, counts of publications or patents, or an economic factor.

The two most commonly used correlation methods are lead-lag correlation, or precursors, which will be applied to the example of wireless data services and is discussed in detail, and bibliometrics. Bibliometrics use counts of publications, patents or citations to measure and interpret scientific and technological advances. It involves, first and foremost, activity measurement. These analyses assume that counts of papers and patents validly indicate

Table 2
A causal model for wireless data services

Force producing change/driving trend	Trend	Impact/effect
• More and more of work and personal lives are spent on the move • Telecommuting and organisations with mobile workforces are on the increase • Globalisation	Increase in time spent away from home or office where users have access to Internet and/or corporate information sources	Demand for ubiquitous access to information and services (personal and business)
		Demand for greater convenience—ability to control home appliances from anywhere (monitor alarm, set VCR/central heating, etc.)
	Increase in time spent away from home town or city	Demand for access to location-based information from mobile devices (e.g., directions to get from X to Y; location of nearest restaurant, pharmacy, etc.)
Various enablers facilitate easier access to a wider range of information (e-mail, eRooms, electronic newletters, Internet)	Information overload	Demand for ability to filter information and customise the presentation according to personal preferences
Dramatic decrease in costs of mobile services	Increase in mobile usage	Mobile phones starting to replace wireline (fixed line) phones
Advances in semiconductor technologies	Smaller components; devices with improved display and computing functionality	Mobile access devices capable of offering complex, multimedia information or services
• Widespread adoption of mobile phones and other mobile access devices, e.g. PDAs • Charging mechanisms such as prepaid instead of contract terms	Increase in number of mobile users	Greater potential customer base for mobile services
	Some users who do not have PC access to the Internet will have mobile phone access	Ability to bring Internet access to new users
• Shorter product life cycles • Increased rates of technological and product innovation	Swift rate of adoption of new technologies and services	Potential rapid adoption of mobile data services
Technology standardisation	Various organisations working on standards for 3G based on the Code Division Multiple Access (CDMA) protocol	Seamless roaming and accessing of data services globally

(continued on next page)

Table 2 (*continued*)

Force producing change/driving trend	Trend	Impact/effect
Introduction of new device linking technologies such as Bluetooth	• Increase in number of networked peripherals • Pervasive computing	• Greater usefulness and convenience of mobile phones and other access devices • Enables a greater number of possible data services
Information or services are accessed from a wide range of devices	Use of metalanguages such as XML, which makes the manipulation of device and format independent	Information consistency can be achieved regardless of access device utilised

research and development (R&D) activity in target subject areas and reflect the emphases of institutions to which they are linked [9].

4.2.1. Lead-lag correlation

Lead-lag correlation, or precursors, describes a time-based relationship that exists between the experimental or niche demonstration of an ability and its widespread commercial usage. This is common in the military environment where technologies are often applied a few years before widespread usage. Also, technologies utilised in racing cars tend to diffuse to commercial vehicles after a period of time.

Another instance of this technique is where the situation or experience in a more mature market may serve as a precursor of possible change in a less mature market. In the case of wireless data viewed from the perspective of an European MNO, the Asian market can be examined as a more mature wireless data market. The Japanese operator NTT DoCoMo, for example, has established itself as the global leader in wireless data with its i-mode services and can provide some precursor information for European operators.

4.2.2. The experience of NTT DoCoMo

NTT DoCoMo is the largest MNO in Japan. It launched wireless data services based on its i-mode data transmission protocol in February 1999. i-Mode is a 9.6-kbps packet-switched protocol, which was implemented on DoCoMo's Personal Digital Cellular (PDC) network. Within just 10 months, there were 2.65 million subscribers to i-mode, representing 10% of DoCoMo's users. Revenues from i-mode account for approximately 15% of total revenues. By March 2001, i-mode was forecasted to have 13.2 million subscribers [10].

The argument can be made that there are significant differences between the Japanese and European markets, such as that Japanese consumers tend to be very early adopters of new

technologies or services, that the average mobile terminal replacement cycle is 9 months in Japan vis-à-vis almost 18 months in Europe and that i-mode data transfer is slower compared to GPRS and UMTS (9.6 vs. 114 kbps for GPRS and 2 Mbps for UMTS). However, the i-mode experience could still provide some indicators of the possible evolution and growth of wireless data services to European operators [11], viz.:

- Richness of content has led to a high growth in the number of subscribers, which has resulted in greater interest from content suppliers in a self-reinforcing trend. Developing a balanced portfolio of data services addressing the needs of specific segments should therefore be a high priority.
- A side effect of the offering of data services was an increase in voice usage. This is partly ascribed to subscribers making calls after accessing data services, e.g., responding with a call to an e-mail that was received.
- Churn rates have fallen with the introduction of i-mode. This is significant in light of the fact that customer retention is currently a major issue for most MNOs.
- User friendliness is one of the most important attributes from the end-user point of view, and this is increased by attractive charging schemes where users are only charged for the information they download.
- By launching i-mode in a 2G environment, DoCoMo has prepared and educated the market for the introduction of 3G wireless data services. European operators need not wait for UMTS to be deployed. Many services can be offered on GPRS and even on the GSM network in a less complex form.

4.3. Competitor analysis

An analysis of competitors and their activities firstly enables an organisation to identify potential threats and opportunities originating from this source. Secondly, where the source of an opportunity or threat is not from competitors per se (such as new regulation that will impact all entities in the industry), knowledge of current and potential competitors as well as their activities and capabilities will enable the best possible response to the threat or opportunity to be formulated.

Analysing *potential* competitors is a crucial but challenging task since, as mentioned earlier, industry-shattering and paradigm-shifting innovations very often originate in an entirely different industry than the one that they eventually have the greatest impact on. In the wireless data world, for example, it is likely that users will, when they wish to access data services or applications, do so through a portal similar to Internet portals or homepages. An MNO does not only face competition from other MNOs in the provision of a mobile portal but also from the device manufacturers (e.g., Nokia could program their portal or homepage to be the default on all of their phones and other access devices) as well as current Internet portal companies, as witnessed by the launch of initiatives such as AOL Anywhere and Yahoo Everywhere. Similarly, in the provision of payment mechanisms for mobile services and applications, banks could be potential competitors.

While it is not viable to take a specific MNO as an example here and to perform a detailed analysis of its competitors and their activities, the rest of this subsection will focus on potential competing technologies for wireless data.

4.3.1. Competing technologies

There are a number of wired or fixed-line technologies that could provide some services that will be in partial competition with wireless data services as enabled by 2.5G and 3G technologies. These include Integrated Services Digital Network (ISDN), Digital Subscriber Line (DSL), as well as Fibre to the Curb (FTTC) and Fibre to the Home (FTTH). Some of these technologies can provide greater data transfer rates than UMTS, in selected cases over 52 Mbps. However, the key factors that differentiate wireless data services from services offered on the above technologies are mobility (the ability to access services anytime, anywhere and on any device), as well as location-based services. Location-based services utilise information about a user's location, e.g., directions to the nearest pharmacy, restaurant or hospital in the user's vicinity, for example.

A competing wireless technology is wireless LANs (W-LANs). Making use of technologies such as IEEE 802.11b and unlicensed frequencies in the 2.4 GHz band, a range of W-LAN operators is springing up and rolling out short-range, high speed data access points for business travelers in locations such as airports lounges, hotel lobbies and conference centres. While these networks cannot hope to match the coverage of wireless networks, they do offer download speeds of up to 11 Mbps. British consultant BWCS has forecasted that there will be 114,220 wireless hotspots globally in 2006, up from 6300 in 2001. They foresee 17 million W-LAN hotspot users by 2006, generating annual revenues of some US$7.3 billion [12]. However, it should firstly be kept in mind that these services are only accessible via enabled PDAs and laptop PCs. Secondly, since coverage is limited these services are not a direct competitor to 2.5G and 3G services.

4.4. Analysis of technological artefacts

There are various possible applications of this group of techniques. One example is where no specific technological development that could represent a threat to an organisation has been identified, but the organisation is attempting to ascertain what such a development possibly could be. By anticipating the changes that could possibly occur, the organisation can better respond to them. Therefore, the purpose of this type of analysis is to try and anticipate possible changes in technological artefacts (products, processes, services, etc.) that may occur. A second possible application is to assess the probable success of an envisioned entity made possible by technological development, taking into account various technological, organisational and market factors. A framework that evaluates success in terms of technology and business contexts suggested by White and Graham [13] is an example of this application.

Another possible use of this group of techniques is where a specific technological development of interest to the organisation has been identified, but it has not been

commercially exploited yet. The purpose here is to identify issues such as key uncertainties or bottlenecks, as well as supporting or complementary technologies needed for commercial development. These will represent "factors to watch for," which monitoring and scanning personnel will be specifically on the lookout for. This application of the analysis of technological artefacts will be applied to 2.5/3G wireless data services.

4.4.1. Issues in the commercialisation of 2.5/3G wireless data services

Since 2.5G data services are only starting to be commercialised and no 3G services have been commercialised in Europe at the time of writing this article, some supporting and complementary technologies, which will facilitate or enhance the uptake of these data services, will be considered.

As mentioned previously, it should be kept in mind that users will access data services not only via mobile phones and other mobile access devices but via other devices and in other formats as well. As an example, while out of the office, a specific user will access information about product stock levels on his or her mobile-enabled PDA using the WAP for data transfer (assuming the WAP protocol is used in the 2.5/3G environment), where information is displayed in a text format (Wireless Markup Language or WML) on the device screen. When this user is driving, he or she may want to access the same information via a mobile phone, but would prefer to have this read to him or her, utilising information in the Voice Markup Language (VoxML). Returning to his or her office, the user will access the information via the Internet on a PC in Hypertext Markup Language (HTML). At home, services might be accessed using interactive TV (i-TV).

The first implication of this is that information consistency, regardless of access device or access format, will be of crucial importance. This can be partly achieved through the use of information in a "metalanguage" such as Extensible Markup Language (XML). Information in XML can easily be translated into WML, HTML or VoxML depending on the access device and format required. The development and adoption of XML is therefore a factor to monitor.

Secondly, technologies that link the wireless environment (wireless data services), the wired environment (Internet) and the physical world are key complementary and supporting technologies for wireless data services and applications. An example is the Live Reply functionality provided by AmVia's Unified Messaging offering. A text-to-speech engine can read a user's e-mail to him or her via the mobile phone, and the user can then reply by sending a voice response. This voice response is recorded and sent as a .WAV attachment, which the sender of the original mail can access on his or her PC [14].

The Gartner Group has used the term 'Supranet' to describe the emerging ubiquitous network infrastructure born out of the convergence of wireless and wired telephony, satellite, television (cable and broadcast) and radio communications, that will link the "e-world" (variety of electronic devices) and the "p-world" (physical world) [15]. Examples of specific technologies that are mentioned in this regard are barcode scanning and speech recognition. Other complementary and supporting technologies include document scanning and optical character recognition (OCR) as well as Bluetooth. These technologies should thus be monitored for advances and breakthroughs.

4.5. Industry/sector analysis

This is a group of techniques concerned with identifying indicators that might provide warning of possible change in the industry or sector and which could lead to disruptions or paradigm shifts.

One set of indicators is specific patterns of activity in the industry. The formation of a joint venture, for example, could be a signal that change may be taking place in the near future. Similarly, the announcement of a new degree or research program by universities could indicate that the specific field is one to monitor closely. In some cases, new instrumentation may be vital to pacing progress in a field and these may serve as indicators of advances.

It is also worthwhile to determine whether the technologies of interest in an industry are in their mature phase, when the field is ripe for a possible technological discontinuity. For example, if the basis of competition is cost instead of performance or differentiated features, the technology may have reached its mature phase.

The fact that wireless data is an important development to consider is reinforced by the formation of a number of joint ventures in the industry. Vizzavi, for example, is a joint venture between media group Vivendi Universal and the Vodafone group of MNOs to build a multi-access European portal. (The term multi-access portal refers to the fact that it could be accessed via a range of devices, e.g., PCs, mobile phones, PDAs and i-TV.) The two companies are aspiring to "...build a leading Internet business by pursuing the growth possibilities of Internet services, mobile data and interactive television." This will be enabled by the combination of Vodafone's leading position in mobile communications and Vivendi's broad interests in media and services [16]. Another example is the announcement by newly merged media conglomerate AOL Time Warner that it has entered into an agreement with Nokia to provide an Internet browser for wireless devices.

4.5.1. Generic industry conditions

Aguilar [17] argues that there are certain generic conditions relating to any industry that have specific implications and that certain particular areas of attention therefore exist that should be carefully investigated. Important aspects are industry size, growth, profitability, materials, products and processes. Some selected examples are shown in Table 3.

Examining industry conditions as listed in Table 3, the wireless data industry will very likely be a large industry and subject to government attention. The provision of payment mechanisms by an MNO could, for example, require a banking license. The regulatory environment, hence, needs to be closely monitored. The products in the industry have a high technical content so that the industry will most likely have a high rate of technological innovation. In addition, this should be a relatively profitable industry, leading to high levels of competition. These two factors imply that threat and opportunity assessment, supported by a monitoring and scanning program, will be of utmost importance for organisations to keep abreast of technological developments as well as competitors' actions.

It is often observed that following a radical innovation and the birth of a new industry or sector, the industry seems to be characterised at first by a stage of aggressive vertical integration, and then by a phase vertical disintegration as the industry matures. In the

Table 3
Generic industry conditions with implications and areas of attention (after Aguilar [17])

Conditions	Implications	Areas of attention
Large industry	Subject to government attention	Government regulation, policies or other action
	Entry attractive to large, well-financed firms	Continuous threats of new competition
Products with a high technical content	Technical services	Customer's market
	Technical activities such as R&D	Technical innovations
Relatively profitable industry	Entry attractive to large, well-financed firms	Continuous threats of new competition
	Integration forwards from raw materials OR integration backwards from following stages	Structural changes in industry Licensing possibilities
	Diversification	Licensing possibilities Structural changes in industry
Important source of foreign exchange	Subject to government attention	Government regulation, policies or other action
Processes require high capital expenditure	Need to produce near capacity	Prices Capacity
Processes often produce side-products	Companies sometimes involved with unwanted secondary markets	Dumping Prices Capacity
Bulk, undifferentiated products	Raw materials important	Suppliers and raw materials Capacity Prices
	International trade high	Foreign activities
	Long-term contracts	Sales negotiations Customer's market

automobile industry, for example, in the 1920s, Ford acquired forests, mills and rubber plants for the supply of wood and tyres for its vehicles. Over time, the industry has become vertically disintegrated with Bosch, as an example, supplying electronic parts to a range of different manufacturers.

This same situation could to some degree be applicable to the wireless data industry and MNOs. It is probable that MNOs will initially perform activities such as the development of applications and services as well as application hosting and maintenance in-house or through the acquisition of a software developing company. At a more mature industry stage, vertical disintegration could take place with external parties primarily performing these activities.

4.5.2. A model of technological change in an industry

Anderson and Tushman [18] describe a cyclical model of technological change as illustrated in Fig. 2. A technology cycle is seen to consist of four components: technological discontinuities, eras of ferment, dominant designs and eras of incremental change.

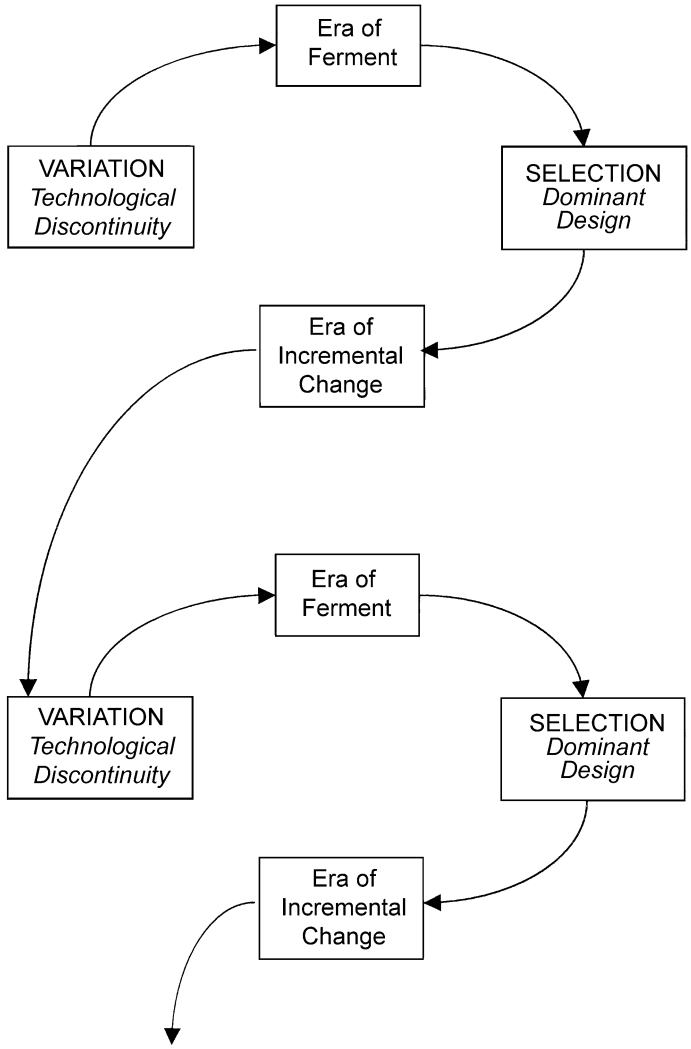

Fig. 2. A cyclical model of technological change (after Andersen and Tushman [18]).

Technological discontinuities are typically innovations that advance a relevant technological frontier by an order of magnitude and that involve fundamentally different product or process design. This ushers in an era of experimentation and uncertainty as organisations struggle to absorb the ne7w technology. This era of ferment is characterised by both competition between the old and new regimes and competition with the new regime. Several versions of the breakthrough technology may appear which are often incompatible. This period is closed by the emergence of a dominant design. A dominant design is a single architecture that establishes dominance in a product class [19]. Uncertainty in the industry or sector now decreases. Examples of dominant designs are the QWERTY keyboard layout, VHS as a format for videocassette recorders and the IBM PC. After domi-

nant designs emerge, technical progress is driven by numerous incremental product innovations, as well as process innovations. This era is ended by the emergence of the next technological discontinuity.

Applying the above to the wireless data example, it can be argued that 2.5/3G wireless data services represent a technological discontinuity through significant increases in performance (order of magnitude improvement in data transfer rates; also packet-switching and always-on functionality). The era of ferment following this technological discontinuity is and will be characterised by experimentation with different radio access and data transmission protocols. As an example, 3G services will be based on the CDMA radio access protocol mentioned earlier, but, at this stage, there are several versions of CDMA that is being experimented with, such as W-CDMA and CDMA2000.

Similarly, in terms of data transmission protocols, most GSM data services offered by Western operators have utilised WAP. As was shown in a previous section, Japanese operator NTT DoCoMo has made use of a proprietary protocol named i-mode, which is based on a compact HTML format (cHTML). A number of other operators are planning to launch i-mode services as well—Dutch mobile operator KPN Mobile as well as Italy's Telecom Italia Mobile (TIM) have announced the launch of i-mode services in Europe from September 2001. In partnership with DoCoMo, US operator AT&T is also planning the launch of i-mode services [20]. It remains to be seen whether one of these two transmission protocols will be the dominant design in the 2.5/3G environment, or whether an altogether new data transmission protocol will emerge and become dominant.

4.5.3. Changes in the industry ecology—the effects of a hybrid technology

Under a given technology regime, an industry is typically characterised by a certain ecology. A manifestation of this ecology is the ordering of the industry in terms of market leaders. It is a well-known phenomenon that, when a technological innovation invades an industry, the industry ecology changes and new companies become the market leaders (see, for example, Refs. [3,4,21]). One would therefore expect that the industry ecology will change when 2G technology is substituted by 3G.

Although it is too early to speculate on who the new winners will be, one can postulate that the introduction of 2.5G will definitely distort the picture. Many of the large players have made significant investments in 3G technology and have incurred serious debt in the process. If 2.5G takes off as it may, it will delay the introduction of 3G, as hybrid technologies often do. Some of the existing and even a few new players will push 2.5G technology. Even though this may ultimately help 3G technology, the time delay may cause the big 3G investors to run into serious financial problems because they will not be in a position to recoup their investments fast enough. If the content providers do not create a demand for more bandwidth—which is 3G's advantage over 2.5G–3G may have an even tougher time taking off. It may turn out that 2.5G becomes a disruptive technology even before 3G has had the time to fully come to market [4]. However the scenario plays out, the introduction of 2.5G will influence the ultimate 3G industry ecology, i.e., the 3G industry ecology will have looked different had 2.5G not appeared in the scene. An assessment of technological threats and opportunities should take this distortion into account.

4.6. Analysis of other signals

Apart from the analysis techniques mentioned thus far, there are a number of other incidences that could serve as signals that a potential development is of significance. These signals include, among others:

- Notifications of first conferences on a specific subject
- Increases in attendance at conferences
- Patents that are applied for
- Regulatory announcements (e.g., US Clean Car Initiative and the establishment of NTSC as the colour television standard in the US)
- Population trends
- Consumer attitudes

The strength of a signal will typically follow an S-pattern, reaching a maximum at the point in time when an entity is commercially introduced. This is indicated in Fig. 3 [22] as time t_5. One possible measure of signal strength could be the frequency of appearance in literature. The source of a signal could be a criterion as well. For example, signals at time t_1 may include informal discussions at conferences or symposia or networking with industry contacts—these signals could be considered to be relatively weak or tentative in nature. Stronger signals such as those at time t_2 might be found in company R&D reports or scientific papers. Signal intensity will further increase, as shown at times t_3 (where the sources of signals could be patent applications or the formation of alliances) and t_4 (sources such as the public announcement of product or process developments).

One of the signals for the 2.5/3G wireless data development is a number of first conferences. For example, a first conference on the WAP was held in 2000 in Johannesburg, South Africa, and a number of m-commerce exhibitions and conferences in 2000 in London,

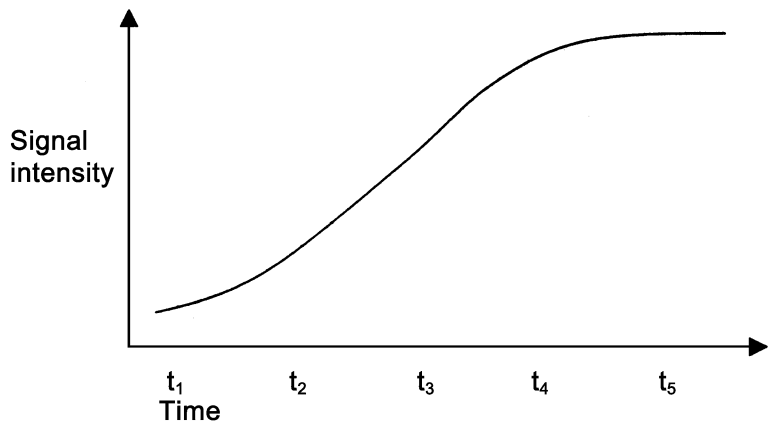

Fig. 3. The relation between signal intensity and time before introduction (after Ashton [22]).

Johannesburg and Dubai. In 2001, the m-commerce conferences will be at a greater number of venues, indicating an increase in signal strength.

The formation of a number of associations and forums related to wireless data serves as a further signal. This includes the WAP Forum, Mobile Commerce World and the 3G Partnership Project (3GPP).

5. Conclusions

Technological threat and opportunity assessment has been shown to be a useful framework for identifying technological developments that could be of significance for an organisation and for determining what the impacts on the organisation could be. In this article, one of the central components of a proposed methodology, namely analysing various aspects of technological developments, has been focused on.

It was shown that there are a number of different analysis techniques that could be utilised. By applying these techniques to a specific technological development, namely the offering of 2.5G and 3G wireless data services by a European MNO, a better understanding of these analysis techniques and their use was gained. While these techniques could be compared in terms of usefulness and applicability, the optimal technique to use will depend on the particular technological development, organisation and industry in question and hence there is no ‘‘best’’ technique.

The article has illustrated that the analysis techniques cover a wide range of issues, from the political, economic, social and technological forces that drive technological change to an analysis of competitors and their activities. The application of these techniques will enable an organisation to better understand the nature of technological developments, and could support an assessment of the impacts of developments on the organisation. By better understanding the threats and opportunities it is facing, the organisation will be able respond in the most optimal way. In terms of the specific example of this article, MNOs will need to make decisions about where and how to play in the emerging 2.5/3G wireless data value chain, assess new capabilities and competencies they will require and make the required changes to their business model and operations.

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Gert T. du Preez is a Senior Consultant in the communications industry practice of Deloitte Consulting in Johannesburg, South Africa. Carl W.I. Pistorius is the Principal and Vice Chancellor of the University of Pretoria, Pretoria, South Africa and the Co-Director of the Institute for Technological Innovation (ITI) at the university.