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TECHNOLOGICAL INNOVATION AND FIRM DEVELOPMENT: THE CASE OF INFOVALLEY DIGITAL AUTOPSY SYSTEM COMMERCIALISATION

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ABSTRACT

Current research emphasises the importance of the successful commercialisation of technology in the development of small firms and the need to address unique contextual dimensions when examining the concept of commercialisation. Guided by product and venture development lifecycle models as well as a structuration perspective, this case study examines how an entrepreneurial venture called Infovalley Life Sciences develops and commercialises the firm's digital human autopsy system despite the fact that the firm operates within an underdeveloped innovation system context. In-depth interviews were conducted with key individuals involved in the innovation and venture development processes. Analysis indicates that the entrepreneur and his or her team co-evolve with their business contexts in creating a favourable nvironment for themselves. This process requires the entrepreneur to integrate his or her broad knowledge of technology applications and the market with his or her team's highly specialised knowledge in the core technology domain; this process results in a successful product launch. This leads to the creation of internal core capability, which supports the commercialisation of new products and thereby contributes to the firm's development and growth. This link between structuration and resource-based perspectives of entrepreneurship augments the conceptualisation of entrepreneurship, technological innovation and firm's development.

Keywords: innovation, firm development, entrepreneurial venture, digital human autopsy system, entrepreneurship, case study methodology, medical informatics systems, Infovalley, Malaysia

INTRODUCTION

Technological innovation is defined in this study as the process of developing and commercialising a new concept into a useful technology-based product, service or system (Tornatzky, Eveland, & Fleischer, 1990, p. 9–25). Especially for small technology-based firms, technological innovation is a vital process in creating wealth and developing immature economies (Audretsch, 2002; Martin, 1994, p. 287–303). When sold at a profit, the new products that come from such

innovations not only provide financial returns to the inventors and their partners, but may also help in creating jobs (Jones-Evans & Westhead, 1996). Furthermore, when these products have a high level of utility, they usually benefit society in general. This highlights the importance of successful product commercialisation in contributing to the growth of new firms; this growth in turn contributes to a society's overall well-being and economic development (Martin, 1994, p. 287–303).

While both the commercialisation of new products within the medical field and the growth of the firms that develop them are important for a society's well-being, there is a lack of research on these important trends within the context of an immature market, such as Malaysia. Small firms in Malaysia face problems related to the underdevelopment of business clusters and the venture capital industry (Khairul Akmaliah & Mohd Fuaad, 2007, p. 126–160), both of which are important elements in supporting technological innovation and firm growth (Porter, 1998; Nelson & Rosenberg, 1993, p. 3–21). [A business cluster refers to a business context that is comprised of a highly interconnected network of people, key resources and essential support institutions and systems (Porter, 1998)].

This lack of research deprives entrepreneurs and managers operating in this context of theories that could be operationalised in order to commercialise their products and grow their firms. Thus, research is necessary to identify the most influential factors in the development and commercialisation of new systems and related growth in new technology-based firms. Such findings would help to refine existing assumptions about the relationships between these processes across various business contexts (Gartner, 1985; Zahra, 2007).

Examining these linkages requires documenting both the processes of commercialisation and firm growth and their contexts. This requires an in-depth conceptual analysis using a process-oriented theoretical lens. Thus, process-oriented concepts of innovation and venture development (Churchill & Lewis, 1983; Greiner, 1998; Kroeger, 1974) combined with a structuration-based perspective of entrepreneurship (Ma & Tan, 2006; Sarason, Dean, & Dillard, 2006; Shane & Venkataraman, 2000) are utilised as the conceptual framework for this study; the case study technique selected is its methodology (Yin, 1994, p. 1–17).

The chosen case study involves Infovalley Life Sciences (http://www.infovalley .net.my), a company that has developed and commercialised a medical informatics system called the digital autopsy system. It is reputed to be the only company in the world that has conceptualised and developed a digital autopsy facility for use within non-military settings. The company's digital autopsy

system has the potential to replace the existing standard autopsy, which is a procedure conducted on a dead body, typically with the aim of collecting evidence on the cause of death. It is also used to train medical students and to identify diseases and the effects of medicine (Bigg, 2004; Becker, 2005).

Medical informatics is a scientific discipline that deals with the acquisition, storage, and use of health or medical information (Stead, 1998; Hersch, n.d.). As implied by the term, a medical informatics system, like a digital autopsy system, is typically comprised of knowledge regarding medical science and/or its applications, information systems, and statistical methods (Frisse, Braude, Florance, & Fuller, 1995). In Malaysia, the demand for medical informatics software solutions began increasing in the mid-1990s, particularly after the government encouraged the development of IT-based companies and initiated more demand for IT-based medical solutions via its Multimedia Super Corridor (MSC)[1] project. Since the majority of Malaysian hospitals are owned by the government, the government has significantly influenced the demand for medicine and biotechnology systems and solutions (Abu Bakar, 2001; Mohan & Raja Razali, 2004). As IT and biotechnology converge, opportunities are huge for achieving high levels of growth among businesses involved in the biotech industry (Mohamed Arif, 2005). Therefore, this study's research question is:

> How has Infovalley Life Sciences managed to develop the digital autopsy system and commercialise it within a business environment that is lucrative but still has an underdeveloped innovation support system?

Conceptual Framework: Innovation and New Venture Development Lifecycle and Structuration Perspective of Entrepreneurship

In this study, the process-oriented concepts of innovation and the venture development lifecycle are combined with the structuration-based notion of entrepreneurship to provide a basis for a conceptual framework.

The product/innovation lifecycle model

The developing stages of a product can be broadly divided into four phases (Bright, 1969, p. 28). The first stage is the *product conception and development* stage. Within this phase, a firm recognises a business opportunity, refines this opportunity into a viable business idea, and obtains necessary resources, which can be financial-, human-, and/or knowledge-based (Champion & Carr, 2000); these resources are needed to ensure that the business idea can be successfully developed into a physical product. The second stage is the *commercialisation* stage, in which the firm uses its resources to develop the idea into a prototype,

tests it to ensure it is properly built, and, once this is completed, manufactures and markets the product to potential customers.

The next stage is the *growth* stage. In this stage, the firm's aim is to increase the sales volume of its product and achieve profitability. However, during this point of business development, the firm has to properly manage its production, sales and distribution of its product to make these processes more efficient and effective. The final stage is *adaptation*. In this stage, the sales growth of the firm's product and its increased revenue attract business rivals. If no preventive measures are deployed to counter the competitive threats, sales of the product will decrease, and its production will eventually cease. While this product lifecycle process appears linear, some of the activities may occur simultaneously. Also, the time taken for each stage varies by industry and organisational context (Bright, 1969: 28; Tornatzky et al., 1990, p. 27–50).

The new venture development lifecycle model

The new venture development lifecycle process can be separated into several phases (Churchill & Lewis, 1983; Kroeger, 1974; Greiner, 1998; Timmons, 1994, p. 207–233; Sullivan, 2000). Researchers have suggested that in order for a venture (or firm) to progress from one phase to the next, an entrepreneur must apply specific skills so as to develop and/or acquire specific capabilities matched to the unique requirements of each phase. Moreover, in completing each phase, there are several mini-crises that must be overcome, and the progression from one phase to the next is marked by a large crisis; overcoming this crisis determines a firm's ability to move to next phase (Greiner, 1998).

Churchill and Lewis's (1983) conceptualisation focuses on the business activities that are performed by a firm and the concerns of the firm in each of the phases. In the first phase, called the *existence* phase, a firm recognises a business opportunity, obtains the required resources to turn this opportunity into a physical product, and then manufactures and markets this product to potential buyers. The concern of the firm at this phase is to have a viable product and market. Next is the *survival* phase, in which the firm struggles to attract enough customers to provide revenue so as to allow it to sustain its operations, be able to manufacture more products, and pay off debts. During this phase, the concern of the firm is on its ability to transform itself from a losing operation to a profitable business. These two phases can also be referred to together as the *start-up* phase (Timmons, 1994, p. 207–233).

The third phase is the *success* phase, in which the firm manages to turn its venture into a profitable business. The main concern that the firm has at this phase is whether to use its current cash to support future expansion of its

operations or to stabilise its business and retain current profits. In the following phase, the *take-off* phase, the firm expands its operations rapidly, enters new markets, introduces more products, and fights off new competitors. At this phase, the firm has two main concerns. First, it is concerned about whether its current organisational structure is adequate to support its expanding operations. The second concern is whether it has enough cash to continue to support its growing business activities. Timmons refer to these two phases together as the *growth* phase (1994, p. 207–233).

The last phase of this venture development process is the *resource maturity* phase. In this phase, the firm has transformed itself into a full-fledged organisation with a clear hierarchical structure, properly defined functions and responsibilities for its staff, and well-coordinated business processes and activities. Its main concerns at this phase are to consolidate its profits from activities performed in the *take-off* phase and to retain its flexibility and entrepreneurial spirit even though it has turned itself into a large organisation. Timmons refers to these as the *maturity* and *stability* phases (1994, p. 207–233).

Structuration perspective of entrepreneurship

A structuration perspective suggests that the identification and development of business opportunities is idiosyncratic to each entrepreneur. His or her interaction with the context is usually the most influential factor in the successful creation and development of a new business (Sarason et al., 2006; Shane & Venkataraman, 2000). From this perspective, an entrepreneur is seen as continually modifying his or her behaviour and/or his or her business environment in order to achieve his or her goals; in other words, the entrepreneur and the organisational context develop together. Therefore, one should not consider the entrepreneur who brings forth an innovation as separate from the business opportunities that he or she has recognised and exploited (Sarason et al., 2006; Shane & Venkataraman, 2000). In fact, the process of recognising and exploiting new business opportunities occurs through the entrepreneur when he or she creates his or her own "opportunistic environment" (Ma & Tan, 2006). While many people may receive the same or similar exposure to information concerning new business opportunities, the majority remain unaware of them, and thus, only a few are able to recognise the presence of such opportunities (Shane & Venkataraman, 2000; Ma & Tan, 2006).

Moreover, from the proportionately small group who do recognise such opportunities, still fewer have the cognitive ability and other required capabilities to exploit the opportunities to the point of creating a new venture and achieving a level of profitability sufficient to fully recover the costs involved (Shane & Venkataraman, 2000). In addition, since an entrepreneur is usually supported by

his or her venture partners, the quality of an entrepreneurial team supersedes in importance any other types of strengths, including potential markets and technological leadership (Timmons, 1994, p. 3–37). Therefore, it is only logical that a structuration perspective further suggests that the development of a new venture, which is typically triggered by the recognition and development of a business opportunity, is an idiosyncratic phenomenon as well. That is, its trajectory is determined by the interactions of the entrepreneur and his or her team with their business context (Sarason et al., 2006).

The above models and perspectives, when viewed as a whole, provide a useful framework for analysing the development and commercialisation of an innovation (such as the digital autopsy system) by an entrepreneurial venture (like Infovalley Life Sciences) and the subsequent development of this venture. This study examines the processes of innovation and new venture development with the aim of identifying: (a) the important activities performed in these processes, (b) the significant constructs that influence these processes, and (c) the potential linkages of these constructs with the processes of innovation and venture development.

RESEARCH METHODOLOGY

This study addresses a theoretical gap in the literature on innovation and firm development in business contexts characterised as underdeveloped. Thus, this study focuses on a "how"-type research question and the development of a conceptual framework (Halinen & Törnroos, 2005; Cavana, Delahaye, & Sekaran, 2001, p. 1–44). This, in turn, has led to the use of a process-oriented case study methodology to examine innovation and venture development (Eisenhardt, 1989; Yin, 1994, p. 1–17; Pettigrew, 1997). It is similar in design to the method used by Coviello and Munro (1997). The conceptual framework has also guided the design of the study's interview protocol. As there were no comparable cases, this research was by necessity a single-case study.

The primary method of data collection was in-depth interviews with key individuals involved in the company's innovation and development. They included the lead entrepreneur-founder of Infovalley, Mathavan A. Chandran (hereafter referred to as Mathavan), Anu Sheela, the company's vice president of human resources and administration, and the lead scientist of the digital autopsy project, Dr. Pramod G. Bagali. They were asked to describe the development, launch and growth of Infovalley Life Sciences (see the interview protocol in Appendix A). All interviews were conducted from June through December 2006, and they were followed up with e-mails, which were sent to clarify data collected during the interview. Information was also gathered from public sources,

including the *New Straits Times Press* (NSTP) e-media, the *Edge Daily* (www.theedgedaily.com.my), and the *STAR Online* (www.staronline.com.my).

In analysing the data, Eisenhardt's process (1989) of building a new theory via the case study method was adopted. First, information surrounding the case was put into chronological order from the approximate date when the idea for the new system was first conceived to the date of the final interview in December 2006. This phase of case data analysis matches with the study's process-oriented conceptual framework, and this format is similar to the one employed by Coviello and Munro (1997). Second, the case data were analysed using the study's conceptual framework, and a processual model of innovation and venture developments was constructed as a result. The model focused on a medical informatics system that was developed within an underdeveloped business context. The variables that influenced these developments were also identified. The model and construct developments were iterative and involved comparing the study's findings with those in existing literature to help establish internal validity.

FINDINGS

Part 1: The Infovalley Group of Companies: Company Formation and Initial Business Development (2000–2003)

Mathavan, who is the founder and lead entrepreneur of the Infovalley Group of Companies, graduated in 1992 from the Universiti Pertanian Malaysia (UPM, later renamed to Universiti Putra Malaysia) with majors in Biochemistry and Chemistry. During his undergraduate studies, Mathavan's father died due to an illness, which led to financial hardship for his family and financial insecurity for him. Mathavan first worked at a company that produced inorganic chemicals, and then at a company that was involved in petrochemicals and chemicals. While working at the second company, he also attended the International Islamic University's MBA programme in Corporate Finance. Later, he became a business manager at a multinational company.

While still employed, he was constantly searching for an opportunity to start his own business, and in mid-2000, he saw his chance. At that time, the Malaysian MSC project was expanding, and e-learning was selected as one of its flagship product categories. Moreover, the Malaysian government was helping to create demand for this application. Believing in the potential growth of the education and consulting markets, Mathavan left his post at the multinational company and formed an e-learning company with two other entrepreneurs. They set up an office in the UPM-MTDC Incubator in August 2000 and used their own money

as seed funding. Within the first six months of operation, the partners managed to make a profit. In 2001, however, after eight months of operation, Mathavan left the venture because of disagreements with his partners.

Mathavan then did consulting work to support himself for a number of months. While doing this, he discovered that biotechnology was a growing industry worldwide and that he had a real opportunity to harvest the industry's potential. Being determined to build his own long-lasting business someday, he decided to focus on this area of business and started a new company called Infovalley in June 2003.

He soon noticed that a long gestation time and a large capital investment were the two main challenges faced by those in this industry. To overcome the latter challenge, he formed Infovalley Business Management as a subsidiary of Infovalley. This subsidiary was his venture's management consulting arm, and he utilised revenues from it to finance the development of his biotech business. The money was specifically used to recruit scientists and technicians who were needed to support the company's development. The first product developed by this business was a bioinformatics software solution.

In 2002, after Mathavan had single-handedly run the company for 12 months, Sheela (the current vice president of human resources and administration) joined him. Before she was hired, Mathavan had no office; he only had a laptop to help him manage his business. Mathavan explained how the first staff members were hired:

> Let's say now you need some consulting work and decide that my work is worth a fee of RM120,000. So now, if I hire one fellow with a salary of RM10,000 per month, with that money, I could pay him for 12 months. Then, upon getting another consulting contract, I bring in another person. So, for each consulting contract I got signed, I'll match that against a new recruited employee. Of course there is a risk, like the contract may be called off, but that is the risk in business.

In financing his venture, Mathavan avoided debts and equity-based money from venture capitalists or rich individuals, also known as business angels, as he was not convinced of their long-term benefits. Mathavan started hiring part-time employees in April 2003, and a year later, he began hiring full-time staff. This coincided with the opening of the company's first office in Bangsar Baru, Kuala Lumpur, and marked a more organised effort of the company in managing its bioinformatics business.

In August 2004, Mr. Mathavan formed a new company called Infovalley Life Sciences, a subsidiary that focused on developing bioinformatics software

solutions. It was established to fulfil a major requirement for an MSC Malaysia Status[2] application, which dictated that his company specialise in one of the MSC technology fields. Having MSC Malaysia status would enable the company to obtain tax exemptions for a period of 10 years and to hire an unlimited number of foreign experts.

Mathavan continued to utilise the money generated from his consulting work to fund the conceptualisation, production, and business development of Infovalley Life Science's bioinformatics solutions. Uncertainty about the venture's success in the early days forced the company to employ a unique hiring practice, as explained by Mathavan:

> All these early guys (the five staff members) are specialists, but they also have knowledge in multiple domains within their specialty—generalists within a specialized environment. But as the intensity in the specialized domains increased, we hired specialists for that specialized environment.

All these earlier team members were hand-picked by Mathavan himself, who from the beginning only hired programmers from Bangalore, India. According to him, Bangalore's lower high-end programming cost helped to reduce the company's overall business cost further. Later, this team of human resources was managed under Infovalley's wholly-owned subsidiary in Bangalore, which was called Infovalley Biosystems (India) Pvt. Ltd. and was incorporated in April 2005.

In February 2004, Infovalley offered its first bioinformatics solutions for sale for about RM700,000 (approx. USD200,000) through its subsidiary, Infovalley Life Sciences. Customers were willing to pay 40% of the contract value in advance to fund the initial development work. Using that money, extra hands were recruited to begin the actual work. Financial slack from this and other sales that followed was injected back into the business development of Infovalley Life Sciences.

In its initial stage, Infovalley Life Sciences only developed solutions for its customers. However, its scientists and bioinformaticians later began to help customers operate the software solution. Eventually, Infovalley became extensively involved in its customers' R&D initiatives, thereby extending its services into R&D and even initiating some joint biotech R&D projects with its customers. These indirectly expanded the subsidiary's R&D knowledge base in biotechnology. To manage these efforts, Infovalley formed another subsidiary in December 2003 called Generti Biosystems, and it was established in same year as the concept of a digital autopsy system was conceived.

Part 2: The Infovalley Group of Companies: A Growing Bioinformatics Business; Infovalley's Digital Autopsy System: Opportunity Recognition and Initial Exploitation (2003–2005)

The development of the Digital Autopsy System at Infovalley began in early 2003, when the British Museum needed a system that could scan a 1,000-year-old mummy without destroying it in the process. It knew of a digital autopsy system called *Virtopsy* that was being used at the University of Bern's Institute of Forensic Medicine, in Switzerland. The development of *Virtopsy* was initiated by two research teams—one from the University of Berne's Institute of Forensic Medicine in Switzerland and the other from Linkoping University in Sweden (Thali et al., 2003; Toh & Singh, 2006). Since its conception, the *Virtopsy* system had been utilised in Swedish and Swiss hospitals for research purposes only and not for standard autopsies.

However, the British museum found that the *Virtopsy* system was unsuitable in meeting its needs. It contacted Silicon Graphics International (SGI), the computing system vendor for Bern University, to determine if an alternative option was available, and SGI head office contacted its Asia-Pacific group. This group approached its Australian unit, which in turn alerted Infovalley about possible involvement.

According to Mathavan, SGI Australia was informed about Infovalley's high-definition visualisation programme by Bob Bishop, the founder and chairman of SGI.[3] Mathavan explained that while attending the MSC International Advisory Panel (IAP) Meeting in Putrajaya in 2003, he had a brief informal discussion with Bob Bishop, who was one of the 18 IAP members then appointed to directly advise the Malaysian Prime Minister.

After that meeting, SGI Australia contacted Mathavan to inquire if Infovalley could develop a better high-definition visualisation system. His answer was affirmative, as Infovalley already had a system up and running, although it was still very much in its infancy. His small development team at that time was enthusiastic about the project. According to Mathavan, they "had nothing to lose" for being innovative as the fulfiled the assignment, as they were not shackled by existing procedures, shared beliefs, current rules or embedded culture. The earlier "generalist" nature of the team also contributed to the exploratory culture among team members. The team managed to create a programme solution prototype that satisfied SGI, prompting SGI to invite Infovalley to become its partner in the project.

Following the success of the "mummy" project, Bob Bishop advised Mathavan to "look deeper into the virtual autopsy solution". He was receptive to the suggestion, because his company had an expert who could provide advice on autopsy system development. This expert was Dr. Pramod Bagali, an Indian national who was at that time involved in a bioinformatics project; he was a forensic pathologist by training. He was one of the five pioneering scientists recruited by Mathavan; moreover, he was asked to lead the digital autopsy project. Work on the digital autopsy concept officially started in early 2004. Pramod, who was passionate about creating a more humane autopsy system and overcoming the many limitations associated with physical autopsies, did the initial work while he was still in India. He was a part-time scientist at Infovalley's Bangalore office before working full-time, a decision he made, because he prefers the exploratory culture within the company and believes in its future.

The doctor had conducted more than 9,000 autopsies as a forensic pathologist in the Indian army. Drawing from his long working experience and his passion for developing a more humane method of autopsy, he designed the original blueprint for the project and outlined the initial functional requirements for the system. Eventually the development team for the digital autopsy system solution was comprised of 20 experts from Malaysia and India, including bioinformaticians, medical doctors, forensic pathologists, systems engineers, and programmers. The Indian team operated under Infovalley's wholly-owned subsidiary in Bangalore called Infovalley Biosystems (India) Pvt. Ltd., which was incorporated in April 2005.

The Indian team was brought into the autopsy project, because they had a great depth of knowledge in the development of vital system algorithms. Hiring these experts was also done at a lower cost compared to Malaysian employees. Moreover, having them would enable Infovalley to collaborate with more international partners located in India, thereby enhancing the chances to achieve its goals of entering the US and European markets. However, programme compilation, software integration, and system testing were all performed in Malaysia, because by those stages of system development, Pramod, the team's head, had been transferred to Malaysia.

In March 2005, the management of the digital autopsy system was assigned to iGene, a newly-formed Malaysian subsidiary of Infovalley. This was to ensure that scientists and technologists in that subsidiary focused their efforts solely on developing the digital autopsy system. Nevertheless, in order to capitalise on Infovalley's well-established reputation, its name would be used when marketing the Digital Autopsy System.

In June 2005, approximately a year after the system was conceived, it was ready for demonstration. During the Inaugural Biotech IAP meeting in Los Angeles, the system was shown to the Malaysia's Prime Minister and his delegation, which included the Minister of the Ministry of Science, Technology and Innovation (MOSTI). The Prime Minister was receptive to the concept and suggested that the technology be further developed, with the idea of ultimately establishing it as the new standard autopsy procedure in Malaysia – a nation in which the previous autopsy standard was opposed by its majority Muslim population. In fact, in 1984, Malaysia's Majlis Fatwa Malaysia (National Fatwa Council)[4] had decreed that autopsy should only be conducted on bodies of Muslims in unavoidable circumstances, such as when it was required by court order; see the official website of the Malaysia's National Fatwa Council at http://www.e-fatwa.gov.my.

The Prime Minister then invited Infovalley to provide another presentation to other Malaysian government officials at the Multimedia Development Corporation's (MDeC) Virtual Reality Centre in Cyberjaya in October 2005. MOSTI later requested that Infovalley present the digital autopsy system concept in detail and also suggested that briefings be made to the Ministry of Health, as that ministry would be the final end-user of the system. Following these presentations, the Ministry of Health in turn recommended that Infovalley conduct several meetings with other relevant governmental and non-governmental organisations to seek their feedback. These included the Royal Malaysian Police Department, the Attorney General, the Islamic Development Authority (under the Prime Minister's Office), the National Fatwa Council, and the Malaysian Legal Council.

Part 3: Infovalley's Digital Autopsy System Commercialisation: Gaining Acceptance for the System and Organising the Pilot Digital Autopsy Facility (2006 and Beyond)

Having proven the market feasibility of the autopsy system, Mathavan and his team began to rally support for the system among the system stakeholders. Autopsy had long been performed according to stringent, established procedures to which the digital autopsy system had to comply. To ensure it would be authorised for use in Malaysia, Infovalley had to make sure its system complied with policies and procedural requirements of a number of official scientific bodies of oversight, which included:

1. the International Forensic Medical Examination,
2. the National Institute of Forensic Medicine (NIFM), which is the governing body of Malaysian forensic pathology,
3. the standard British Commonwealth practices,
4. the Criminal Procedure Codes (CPCs),

5. the Global Technical Working Group, and
6. the Digital Imaging and Communications in Medicine (DICOM) standards.

Endorsements were also sought from various departments and agencies in the Malaysian Ministry of Health, which would supervise the use of the digital autopsy system in its implementation in government hospitals. Discussions were also conducted with and presentations were made to the Royal Malaysian Police Department, which gave input regarding how the system's data capturing and storage processes would be beneficial to law enforcement work. Infovalley also held discussions with the Attorney General's office to obtain approval on the standard operating procedures (SOP) for the system's use. This was also to ensure that the system could be seamlessly integrated into the Malaysian judicial system, especially when it was used for court cases involving forensic medicine (Toh & Singh, 2006). As a result, it received the requested support from the Attorney General's Office.

Approval was also obtained from the Department of Islamic Development of Malaysia (JAKIM) and the National Fatwa Council of Malaysia. After gaining a better understanding of its features and functions, the two departments were keen on endorsing the use of the Digital Autopsy System in Malaysia, as it would solve some of the problems that had caused Islamic leaders to discourage autopsies on the bodies of deceased Muslims. According to Mathavan, by December 2005, both JAKIM and the National Fatwa Council had begun to further study the digital autopsy system to formulate a religious decree addressing the use of digital autopsy on deceased Malaysian Muslims. They formulated a preliminary decree stating that should the initial findings from the digital autopsy be found inconclusive, then a standard autopsy could be recommended as the next course of action. Given Malaysia's large Muslim population and the fact that Islam is the country's official religion, this was a huge boost for gaining acceptance of the digital autopsy system by authorities in Malaysian hospitals and by those responsible for setting forensic standards in the country.

While the company was seeking approval from relevant authorities, the digital autopsy system was continually tested. Finalising the system completion involved setting up a Digital Autopsy Test Facility at the Hospital Universiti Kebangsaan Malaysia (HUKM) and consulting experts from the Forensic Units of HUKM and Hospital Kuala Lumpur (HKL) for their advice on facility set-up.

In December 2005, Infovalley received authorisation from the Prime Minister's Office and MOSTI to build a pilot digital autopsy facility in one of the government hospitals; it would be fully financed by MOSTI. A budget of

RM10 million (approximately USD3 million) was allocated to Infovalley for the installation of the facility, which was to be equipped with the first digital autopsy system designed for common usage in the world. While the facility would be owned by MOSTI, it would be implemented and managed by the Ministry of Health. Mathavan summarised the process of developing and commercialising the digital autopsy system:

> Once the business side established the utility of the system, then the business team described about the market to the science team (medical team), who in turn developed the conceptualisation further. Then, the technology team came in. The business team visited the customers again, and discussed with them about the concept, and based on the input, the business team continued to communicate with the science and technology teams. So, the cycle was business-science-technology, which occurred iteratively. When needed, the technologists and scientists also met with the customers to explain technical matters, and to build up our case.

As its autopsy system was now going to be an entire facility, Infovalley was required not only to put together an information systems (that is, the hardware and software) but also to integrate all the necessary parts, including the construction of the building and the setting up of necessary furniture and systems within it. The planned facility had two major components: (1) the physical facility, which was an area of about 2,500 sq feet planned to be located next to the hospital mortuary, and (2) Infovalley's Internet-based Digital Autopsy System, which was to be operated using its in-house design software (called INFOPSY V1.2) and supported by necessary hardware, including medical imaging and visualisation input/output devices (processors, network systems, and a computer display) from General Electric (GE) and SGI machines.

According to Mathavan, once implemented, the user-friendly navigational tools would enable forensic pathologists to conduct autopsy with ease. They would only need to check results; and if they were not satisfied with the results of the digital autopsy for any part of the body, they could then proceed with a standard autopsy on the specific parts without the need to physically cut open other parts of the body. While the Digital Autopsy System was originally intended to complement the standard traditional autopsy, both its developers and users were well aware that it had the potential to become the dominant method of autopsy over time.

The company had to prepare SOP for the hospital based on the requirements of the National Institute of Forensic Medicine and the Royal Malaysian Police regarding how to handle dead bodies. It also was required to provide domain training in the medical applications of the system (e.g., how to interpret visual results) and systems training (e.g., how to reboot the system) to the health

professionals at that hospital. Infovalley planned to have its own forensic pathologists (two Indian nationals and one Australian) conduct the former type of training and its systems engineers conduct the latter type of training. As part of its nationwide roll-out, the company intended to install the unit at all six regional forensic centres in Malaysia.

With the finalisation of INFOPSY™ V1.2, the company's forensic medicine application software design, by the end of September 2006, the company had completed the development of its first-generation digital autopsy system. When combined with crime scene and/or related situational images, the system would enable pathologists and other relevant authorities to construct an entire image necessary to make decisions related to autopsy results.

Also by the end of September 2006, Infovalley had appointed a corporate financing house to raise RM20 million (approximately USD5 million) in funds for iGene, its subsidiary that manages the Digital Autopsy System. About 70% of the fund was set aside for business development, and the rest was intended for R&D activities. This fund was deemed necessary in order to support the aggressive global expansion that was part of iGene's long-term strategic planning. Among other things, the plan called for the establishment of offices in five different countries. Nevertheless, by the end of September 2006, neither the pilot nor the test-facility had yet been implemented, since the company was still waiting for authorisation from the respective ministries to proceed.

At the same time, the company also managed to secure a grant from MOSTI to develop and initiate clinical validation of its molecular diagnostic kit, which originated from its earlier biotechnology R&D. Its contractual bioinformatics software solution business had continued to grow over the years and successfully entered the US market in August 2005. Being profitable from the start and adding additional products, the company continued to register more revenues. Moreover, Infovalley Business Management, the subsidiary consulting arm, was still in operation.

The company retained all its pioneer staff that it had recruited in its early days. The senior scientists had been given stock options as retention incentives, while the company's human resources plan was to hire more business-oriented people. The company had approximately 45 staff members, and 12 of them were PhD holders. There were 22 staff members in Malaysia and 23 employees in Bangalore, India. For the Malaysian office, the company was planning to hire up to 58 employees by June 2007 and add another 30 by December the same year, while for the Bangalore office, it intended to have another 10 by December 2007. The number of employees holding PhDs was expected to increase to 20 by the end of 2007.

Up to September 2006, Mathavan owned 90% of Infovalley and Sheela retained the remaining 10%. Infovalley Life Sciences was once 100%-owned by Mathavan, however by early 2006, Mathavan had given up 35% of his shares in the other two subsidiaries to individual investors in return for capital for business expansion.

According to him, he had no current plan to publicly list Infovalley as a way to gain more capital to support its aggressive growth plans. There were several reasons for this. First, he believed that the bioinformatics and biotechnology capital market was not yet fully developed in Malaysia. Before a reasonable level of market acceptance can be achieved, the targeted customers and the larger business community must be convinced of the system's usefulness and capacity for value creation. Second, even if the market accepts the technology, given the demanding capital utilisation in the medical and bioinformatics businesses, the amount of money raised through public listing could be easily used up within a short period of time. Therefore, the company decided to create a larger market first with regard to the Digital Autopsy System in Malaysia and, later, in other foreign countries. Logically, the local market for the system seemed to hold huge potential. When it becomes common practice to use the system in hospitals around the world, the market for the system is bound to grow very quickly.

DISCUSSION

The recognition of a new business opportunity in the field of bioinformatics was the impetus for starting the Infovalley venture. The *startup* phase of the company began with the development of bioinformatics solutions (*Product No. 1*) for contractual customers. Having know-how in bioinformatics solutions and being able to use contractual revenues to recruit experts as well as finance other expenses allowed the company to engage in other exploratory works. The first of these was the development of a molecular chip used to detect genetic diseases (*Product No. 2*). Moreover, by leveraging its strengths in high-intensity computing and high-definition visualisation as part of its development of bioinformatics solutions, the company was able to enter into a new market of medical informatics, creating the Digital Autopsy System (*Product No. 3*). This system, which is the first full-fledged digital autopsy system in the world, is designed for common usage and has the potential to make a substantial change in the world by replacing standard autopsy methods and by making possible a wide range of applications with regard to both autopsy procedures and the Digital Autopsy System itself.

Specifically in the case of the Digital Autopsy System, we can identify five critical milestones in its initiation, development and commercialisation (see

Appendix B). At each of these milestones, interactions occurred between the company's internal managerial context and its external business environment.

The First Milestone

The Digital Autopsy System innovation (*Product No. 3*) started when the lead entrepreneur initiated a connection with the founder and chairman of SGI. This connection led SGI to offer a "mummy assignment" to the company. By handling this assignment, the company developed a much-improved visualisation technology as a solution. This first milestone, proving the utility of the technology, involved establishing the usefulness of the core imaging and visualisation technology to the medical informatics field. This milestone was undoubtedly reached because of the lead entrepreneur's persistence in finding new business opportunities. He was driven by his past working experience, plus his acquired knowledge and skill. There was also a synergistic effect between his strengths and those of his development team. The entire team's readiness to capitalise on their existing strengths in high-intensity computing and high-definition visualisation (an internal factor) by taking up the mummy assignment (an external "trigger") was key to their success.

The Second Milestone

The recognition of a business opportunity and matching the technology utility with its commercialised application, can be considered the second milestone reached by the business. It was also achieved through the lead entrepreneur's connection with the SGI founder and chairman. Thus, the creation of connections led to confirmation of the core technology value and helped open the window to a new business opportunity. These two major milestones demonstrate how the lead entrepreneur continually "modified" his environment in two important ways. First, accumulated the needed capital via his consulting work as well as recruited key scientists by utilising funds obtained through this work. Second, he communicated with external experts, which provided with him an exclusive window for new business opportunities (Sarason et al., 2006; Shane & Venkataraman, 2000).

In fact, one direct communication with an expert happened over the course of a meeting. As such, this was a distinct event that played a key role leading to the recognition of a business opportunity. The event itself happened partly because of the availability of a government-based platform (the IAP), which enabled the lead entrepreneur to interact with an expert and to directly access new business ideas from him. It highlights the importance of IAP to Malaysian entrepreneurs; in this case, the IAP appointee helped Mathavan build a critical "intellectual networks" and exposed him to a new business opportunity. Socialisation with an expert thus

can enable a more seamless transfer of new concepts and of new information about potential markets, thus affirming and extending Locke's (1999) views about the importance of "focused" interactions in achieving business success. This study, which shows an expert as the main source of information for a new business opportunity, thus extends the findings of Ozgen and Baron (2007); they argue that social networks are a significant source of information for new product ideas. The focused interactions studied here were guided by Mathavan's aspirations to build a large, successful company. This affirms Locke's emphasis on the importance of "strategised" networks as well as Watson, Hogarth-Scott, and Wilson's (1998) findings that an entrepreneur's growth orientations determines the outcome of his or her firm.

The Third Milestone

Equally important is the availability of one or more leading internal experts. Pramod, the forensic pathologist whose core domain of expertise and passion is autopsy, served as exactly such an expert for Infovalley. After agreeing to join the project, he brought a passion to develop a more humane autopsy system, and his vast experience in the field significantly influenced the events as they unfolded. Thus, his joining can be considered the third milestone for the business. He designed the system blueprint and determined its functional requirements, which served as important precursors to the system's actual development.

Also significant in the initial stages of development was the company's own entrepreneurial spirit, which encouraged creativity by allowing its members to explore new territory and accept new challenges. This was achieved partly through Mathavan's unique hiring strategy that involved recruiting "generalist-specialists" as well as through his ability to spot talented scientists and technologists for recruitment. These were thus important factors in creating a team of creative people and an environment in which they could do their best work.

Additionally, at the time as the Digital Autopsy System was developed, the company had already collected revenues from its other businesses. It had also established infrastructure for managing new product development and maintaining key partnerships; this infrastructure developed as a result of its bioinformatics business activities. Overall, this infrastructure characterised the company's "internal core capability," which provided support for the development of the Digital Autopsy System.

The Fourth Milestone

The demonstration of the Digital Autopsy System's technological usefulness to Malaysian government officials was a fourth milestone. This was made possible because SGI's CEO, in his capacity as one of the IAP members, acted as a "matchmaker" between Infovalley and the Malaysian government. This highlights the importance of an advisory body like IAP as a supportive marketing channel for increasing an innovation's visibility among targeted potential customer groups.

The Fifth Milestone

After these four milestones, there were continual efforts by the entrepreneurial team to exploit this new business opportunity and to build up a case of the commercial viability of the Digital Autopsy System. This involved adapting internal research behaviour and technology to match market needs. The adaptations included: (1) rapid exchanges in information between the company's business side and major technology decision-makers (government ministries, the main autopsy procedural authorities, and religious authorities) and (2) effective internal communications among members of the respective departments of the business, including the business (or marketing) side, the scientific (or medical) side, and the technological (IT) side. This was an iterative process that involved continually repeating the same or similar activities and approaches. This process was designed to exploit the business opportunity in every way possible, with the goal of eventually commercialising the Digital Autopsy System.

The team's efforts finally paid off when they received the necessary approval from various government ministry offices to implement a digital autopsy pilot facility in a government hospital in Malaysia. Making this first sale for RM10 million, which provided the testing environment for the system and sponsors for its commercialisation, and receiving indications of further possible commitment from the government for the installation of more systems in the future constitute the fifth milestone. Reaching this milestone was critical in ensuring the marketability of the system. The system's acceptance clearly was facilitated by the fact that it met the Malaysian Muslim population's religious needs, received endorsements from key decision-makers in Malaysian religious groups, and had complied with all medical and scientific autopsy standards and requirements.

By September 2006, the pilot digital autopsy facility was not yet installed; therefore, information on its implementation is not available. Nevertheless, a number of issues related to the Digital Autopsy System's implementation must be addressed, including whether the company will be able to manoeuvre around the

bureaucratic "red tape" of government ministries. This is especially pertinent, as the pilot system and facility are owned by MOSTI, but the hospitals are under the supervision of another ministry, the Ministry of Health. The system and facility must adapt to various different organisational structures and procedures imposed by the Ministry of Health and by the various hospitals. At the hospital level, the system implementation must be carefully planned and executed, as the facility could easily be labelled by some as a radical hospital innovation. The facility is entirely new to its adopting hospitals as well as to its end-users, the medical examiners and forensic pathologists. There are several concerns regarding its implementation. First, the system may require rigorous and time-consuming testing to ensure the reliability of the data retrieved and thus valid autopsy results. Second, the medical examiners and forensic pathologists may require some undetermined amount of time to become familiar with and have confidence in the facility's reliability and usage.

The decision to implement involves several levels of the Ministry of Health, hospitals and end-users; it thus adds to a complex process of innovation implementation. Addressing any implementation issues is critical, because the ultimate aim of the innovation process is to fully implement the new digital system, with all features and functions utilised by end-users (DePietro, Wiarda, & Fleischer, 1990, p. 151–175; Fleischer & Roitman, 1990, p. 197–232; Chiasson et al., 2007). Additionally, a successful, fully implemented pilot would likely influence the fate of future system implementations and thereby would also influence the profitability and sustainability of Infovalley.

While developing the Digital Autopsy System, Infovalley also completed the development of its other exploratory work, the molecular chip project. It also continued to accept more contractual projects from various government and private agencies for bioinformatics solutions, both locally and abroad. Both the contractual and successfully-developed exploratory projects increased the company's revenues and allowed it to proceed to the *growth* phase. As the Digital Autopsy System has a large potential market, a fully launched system is expected to accelerate the growth and increase the value of the Infovalley venture and its group of companies. As developing and implementing medical and health care solutions naturally extends to servicing the customers, the services component of the Infovalley business is also expected to experience high growth. With these developments and other new injections of capital, the company is geared toward moving to the *maturity* stage and reaching *stability*.

Another finding worth noting is the differences found in opportunity recognition processes among the three major businesses of Infovalley. In the first business (*Product No. 1*), identifying client needs and then determining the capabilities and technologies necessary to serve them characterised the way Infovalley's

bioinformatics solutions business developed. This indicates a purposeful opportunity recognition process (Ardichvili, Cardozo, & Ray, 2003). In contrast to the first business, frequent interactions with clients in the second business (*Product No. 2*) enabled the company to recognise opportunities in biotechnology R&D, which led it to develop the molecular diagnostic kit. This could be classified as an unintentional opportunity recognition process, as the venture was not purposefully looking for a new opportunity but rather discovered it accidentally. In the third business (*Product No. 3*) involving the Digital Autopsy System, the developmental process was a *hybrid* one, as it was both a purposeful and unintentional discovery. It was purposeful insofar as the lead entrepreneur introduced himself to the SGI chair. Yet, it was unintentional, since while Mathavan was trying to prove the utility of the core technology, he realised the existence of the third business opportunity through a discussion with an expert on that issue. With each subsequent product (*Products No. 1–3*), the company continuously enhanced its ability to identify, develop, and exploit new opportunities to meet market needs. The high-growth orientation of the founder toward his firm appeared to be a significant factor in triggering the movement from one phase to the next. This finding shows that the entrepreneur's aspiration for his or her company not only determines the outcome of the venture development, but it also helps trigger movement to the next phase. This is similar to Churchill and Lewis's (1983) and Watson et al.'s (1998) propositions.

The findings also indicate that the life experiences of the lead entrepreneur had direct and indirect effects on the venture's developmental growth path (Cope, 2005). These experiences include: Mathavan's past financial insecurity, his previous experience in starting, managing, and facing the failure of his first venture, and his experience in successfully developing and selling bioinformatics solutions (the first business of Infovalley). His past financial insecurity motivated him to continually seek opportunities and influenced him to be a successful manager in his early corporate life and a persistent entrepreneur later on. Nevertheless, with no previous experience in starting an entrepreneurial firm and a lack of reference points or role models around him, Mathavan was forced to develop business acumen on his own and rapidly acquired the necessary skills and knowledge.

The conflict between Mathavan and his partners in the previous e-learning venture, which influenced him to adopt a more cautious ownership management strategy for Infovalley, demonstrates how past experience helps shape an entrepreneur's current behaviour (Cope, 2005).

His "cautiousness" may have led to a more meticulous information-gathering process in assessing new markets and associated risks, thus improving the possibility of the venture's success. The previous experience may have also

influenced him to be more aware of the importance of team cohesiveness in running his business. This could have influenced him to develop more effective recruitment processes and business strategies. However, it also shows that an entrepreneur may become more risk averse in certain contexts; as such, he could become an impediment to the company's growth.

Moreover, in developing business concepts and products, Infovalley's founder and his team not only capitalised on existing networks but also formed new networks with university professors, scientists and researchers in several public research centres. The existing underdeveloped innovation system did not seem to have a significant effect on Infovalley. For example, acquiring funding was not a major problem for Mathavan. It was his personal decision not to seek or use outside money for his business in its seeding phase; rather, he utilised his profits from consulting to fund the biotech business. Revenues from the business consulting were also supplemented by contractual projects, for which revenues were assured and received with less delay in comparison to exploratory projects. The revenues were used to fund the exploratory works, which in turn supported the expansion of the company's business portfolio. In addition, having MSC status enabled the company to secure government grants and tax breaks that helped reduce their capital burden while developing new products. Having this status also enabled the company to hire an unlimited number of foreigners who have the required expertise at cheaper costs. Perhaps Mathavan used this as a deliberate strategy, simply because he knew how difficult it was to get seed funding in Malaysia.

Moreover, not being in a clustered environment did not appear to cause a major problem for Mathavan's venture. First, he was able to overcome the lack of opportunities to socialise with experts, which is usually associated with an underdeveloped innovation support system. This was accomplished by connecting with an expert that offered him insights on a new business opportunity. Second, when the Digital Autopsy System was first initiated, Mathavan's company already had an infrastructure to manage new product development as well as the needed partnerships to support the company's software and hardware integration. Therefore, the benefit of being in a clustered environment in term of close support from hardware and software vendors was irrelevant for his company. All of this supports the idea that entrepreneurial team capability is the major determinant of successful product commercialisation and new company development (Kroeger, 1974; Timmons, 1994, pp. 3–37, 207–233).

CONCLUSIONS AND IMPLICATIONS ON SYSTEM COMMERCIALISATION AND FIRM DEVELOPMENT

The venture team members' ability to create an environment for themselves in which opportunities were quickly recognised and fully exploited and their ability to act within the limit of that environment are two important variables that influenced the success of the Digital Autopsy System's development and commercialisation. These two abilities were guided by the founder's aim toward achieving high-growth for his company and sustained by him and his team through their need to succeed. On the other hand, having successfully developed a product family that comprised of an expanded portfolio of contractual and exploratory projects that was built on each product's strengths appeared to be the critical factors for the firm's successful development as a business.

Taken together, these core characteristics helped Infovalley Life Sciences overcome the problems of innovation system immaturity in which it operated in. This finding is consistent with a structuration perspective of entrepreneurship, which proposes that both the entrepreneur and the firm *co-evolve* with their business contexts (Sarason et al., 2006). The founder's past experience, aspirations for his or her company, and breadth of knowledge as well as his or her team's depth of knowledge (Alvarez & Barney, 2002, p. 89–105; Kirzner, 1973; Newbert, Gopalakrishnan, & Kirchhoff, 2008), emerge as important constructs in the co-evolution process.

Moreover, the concept of entrepreneurial actions at the individual (entrepreneur) and firm (venture-team) levels, which is developed based on the resource-based perspective of entrepreneurship (Alvarez & Barney, 2002, p. 89–105), is useful in explaining the recurring actions of the entrepreneur and his team (entrepreneurial actions) and their co-evolution with their environment. These developmental and adaptive actions reflect the team's capabilities in commercialising the system and growing the firm.

These entrepreneurial actions, in turn, can be distinguished into two types. The first group is a set of variables that influence the success of product commercialisation, while the second group of factors has an effect on the success of the company's development as a business. The first set of actions involves continuous iterations of individual, entrepreneurial actions and firm-level, venture-team actions. All three of the firm's businesses involved the lead entrepreneur and his venture team continually creating an "opportunistic environment."

The continuous high alertness toward new business opportunities and the integration of the entrepreneur's knowledge breadth about the market and

technology applications with his team's knowledge depth in the core technology domain began with the company's first product development. In this process, the entrepreneur was highly attentive and had high entrepreneurial alertness to new opportunities; in turn, the venture team was ready and able to pursue new challenges. As a result, the entrepreneur's knowledge breadth and the specialised knowledge and resources of the team were integrated (Alvarez & Barney, 2002, p. 89–105; Kirzner, 1973), leading to the development of the business opportunity. The past development of two successful products created an internal core capability within the firm, which supported the development and commercialisation of other new products. The successful development of products, in turn, contributed to the development and growth of the firm.

Augmenting a structuration perspective of entrepreneurship with a resource-based view of entrepreneurial actions and firm development reveals close linkages between the processes of entrepreneurship, product commercialisation and company development and a firm's business contexts.

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APPENDIX A

List of Interview Questions

1. What circumstances directly preceded the venture's beginnings? Who initiated the venture? Does the current leadership include those persons? If not, who is currently in charge?
2. What is the ownership, leadership, and management structure of the new venture?
3. What are the entrepreneurial team members like, in terms of leadership, background experience, skills, motivations and aspirations?
4. How did the new digital autopsy concept originate? How did the lead entrepreneur and his team identify the business opportunities related to this new concept?
5. How did their taking advantage of the opportunities unfold? Especially, at which point of the "opportunity development" did the entrepreneurial team officially decide to exploit the opportunity?
6. What were/are the proposed values of the digital autopsy system? What were the competitive strategies employed when entering the market and growing the business?
7. What problems has the venture faced in regard to its innovation support system/ context? (Consider: an underdeveloped location context and an underdeveloped venture capital industry) And what strategies, if any, have been employed to overcome these problems?
8. What problems has the venture faced in regard to its industry—in this case, the medical/bio informatics applications industry? What strategies have been employed to overcome such problems?
9. What problems has the venture faced, specifically in regard to the Malaysian medical medical/bio informatics applications market? (Consider: infrastructural issues, culturally-based issues, economic and social issues, etc.) What strategies have been utilized in overcoming these problems and achieving success in the marketplace?
10. What other problems have been encountered so far (as of late 2006)? What preparations are being made for problems yet anticipated?
11. Who have been the venture's supporters? What do you know of their motivations? What have been their contributions so far?
12. What developmental stages and processes have been navigated so far—both in the development of the business itself, and in the development of the medical/bio informatics innovation that is the core of your business?

[Some of these questions were taken from Khairul Akmaliah, Mohd Fuaad, Hanninen, and Walsh (2009) and some were adapted from Carrier, Raymond, and Altaief (2004); Khairul Akmaliah (2007); Sanz-Velasco (2006); Shane and Venkataraman (2000); Timmons (1994, pp. 34–37; 207–233)].

APPENDIX B

Process of Digital Autopsy System Innovation and Firm Development

Innovation and Firm Development Process	Milestones
Infovalley Group of Companies: Company Formation and Initial Business Development	
2001	
• Mathavan left his e-learning venture and started to search for other possible business opportunities	
• He took a consulting job to support himself and to finance new business exploration	
• He became aware of bioinformatics as an emerging industry within the field of biotechnology, but he saw that businesses in the industry typically had a long gestation time and required huge financial commitment.	
2002	
• Mathavan formed Infovalley and created a subsidiary called Infovalley Business Management to manage consulting activities.	*Formed a new company and created a consulting subsidiary*
• He put money earned from consulting into bioinformatics exploration projects and started recruiting scientists and technicians to explore the potential markets for bioinformatics solutions.	
Infovalley Group of Companies: Growing Bioinformatics Business and Infovalley's Digital Autopsy System: Opportunity Recognition and Initial Exploitation	
2003	----------
• Mathavan formed Infovalley Life Sciences (Infovalley LS), an MSC Malaysia status company.	*Created a subsidiary that is to focus on biotech business*
• Infovalley LS started developing bioinformatics solution for contractual customers.	*Started bioinformatics solution product development*
• Infovalley LS started integrating vertically into R&D in the bioinformatics field.	*Product Line Extension—Vertical Integration into Biotechnology R&D (Product#2- molecular diagnostic chip project)*
• Infovalley LS found that the core visualisation technology they had created within their bioinformatics domain had a potential market within the field of medical informatics.	---------- *MILESTONE 1* *Utility of core visualisation technology is proven in medical informatics, specifically autopsy*
• Mathavan met and talked with Bob Bishop, founder and chair of Silicon Graphics International (SGI). This resulted in recognition of new possibilities for business ventures in the area of autopsy technology.	---------- *MILESTONE 2* *Recognition of digital autopsy system as a business opportunity*

Early 2004 • Infovalley LS offered a bioinformatics solution for sale for the first time.	---------- *Launched Product #1 (a bioinformatics solution)*
Infovalley LS: Actual Development of the Digital Autopsy System • Infovalley LS was organised to dedicate a more focused effort to the development of a digital autopsy system. • Pramod drew up the system blueprint and established the initial requirements for digital autopsy system functionality. *Mid-2004* • Programming for the Digital Autopsy System was initiated by Malaysian and Indian programmers. *Late 2004* • Programming for the Digital Autopsy System continued.	---------- *MILESTONE 3* *Exploitation of the digital autopsy system business opportunity*
Infovalley's Digital Autopsy System Commercialisation: Gaining the System's Acceptance and Organising a Pilot Digital Autopsy Facility *March 2005* • Infovalley formed iGene, to specifically manage the digital autopsy system development project. *Mid-2005* • Malaysia's Prime Minister and his delegates were introduced to a demo version of the Digital Autopsy System version 1.0 by Silicon Graphics during the Inaugural Biotech IAP meeting in Los Angeles, US.	---------- *MILESTONE 4* *Demonstration of the digital autopsy system utility to Malaysian government officials*
August 2005 • US bioinformatics solutions markets were successfully penetrated.	---------- *Product #1-Bioinformatics solutions business expansion*
October 2005 • iGene gave another presentation to the Malaysian government officials in Cyberjaya. *December 2005* • iGene received an endorsement from MOSTI to set up a pilot digital autopsy facility in a government hospital. • iGene received approval of the system from Malaysia's National Fatwa Council and JAKIM. The two organisations studied the Digital Autopsy System while considering whether to issue a decree declaring that digital autopsy would henceforth be the only kind that should be performed on Malaysian Muslims, except in situations in which the traditional non-digital autopsy is given preference for specified reasons.	---------- *MILESTONE 5* *Getting the first sales order for the Digital Autopsy System (Product #3)*

Infovalley Group of Companies: Growing the Bioinformatics and Digital Autopsy System Businesses, Acquiring More Capital and Expanding into Overseas Markets (2006 and beyond)	---------- *Product #2- molecular diagnostic kit was market-tested*
August 2006 • Infovalley LS received a government grant to test the molecular diagnostic kit.	
September 2006 • The development of the Digital Autopsy System was completed. • The company suggested to the Malaysian Ministry of Health that six digital autopsy facilities be installed in the country. • The company appointed a corporate financing house to raise RM20 million of funds for iGene, the subsidiary that manages the digital autopsy project. • The company to set up marketing arms for the digital autopsy business in multiple countries to penetrate lucrative overseas markets.	---------- *MILESTONE 6 Anticipated Digital Autopsy System business expansion*

ENDNOTES

[1] The Multimedia Super Corridor (MSC) was established in 1996. It is an area where development of new technology-based ventures is encouraged. The MSC is also a project aimed at ultimately making the entire country more conducive for doing business, especially in technology-based/high-growth sectors. As an initial platform, the MSC has a size of 15 km by 50 km and stretches from Kuala Lumpur City Center (KLCC) in the north to Kuala Lumpur International Airport (KLIA) in the south. Designed to incorporate the infrastructures and support services needed to develop new technology-based ventures, the MSC also offers many benefits for already-established technology-based companies. Part of the MSC project involved the launching of four major government-led projects to create markets for technology-based companies—e-government, multipurpose smart card, smart school, and telehealth. Special cyberlaws, policies and practices also have been implemented to support the growth of MSC. (http://www.msc.com.my)

[2] In the fall of each year, IAP members meet with the Malaysian prime minister to discuss two issues: (1) The current level of Malaysia IT development, and (2) recommendations for raising this level. Each member has a separate one-on-one meeting with the Prime Minister, in order to convey personal recommendations. (http://www.mdec.com.my)

[3] Malaysia's National Fatwa Council (Majlis Fatwa Malaysia) is the governing body that generates religious decrees applicable to all Muslims in Malaysia. The group is comprised of all *mufti*s (the head of the Muslim religion in each of the 13 Malaysian states). They meet, discuss, and make decisions regarding current religious concerns, and also issue decrees related to those concerns. The Department of Islamic Development Malaysia (JAKIM) is a Malaysian government institution that coordinates Islamic activities and welfare in the country. JAKIM functions as a central Malaysian agency in regard to Islamic matters, with the aim of upholding progressive and morally high standards for Muslims in the country.