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Managing Innovation in a Supplier Dominated Firm: Considering the way forward

By

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2007

A management project presented in part
consideration for the degree of "*International MBA*".

Executive Summary

One of the most important things to bear in mind when considering innovation is that innovation is essentially change. How that change is managed will determine how innovative a firm actually is and the ability to manage innovation successfully will hopefully lead to a competitive advantage.

Sri Jentayu Global are undeniably a supplier dominated firm and do to some degree depend upon their suppliers. However, they are not as dependent as one might imagine or indeed as the theory may suggest. It is true that Sri Jentayu Global rely upon their suppliers for production inputs as the main source of new technology. They do not however rely upon their suppliers for improvements in their production methods or the technology that they use to produce highly effective body armour. Their ability to continually innovate and how that innovation is managed throughout the organisation, whether it is product or process innovation, is a competence that may lead to a competitive advantage most small manufacturing firms could only aspire to.

It is true that Sri Jentayu Global may not be able to change technological trajectory alone and this is possibly because body armour is such a niche product with a very limited market, within a highly competitive and volatile industry where entry to new markets is the biggest barrier.

Sri Jentayu Global are indeed path-dependant and their learning is indeed incremental but it is believed that their core competencies would most definitely allow them to change paths. They seem more than capable of achieving this, whether it be through vertical or horizontal integration or technology related product diversification. The result, no matter what, would be the development of new competencies. It might even be their existing competencies that allow them to consider a number of strategic alternatives, which will ultimately lead to sustainability through growth, entry to new markets and continual improvements in their product and processes.

A contributing factor to all of this could possibly be the size of the firm, its structure, and its need to survive. Its management of innovation to date may be successful but sustainability may require some changes in managing that innovation. The management team appear to be more than capable of achieving positive results but a much steadier approach may be required when entering into strategic alliances with the large organisations currently being considered. The proposed strategic alliances, if successful, will no doubt lead to new competencies in a variety of areas but the management of the alliances needs careful consideration as no doubt any potential partners have their own reasons for entering into an alliance and they will certainly not be altruistic.

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Introduction and Objectives

This management project focuses upon the subject of innovation management and in particular considers the management of innovation in a small, niche, supplier dominated manufacturing firm based in Malaysia. The following is an explanation of the objectives and focus of this project and it aims to explain why and to whom this study is important. It explains what it is that we want to know and why and the company, its background and some of its hopes and aspirations will also be considered in an attempt to allow the reader a clearer picture.

The initial objective is to identify any information already available from previous innovation management research and related subjects. This has been achieved by undertaking a literature review of current textbooks, academic papers, journals and any appropriate industry or subject related articles. The purpose of this is to expand upon what is already known and to use that information or knowledge when interpreting the research that will be conducted at a later stage. The literature review explores the most appropriate literature for the purpose of this project and it has been broken down into three main subject areas, Innovation Management, Innovation Strategy and Alliances & Networks.

The literature review discusses not only the literature that is significant to the research question but also considers any literature that may be appropriate to the future actions of the firm. It also considers any literature that may be

deemed relevant and of possible use at a later stage of the research process that may be appropriate for the ambitions of this management project.

One of the more important objectives of the project is to identify how the firm can progress its innovation through its strategy, whether planned or otherwise, and to identify whether there are any links when considering those particular choices open to it. This will be achieved by interviewing key senior personnel within the firm. It is hoped that by considering this and reflecting on the work that has been carried out by previous researchers the most suitable choices for the firm can be made by senior management through a clearer understanding of how innovation and strategy might be linked.

The primary importance of this study is of course the achievement of a pass mark in the MBA for which this project is in part consideration, however it is just as important to the organisation and its senior stakeholders. The end result will not only identify if what the firm is currently planning strategically will be to their advantage theoretically but will also go some way to be of use from a managerial perspective. The end results could potentially be used when considering the management of innovation and its use in decision-making and strategic changes within the firm and other firms within the group. The firm will ultimately from this research project and subsequent management report achieve a greater understanding of how the

management of innovation may affect their performance and also aid strategic planning.

As in any organisation the firm in question is continually considering what should be done, according to Fisher (2007) this consideration is what separates strategic questions from research questions. Strategic questions consider the future and research questions consider what has already happened as you can only research those things that are or have been. You can however according to Fisher (2007) research what people think might happen in the future and this will be considered in the Research Methods chapter under the heading of Research method later in the project.

It is important to explain what it is that we would like to find out by considering the research question and defining it by breaking it down to achieve a better understanding of what it is we would like to know and why we want to know it.

"What effect will a change in strategic direction have on the technological trajectory of a supplier dominated firm and can that change be driven by path-dependency or strategic goals alone?"

As we are already aware the firm is considering what it should do to achieve certain goals and those considerations might require a change in strategic direction but will altering the strategic direction lead to a change in the firm's

current technological trajectory? We know that the firm's current trajectory according to Tidd et al (2005) is that of a supplier-dominated firm but what we need to know is whether the firm can change from its current trajectory to a new trajectory by simply changing strategic direction. Considering this we have to judge whether the firm can achieve this change through a change in path-dependency or if it can indeed be achieved by their strategic goals alone. To clarify this if we further consider Tidd et al (2005) and their interpretation of path-dependency:

Firms' strategies are strongly constrained by their current position and by specific opportunities open to them in future: in other words, they are path-dependent. At any point in time, two sets of constraints make path-dependency in corporate innovation strategy inevitable: those of the present and likely future state of technological knowledge, and those of the limits of corporate competence (Tidd et al. 2005, p169).

We understand what the firm's current position is and the potential future openings that it is considering so therefore we understand the firm to be path-dependant. However what we need to understand in more depth is the firm's own understanding of their current technological knowledge, future technological knowledge, where that may come from and how they plan to manage it. We also need a greater understanding of what the firm believes their core competencies to be and whether they can adapt or change their core competencies. Finally, we must identify whether innovation strategies are indeed constrained by technological knowledge and core competencies; this will hopefully be achieved during the research stage of the project. Path-dependency and technological trajectory are considered in greater depth in

the Concepts, Conceptual Frameworks and Theories chapter under the heading of Path-dependency and technological trajectories.

This identifies the definitive objective of this project as being the achievement of a greater understanding of how strategy and innovation can be managed and how they might be linked in achieving a change in technological trajectory, and to identify and understand any possible impact that this may have on the organisation not only when considering the decisions that have to be made in the short-term but also for considering any future impact in the long-term.

The preliminary stages of the research project presented some difficulties in identifying the most appropriate topic of research to suit both the researcher and the organisation alike. I had considered the organisation in question a potential source for a management project for some time. This was due to experience gained from spending a short period within the organisation and identifying the firm as extremely entrepreneurial and showing signs of continual change. The initial proposed project considering Entrepreneurial Orientation did not sit comfortably with the senior management and their request for studying the potential strategic choices available to the firm were very wide in scope and presented a project that could have potentially been too unwieldy for the time frame available to complete the project. Owing to the scale and scope at this level of study the next best option was to identify an alternative subject of personal interest that was somehow related to the

firm regardless of its short-term plans and activities. Bearing this in mind with the future plans of the firm, and an awareness that innovation was perhaps, unbeknown to the senior management, an important part of those plans with a potential link between strategic planning and innovation, the research question was developed.

Another concern that required considerable thought is that it appears that the firm does not deliberately manage what it does strategically from a technological or innovative point of view and this could have presented some problems at the research stage of the project, for example, how to present semi-structured interview questions to a limited number of senior managers with different specialist backgrounds, or ensuring that the depth and scope of those questions do not confuse the issue or cause any overt concern but lead to a better understanding of the firm and the successful gathering of information and evidence relevant to the research question. This and a number of other concerns identified as potential hurdles to be overcome are discussed in the Research Methods chapter under the heading of Research method.

Another consideration in developing the research question was the uncertainty of any definitive direction that the firm was taking when the date for the final research proposal was looming. It was important to ensure that any strategic change in this rapidly changing and flexible organisation did not have any adverse effects on the research project once it had begun.

Therefore, considering innovation management and potential changes in technological trajectories could be an area of study regardless of which direction the firm chose to take.

The Firm: Sri Jentayu Global

Sri Jentayu Global (SJG) was established in 2004 to design and manufacture body armour for local and international markets. Headquartered in Kuala Lumpur, Malaysia with a manufacturing plant in Melaka, Malaysia, SJG manufactures a wide range of Personal Protective Equipment (PPE) and bespoke armour solutions to save people from bullet, blast and knife attacks.

SJG has quickly become recognised as a world leader in the manufacture of gold standard hard and soft armour and bespoke antiballistic solutions due to the successful delivery of a number of high profile contracts. This has been achieved through a partnership with John Marshall Armour Systems (JMAS), which is a world leader in developing antiballistic solutions and is coincidentally retained directly and solely by SJG. Appendix 1 briefly explains what body armour is, how it is made and the materials used in the manufacturing process.

It is important here to consider what the firm is planning and how those plans may affect what the firm does now and possibly in the long-term. The

following are only proposals that are being considered by senior management and are as of yet in the emergent stages of development.

SJG are currently considering the acquisition of a number of companies that will lead to horizontal integration and will also allow them to gain a much greater market share. They are also considering the acquisition of two companies that will allow them to move into other markets through related diversification. The acquisitions could lead to substantial cost reductions throughout the supply chain, which is of course a strategic decision. They are also currently exploring vertical integration with an overseas supplier that will not only bring raw materials to their doorstep but will potentially allow them to become a supplier to other manufacturers and again reduce the supply chain costs and potentially enhance their competencies.

SJG plan to advance their business by enhancing current technology, acquiring new technology, expanding their current product range and expanding their customer base and network. This in turn will lead to a more consistent revenue stream and create greater opportunity for future expansion. In addition to this, the acquisitions that they are considering will hopefully lead to a reduction of manufacturing costs and enhancement of manufacturing capability, an opportunity to restructure the human resource and a chance for senior management to become shareholders in the company.

As mentioned SJG are considering vertical integration by partnering with a weaver who specialises in the weaving of high-strength technical fibres and is licensed by DuPont to weave Aramid, also known as Kevlar, the core constituent of antiballistic products. The proposed vertical integration and associated activities could potentially be set up on a site adjacent to their current manufacturing plant. This will allow SJG greater access to raw materials and potentially put them in a position of competitive advantage, as Aramid is currently a scarce resource. As part of the firm's acquisition programme SJG are considering the purchase of a sports goods manufacturing firm because of the potential that the diversification may lead to. This diversification is however, related-diversification as the process for manufacturing the sports equipment in question uses the same ultraviolet (UV) technology currently used in the manufacture of the antiballistic products. The company is also considering the purchase of a composites company and this diversification could present alternative options to the firm if the need for antiballistic products declines or if indeed the two current strategic alliances encounter any problems.

SJG are also considering the acquisition of two international antiballistic companies that manufacture similar antiballistic products as SJG but the most interesting consideration is the strategic alliances that they are currently developing and advancing.

CamelBak, a re-hydration products specialist company, were seeking new markets through diversification when a chance meeting lead to a combination of SJG's product range and CamelBak's product range. CamelBak have supplied the US Department of Defence for a number of years with their range of military products and this has lead them to achieve a competitive advantage. This advantage may be able to be continued in the new venture with SJG.

The other strategic alliance is with Hitco Carbon Composites Inc an organisation working closely with SJG in developing the antiballistic technology for their core product. It is possible that this partnering could lead to a competitive advantage for a number of reasons and technology transfer may be the main one. This will be considered at a later stage of the project.

SJG are planning to take full advantage of their industry knowledge and innovative abilities through collaborating in an attempt to lead the industry's technological advancements. It is felt that for the purpose of the project there is no need to describe at length the structure of the organisation and how it operates. Therefore, only a brief introduction of what the organisation does and some of the strategic options that it is considering have been discussed here. There is of course a great deal more to be learnt about the company but the research will help to provide any information required for the purpose of the management project.

Literature Review

Introduction

Before considering the literature in any great depth some considerations and concerns about the literature itself have been identified by researchers and authors of innovation management theory. As stated by Garcia and Calantone (2002), the analysis of technological innovation is made all the more difficult due to the various descriptions used in the literature available. Different writers widely use terminology such as radical, incremental, discontinuous and disruptive with little or no consistency or explicit definition. Greener (2002) also supports that the literature on path-dependency can be elusive when considering some of the constraints, therefore making the task of understanding the literature more difficult. One important element to consider whilst reviewing the literature according to Tidd et al (1996), is that the diversity of research regarding innovation management and the accumulation of knowledge has been limited, and most studies have failed to include some appraisal of performance or achievement. Furthermore Tidd (2001) states that most of the research into innovation management has tried to identify a generic form of best practice and that most studies have also only considered the experience of specific sectors and proposes that these limitations could present a risk.

However Brown & Fai (2006) argue that the literature for innovation management has not only been varied and of great value but has highlighted the processes and difficulties of innovation whilst identifying some significant concepts such as path-dependency, technological trajectories and a number of articles leading to a greater understanding of innovation. They do point out though that they believe that there is a weakness in the literature, as it does not address the appropriate issues concerning the changing paradigms of manufacturing and the effects these have on the innovation process, and this will certainly need to be remembered when considering the '4Ps' of innovation discussed later.

Contrary to the views and concerns raised above not only is there an abundance of literature available but quite possibly too much and of course not only varying in quality but also varying in relevance for the purpose of this project.

Throughout this literature review the definitions and meanings where appropriate and requiring a fuller explanation will be clearly described detailing any significance to this piece of work. Where this is not possible, definitions will be discussed in the Concepts, Conceptual Frameworks and Theories chapter. The three main topics of discussion are Innovation Strategy, Alliances and Networks, and Innovation Management, which broadly cover the topic of research.

Innovation management

Tidd et al (2005) recognise that there are a number of definitions for what innovation may be, but they essentially agree that it is the need to complete the development and exploitation of new knowledge. Innovation is often confused with invention but invention is only the beginning of a long process of developing an idea to regular and actual use. Tidd et al (2005) present innovation essentially as change and this can be observed in several forms, but for the purpose of this project, and its relevance to each element of the project as it arises, we will focus on the four broad categories described by Tidd et al, as the '4Ps' of innovation.

'Product innovation' – changes in the things (products/services), which an organisation offers;

'Process innovation' – changes in the ways in which they are created and delivered;

'Position innovation' – changes in the context in which the products/services are introduced;

'Paradigm innovation' – changes in the underlying mental models which frame what the organisation does. (Tidd et al. 2005, p10)

Tidd (2001) also considers a second dimension of innovation, that being novelty. He considers novelty ranging from minor to incremental through to industry transformations, this can be closely linked to the '4Ps' and industry / product maturity.

Path-dependency according to Tidd et al (2005) is linked to technological knowledge and the limits of corporate competence; this in turn constrains a firm's strategy. Competence from an innovative point of view is what a

specific firm is capable of learning and exploiting. Innovation requires changes in technological and complex organisational systems and this requires learning. As this is incremental a firm's learning process is path-dependant and any search for innovation is restrained by the competencies accumulated from the development of their existing product base, so moving from one path of learning to another can be expensive and in some cases impossible.

Sartorius (2006) goes some way to support Tidd et al in that the existence of path-dependency and lock-in can restrict the switch from one technological trajectory to another, and is frequently blocked by considerable barriers. However Sartorius then goes on to suggest that those barriers are subject to substantial changes over time but it makes sense to distinguish between periods of stability where barriers are seen as being high and during periods of instability where barriers are seen as low, therefore meaning new trajectories can be reached with greater ease during periods of instability. Unfortunately, technological change requires the transition from one paradigm to another, so not only is it less likely to occur but it will be associated with higher uncertainty and risk. Sartorius does however counter argue this in support of radical innovation, which can lead to a transition between trajectories in different paradigms. Whilst this may have the potential of greater profitability economically there is still a high degree of uncertainty, which represents a potential threshold for risk-averse individuals. This links with the paradigm of the '4Ps' of innovation and will be

considered in more detail as it addresses a major element of the research question in considering path-dependency and technological trajectories.

Man (2001) takes a more pragmatic view and suggests that technologies often carry "comfort zones" which he describes as the resistance experienced when attempting to intervene new paths. This is related to the adage "if it ain't broke why fix it", leading long-term technologies to continue until problems arise, causing path disruption. This is related to the literature about alliances; the technology has been improved upon but there is a potential change in the product / process innovation, which may lead to a change in the path and trajectory due to proposed alliances, and will be discussed in more detail later. Man further argues that innovation should not mean "settling into" one successful strategy but a continual hunt to challenge existing successful technologies, which could ultimately lead to improved performance through new designs and methods, adding value and possibly lowering costs.

Whilst theorising path-dependency, Greener (2002) states that there are indeed allowances for deviations from the path and even in some cases certain circumstances would allow the creation of a new path, however this change would be predominantly incremental which would only be achieved by circumstance and the actors involved. Path-dependent processes are restricted by the organisational structures, which limit and shape them, but the level of technology should identify whether or not those organisational

structures to a new path are overcome. He also argues the point that institutional approaches to path-dependency stress the importance of rules and routines and their implication in organisations.

According to Drew (2006) disruptive innovation stimulates new types of business models whilst sustainable innovation does not upset existing industry patterns and can be divided into incremental and radical innovation. Daneels (2004) has raised some concerns about how opportunities for disruptive innovation are recognised at an early stage, the potential paths of disruptive technologies and how the new technology can be turned into an opportunity for value creation and strategic advantage. The relevance of this, the changes in path-dependency and how those changes might be achieved leading to a shift in trajectory are a major focus point for this management project and will be revisited.

It is from the theory of path-dependency that technological trajectory was proposed and a firm limited by its competence, or a technology by its knowledge, can be applied equally. Tidd et al (2005) also state that innovation achieves strategic advantage through finding new ways of doing something, so that room can be created for gaining and retaining that advantage. They then go on to suggest that when considering novelty in a product or service it could strategically provide the platform for future variations and generations. It is important that there is a good fit between what the firm already knows about and what it is planning to change. This

should however not discourage moving into new areas of competence, as change has to be necessitated to encourage learning.

Innovation strategy

In the process of strategic change, according to Pavitt (1990) the innovative opportunities open to a firm are strongly related to the firm's size and core business. He states that innovative small firms are generally specialised in their technological strategies where they concentrate on product innovation for specific products. Das & He (2006) discuss the importance of strategic criticality, which identifies that the continued viability of a firm may have to rely on a partnership. Markides (1999) offers a more pragmatic approach for the consideration of innovative strategy by suggesting that the heart and soul of strategy is in asking "who-what-how" questions to assist in the expansion and choice of specific goals and actions. "Who" is to identify new market segments, "what" is for adapting an existing product and "how" relates to manufacturing. This may help identify a change in the trajectory in relation to the research question and lead to a greater understanding of the strategies related to innovation.

Not all innovation according to Moss Kanter (2006) has to be ground-breaking, as incremental innovations can lead to greater profits and indeed an innovation strategy that includes incremental and continuous improvement can free minds to be more responsive to change if a big

breakthrough occurs. One factor that should be considered is the tension caused by innovations from outside an industry, a long known phenomenon, which creates extra pressure on firms to quickly find the next big concept. This may not be relevant in the case of this project due to the nature of the industry and the advancement of the current technology however it will certainly need to be considered as part of the process of identifying what is happening in the organisation and the nature of the current changes being experienced.

Discussing innovation strategy in small firms, Tidd et al (2005) identify that small firms concern themselves with the same worries as large organisations. However these concerns present themselves in different ways and small innovative firms possess some characteristics that separate them from large firms, this is presented in the tables illustrating technological trajectories in the Concepts, Conceptual Frameworks and Theories chapter under the heading of Path-dependency and technological trajectories.

Additional to the readily available literature supporting and explaining strategy and innovation Brown & Fai (2006) discuss the concept of strategic resonance. They define strategic resonance as "an ongoing, dynamic, strategic process whereby customer requirements and organisational capabilities are in harmony and resonate". They go on to say that this is not just strategic fit and is more about capabilities and functions at all levels, and in turn protecting those capabilities that used to take advantage of market

opportunities. This goes some way to support Tidd et al above but surely one should be more willing to consider changing those capabilities in the name of innovation. To that end one would argue that resonance goes against innovation as innovation is about developing and renewing existing capabilities in an attempt through learning to change path-dependency and ultimately technological trajectory. In their defence however Brown & Fai do acknowledge firms practising incremental change or the incorporation of new technologies, which improve established core products gaining the most from strategic resonance. It is this incorporation of new technologies in established core products that may fundamentally contribute an important consideration as part of the research for this project.

According to Bessant et al (2004) most established firms are aware of the need to innovate for growth and a way of differentiating themselves from their competitors. However most of their efforts are incremental or 'me too' products thus identifying a need for discontinuous innovation which relates to anything other than the 'business as usual' approach to innovation. Discontinuous innovation compared to steady state innovation removes you from what Bessant calls the "zero sum" game that many industries fight in on a daily basis.

Bessant et al (2005) believe that whilst firms operate in environments of stability most of the time there are occasions when something happens to dislocate that stability. These are not every day events that can disrupt the

status quo, but can however present new opportunities whilst challenging existing players. A completely new technology that offers much improved functionality or differentiation is a good example of dislocation. This leads to the need and ability to manage innovation under conditions of uncertainty and rapid evolution. Firms in these conditions therefore need to be flexible, agile, with an ability to learn fast and preconceive how things might evolve. Small new firms are often associated with these abilities and frequently conflict with the routines of large organisations. Discontinuities and the innovation opportunities that arise can lead to significant path and technological shifts linking in with the '4Ps' of innovation and highlighting that changes in path-dependency are indeed possible. Bessant et al then go on to say that it is not the scale of novelty or dislocation but the firms' ability to deal with situations that arise outside of its operating abilities. Because such occurrences do not happen on a daily basis they are essentially discontinuous and established firms may experience difficulties in dealing with them effectively. One issue that may cause potential problems is the network of relationships that a firm has with other firms. This is because of the basis of what could be regarded as steady state innovation deals with systems already in place, whereas discontinuous innovation may require the development of new relationships with partners the firm is not usually used to dealing with.

Alliances and networks

Defined broadly as any relationship between companies involving a sharing of common destinies, strategic alliances are cropping up across the globe. A strategic alliance is an agreement between two

or more partners to share knowledge or resources, which could be beneficial to all parties involved (Vyas et al, 1995 p47).

The collaboration of firms occurs for numerous reasons such as the reduction of cost and the risk of technological or market development which can lead to much faster times to market and the development of economies of scale according to Tidd & Izumimoto (2002). However quite often it is to provide short-term resource deficiencies rather than for long-term strategic fit. Bruce et al (1995) identified that whilst many firms formed alliances to reduce time, cost or risk of R&D they were not wholly aware of the benefits of the relationship. Alliances according to Coombs & Hull (1998) have distinct objectives such as product development, or to enter new markets, where joint ventures are likely to have much broader strategic implications. A joint venture in its nature is more formal, involving the creation of a new venture with its own management and resources, representing an ideal opportunity for knowledge acquisition and learning which could quite possibly lead to a change in the direction of path-dependency, leading to a greater insight of what may prove to be relevant for this project.

When considering the acquisition of external knowledge, according to Atuahene-Gima & Patterson (1993), strategic considerations such as competitive advantage, market expansion and extending product portfolio are as equally important strategically. According to Tidd & Izumimoto (2002) strategic alliances, joint ventures and innovation networks provide a superior

prospect for learning but go on to say that little research has been carried out on how firms manage learning from international joint ventures.

Vyas et al (1995) identified that intensified foreign competition, shorter product life cycles, increased capital investment costs and the increasing demand for technologies has led to an increase in alliances and believe that a go-it-alone strategy is no longer a choice. Radjo (2006) supports this with his thoughts on innovation networks. He argues that due to the demand by customers for more choice and greater speed for technology enabled innovation, the traditional model of innovation where firms financed, invented and promoted their innovations alone is no longer fit to meet this growing demand. Vyas et al then go on to consider the benefits of intra- or inter-industry alliances, the arena of alliances and the formation of alliances to produce technology fusion, which not only supports the hopes and aspirations of this project but also goes some way in identifying another avenue to investigate in the due process. Stach (2006) raises a concern for the theory of arenas by emphasising the fact that distance can be a major obstacle, as only by meeting and working alongside each other can personal relationships be developed, thus highlighting not only an interesting argument but also an important consideration for this project and international alliances.

However there are some opposing issues that have been associated with alliances and they should be continually reassessed throughout the alliance;

they are issues such as power imbalance in terms of size, resources and access to markets. Continuing in this vein Stach (2006) claims that alliances that are unsuccessful fail mainly due to implementation issues, personality conflicts and other non-technical factors, but long-term success is more likely if there are communication plans in place and this may oppose his argument of distance being an obstacle.

Contrary to the positive approach of alliances of one form or another Bruce et al (1995) found that collaborations increased the cost of product development, were more difficult to manage, time consuming, less efficient and complicated, but they did find that the risks associated with collaboration were reduced through experience gained in collaborations. They also identified a feeling that during collaborative product development there were changes to personnel, objectives, priorities and market potential which could alter the results of any collaboration.

Complementarity in innovation strategy is another factor that may warrant consideration, as Cassiman & Veugelers (2006) found that internal R&D and external knowledge acquisition are complementary innovation activities. However, the level of complementarity is sensitive to other elements of the firm's strategic environment. Complementarity is observable by the sheer fact that firms actively partake in internal and external knowledge acquisition activities and this may lead to external know-how improving the efficiency of internal R&D if indeed firms are willing to adopt knowledge and ideas from

outside the firm and distance themselves from the 'not invented here' syndrome. Rigby and Zook (2002) support the idea that the most innovative organisations need to seek knowledge from outside, as they cannot exclusively rely on internal sourcing of new innovative ideas. They argue that a combination of internal and external knowledge acquisition can lead to competitive advantage. Whilst there is some empirical evidence available on internal and external sourcing strategies as of yet there is little empirical evidence to support complementarity and innovation strategy. External knowledge is not just linked to innovation; it is also closely linked to entry to new markets previously unobtainable by barriers, and complementarity could be found in the products developed by each firm (Cassiman & Veugelers, 2006).

Alliances are different from other structural transactions, such as mergers or acquisitions, and need to be managed differently. To begin with, alliances are much larger, messier to manage and somewhat open ended in terms of their duration and focus. However, good alliances, like good transactions, require the unflagging focus of senior level managers. In the case of alliances, senior managers need to focus on them throughout the relationship or the alliance risks losing its intended value or obtaining specific business objectives, such as getting products to market faster (Anslinger & Jenk, 2004, p18).

Anslinger & Jenk (2004) report that the reasoning behind such a prolific increase in alliances is due to the need for fast and economically driven expansion into new markets and increased control and influence over customers. Intensified competition, rapid technology advances, upstream innovation and rising development costs are reported to be forcing firms out of their comfort zones in search of growth strategies. They also suggest that

the reason for so many alliance failures is due to performance measurement concepts not being used and that the most appropriate way to achieve this is by establishing a few key objectives and metrics of success.

One consideration suggested by Bessant et al (2005) is that the strategy between players needs to be co-evolutionary with an emphasis on fast learning but with an expectancy of high failure, and that due to the difficulty in predicting dominant design or trajectory trying to pre-plan models for organising or managing the process are of limited value.

Finally Vyas et al (1995) amongst others provide a framework for selecting strategic alliances, which will be built upon at a later stage in this project when considering conceptual frameworks for the overall management project.

The development of this literature review was by no means restricted by scope and quantity of literature available for the chosen subject of research. The quality in some cases resulted in some literature being rejected. However the principal reason for the rejection of literature was due to the scale and being restricted by the word count of the management project. Trying to narrow the literature down can lead to a distortion of the research question and would in turn not meet the requirements of writing the management project or those of the organisation that is subject to the results of the proposed research.

Concepts, Conceptual Frameworks and Theories

Concepts and definitions

As suggested by Fisher (2007) defining the terms and concepts of the management project is of the utmost importance as this will not only lead to a greater understanding of the terms used but will also go some way to explain the research subject. This chapter is of course closely linked to the previous chapter as a great deal of understanding was learnt from the literature review; however closer examination of the definitions will go some way to developing a conceptual framework.

The development of the conceptual framework will be based upon a structured approach rather than grounded approach and this is primarily due to time constraints and the fact that the research question that has been developed has specific terms and concepts that are relevant in answering the question (Fisher, 2007).

Considering the research question again: *What effect will a change in strategic management have on the technological trajectory of a supplier dominated firm and can that change be driven by path-dependency or strategic goals alone*; leads to the consideration of the relevant concepts.

In an attempt to identify the most appropriate concepts and their definitions the research question has been reframed as, strategic innovation through alliances leading to a change in path-dependency and potentially technological trajectories. This is not based upon the research question alone but what is already known about the firm and its current plans, resulting in the following main concepts requiring a clear succinct working definition:

- Strategic alliances – joint ventures, partnerships etc.
- Innovation strategies
- Path-dependency & technological trajectories

Strategic alliances

The actual working definition of what an alliance is and the different types of alliance is more important here than the reason for collaboration or the formation of alliances.

Tidd et al (2005) discuss a number of different types of alliances and it would appear that the most appropriate for this project are strategic alliances and joint ventures. They describe strategic alliances as two or more firms agreeing to develop a new technology or product, informally and with specified end dates, where the formation of a separate firm is not required. Joint ventures on the other hand are more formal and either comprises a firm formed by two or more organisations or a contractually based collaboration.

Coombs & Hull (1998) see joint ventures as formal because they involve the creation of a new enterprise with its own resources and management whereas an alliance generally has the clear purpose of product development or entry to new markets. Vyas et al (1995) define strategic alliances as roughly any affiliation linking firms with shared common goals and an agreement that is favourable to all involved, which includes the sharing of resources and knowledge. On the other hand Anslinger & Jenk (2004) contradict the above and describe alliances as rather open ended in duration, and often run as individual business operations. However, they do agree that they are formed to meet explicit business objectives such as getting products to market more rapidly. An alternative form of alliance presented by Radjou (2006) describes a model of innovation networks, which seamlessly combine internal and external invention and innovation services to optimise product development. Tidd (2001) identified the idea of networks becoming widely used but it is often not specified in what context and there is little agreement on what constitutes a network. However he does add that networks generally became recognized through established relationships with suppliers, distributors, customers and competitors. He goes on to say that networks may be beneficial in cases of joint infrastructures and standards and that networks may be more appropriate where uncertainty exists and may also be more appropriate than full integration or acquisition. This is limited in its use for developing a concept for the purpose of this project but it does identify the different types of alliance.

The concept of product development and market entry through strategic alliances and joint ventures seems to be the most appropriate for this project and therefore the definition proposed by Tidd et al will be used throughout this project and will be clarified and explained further as required.

Innovation strategies

The different conceptual strategies of innovation management discussed in the literature review are relevant to the project however those strategies that may be closely associated with path-dependency and technological trajectories are considered as part of the overall process of developing the conceptual framework.

Pavitt (1990) discusses the strategic management of technology and its relevance to keeping pace with innovative products and processes. He advocates that a firm's strategy will be determined by its size and its accumulated technological competencies. Markides (1999) adds to this by way of considering new opportunities generated by a firm's own competencies, by making the most of expanding current or new niches. This can be achieved by considering new entrants and unconventional sources of competition. As discussed earlier, by considering "who-what-how" the firm can remain strategically flexible and keep up with changing conditions. Cassiman & Veugelers (2006) consider complementarity in innovation strategy and highlight the importance placed upon innovation performance

and the links between internal and external innovation activities. So to achieve positive results there is a need to integrate internal and external knowledge. This appears to be strongly linked to path-dependency, competencies and how firms learn.

Whilst all of the theories considering innovation strategy discussed in the literature review are relevant those considered above may have the most significance to this management project. It would seem that that presented by Cassiman & Veugelers could be more relevant due to its approach and links to the research question. But it would seem that, as with all strategies, an open mind and flexibility is required to change strategies be it due to external or internal forces. So for the purpose of this project the term innovation strategy will remain open-ended and will be discussed in detail as and when necessary. Linked with the conceptual framework it may prove more beneficial to keeping an open mind when considering the options that the framework might suggest.

Path-dependency and technological trajectories

Tidd et al (2005) explain competence as what a specific firm is capable of learning and exploiting, and say that any learning process is normally incremental and therefore a firm's learning process is path-dependent. Most accumulated competencies are strongly related to existing product bases and the costs associated with moving from one path of learning to another can be

prohibitive. Firms are also unable to change path through hiring someone with required competencies, as a firm's existing competencies are rarely those of an individual. From path-dependency comes technological trajectories, and whereas competencies limit a firm, technology can be constrained by knowledge limits. Sartorius (2006) agrees that due to path-dependency the shift from one technological trajectory to another can be restricted by barriers that have to be overcome. Not only is this unlikely but it also has a high degree of risk and uncertainty.

Five major technological trajectories

	Supplier Dominated	Scale Intensive	Science Based	Information Sensitive	Specialised Supplier
Typical core products	<ul style="list-style-type: none"> •Agriculture •Services •Traditional manufacturing 	<ul style="list-style-type: none"> •Bulk materials •Consumer durables •Automobiles •Civil engineering 	<ul style="list-style-type: none"> •Electronics •Chemicals 	<ul style="list-style-type: none"> •Finance •Retailing •Publishing •Travel 	<ul style="list-style-type: none"> •Machinery •Instruments •Software
Main source of technology	<ul style="list-style-type: none"> •Suppliers •Production learning 	<ul style="list-style-type: none"> •Production engineering •Production learning •Suppliers •Design offices 	<ul style="list-style-type: none"> •R&D •Basic research 	<ul style="list-style-type: none"> •Software and systems departments •Supplies 	<ul style="list-style-type: none"> •Design •Advanced users
Main tasks of innovation strategy					
1. Positions	Based on non-technological advantages	Cost effective and safe complex products and processes	Develop technically related products	New products and services	Monitor and respond to user needs
2. Paths	Use of IT in finance and distribution	Incremental integration of new knowledge	Exploit basic science	Design and operation of complex information processing systems	Matching changing technologies to users' needs
3. Processes	Flexible response to user	Diffusion of best practice in design, production and distribution	Obtain complementary assets. Redefine divisional boundaries	To match IT based opportunities with user needs	Strong links with lead users

Table 1: Five major technological trajectories.
Source: Tidd et al 2005, p172.

Categories of innovating small firms

	Superstars: small firms into big since 1950	New technology-based firms (NTBFs)	Specialised suppliers	Supplier dominated
Examples	Polaroid, DEC, TI, Xerox, Intel, Microsoft, Compaq, Sony, Casio, Benetton	Start-ups in electronics, biotechnology and software	Producer goods (machines, components, instruments, software)	Traditional products (e.g. textiles, wood products, food products) and many services
Sources of competitive advantage	Successful exploitation of major invention or technological trajectory	<ol style="list-style-type: none"> 1. Product or process development in fast moving and specialised area 2. Privatising academic research 	Combining technologies to meet users' needs	Integration and adaptation of innovations by suppliers
Main tasks of innovation strategy	Preparing replacements for the original invention (or inventor)	<ol style="list-style-type: none"> 1. 'Superstar' or 'specialised supplier'? 2. Knowledge or money 	Links to advanced users and pervasive technologies	Exploiting new IT based opportunities in design, distribution and co-ordination

Table 2: Categories of innovating small firms.
Source: Tidd et al 2005, p197.

The concepts and definitions of path-dependency above are relevant for the purpose of this project and will be discussed as necessary. The current technological trajectories of the firm are apparent and future potential trajectories and changes in path-dependency could be possible. However it is the purpose of this project to consider these through due process.

Conceptual frameworks

In an attempt to bring the concepts together and to identify their relationship with one another a conceptual framework has been developed. The first part of this chapter will have hopefully clarified and defined the main concepts of the research question and now an attempt will be made to identify any interconnections of those concepts. "Developing conceptual frameworks is not a matter of thinking up completely new things, rather it is done by building upon the knowledge you have acquired from doing a literature review" (Fisher 2007, p125).

A suitable framework has been identified from the literature review and a minor amendment has been made so that it relates not only to the research question but also the relationships between the identified concepts. The proposed framework is based on the framework for selecting strategic alliances by Vyas et al (1995, p 52).

To achieve the best possible understanding of the proposed conceptual framework and how it relates to the research question and the concepts discussed above, each level of the framework shall be discussed in some detail below. The framework has been chosen as it is the most appropriate framework for what is required.

Based on what is already known about SJG and their intentions it is evident that the firms main strategic intentions are alliance related. The formation or entry to any alliance would be classed as a change in strategic direction and therefore any change in the firm's path-dependency or technological trajectory could be directly linked to the outcome of any alliance. This framework is therefore being used to identify potential outcomes of any alliance and how those outcomes might be linked to the concepts of the research question. It will also consider the '4Ps' of innovation and the type of change represented by the '4Ps' and their relationship between what any potential alliance might achieve as a result.

Beginning at the top of the frame work:

Level 1: This represents the organisation Sri Jentayu Global (SJG) and from what we already know about the firm they are considering strategic changes in the form of strategic alliances. In the original framework this was identified by the specific industry that the firm was in. It has been changed to represent the firm so that it is easier to understand.

Level 2: Either side of the framework represents different firms within different industries or sectors with whom SJG could potentially enter into strategic alliances. Whether those firms are in related or unrelated industries at this point is irrelevant. The most important thing to understand here is that this stage allows the firm to group potential partners into specific industries or sectors before considering any potential benefits.

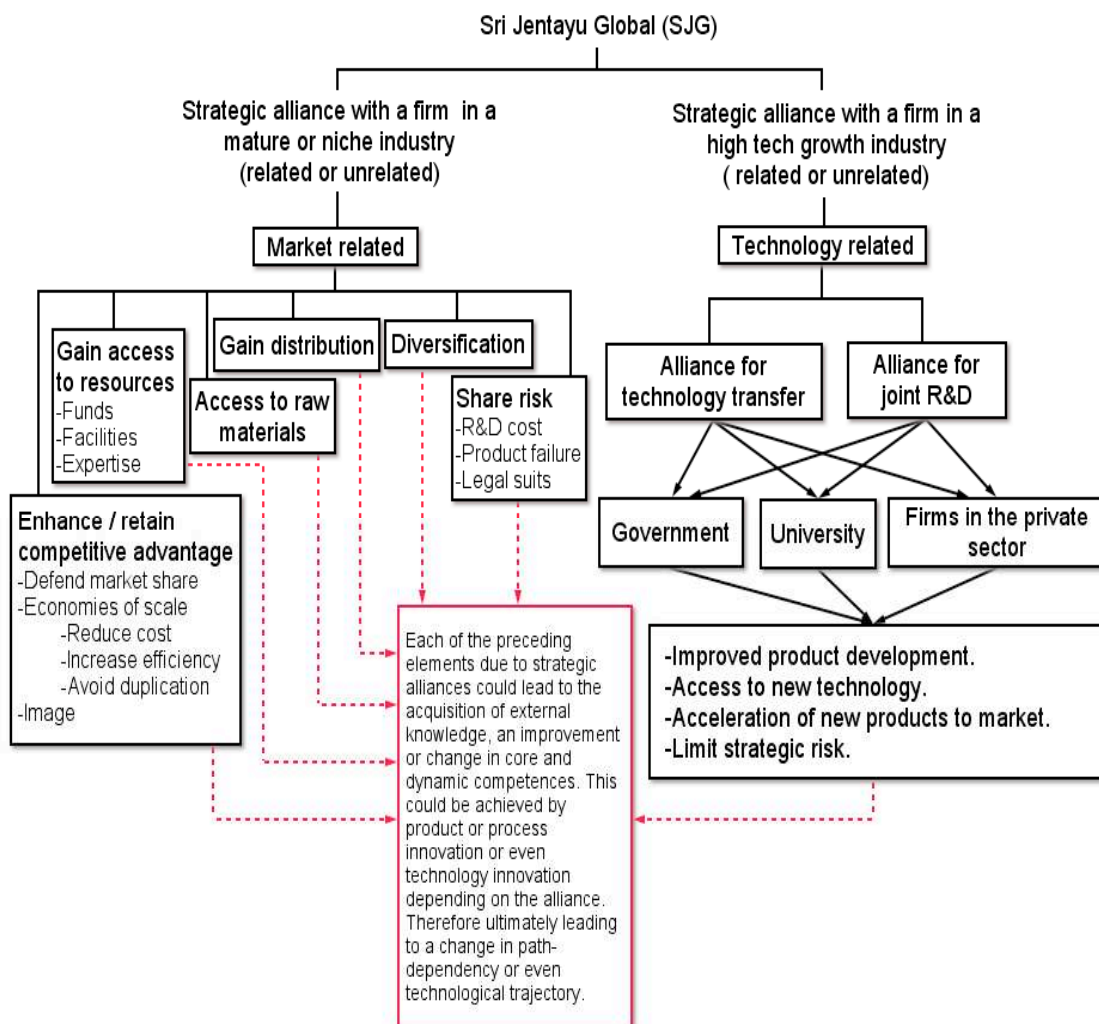


Figure 1: Conceptual framework - based on the Framework for selecting strategic alliances. Source: Vyas et al 1995, p52.

Level 3: Either side of the framework identifies two distinct relationships that have potential links between the firm and those of the firms being considered for alliances. This will help the firm identify a possible role that they will be responsible for in any potential partnering and identify the potential contributions from potential partners. Depending whether the firm that is being considered for some form of strategic alliance is market related and technology related will help the firm further identify their role in the process.

Level 4: The left hand side of the framework identifies the potential advantages that a strategic alliance with a firm that is market related could bring to SJG. The firm they are collaborating with and the benefits the alliance offers will depend on those potential advantages. This links into the '4Ps' of innovation discussed in the literature review and so the changes associated with the '4Ps' and any other considerations will be briefly explored here to demonstrate the conceptual framework.

Share Risk: This could relate to a change in product or position innovation and not only provide protection to the firm but also enhance competencies, acquisition of external knowledge and the sharing of ideas.

Diversification: An alliance leading to diversification could lead to changes in product innovation, paradigm innovation and change or enhance the firm's competencies and increase technological knowledge.

Gain distribution: Position innovation will most likely be affected by any

alliance which is being entered into for this purpose, however increased distribution may just be a by-product of another alliance.

Access to raw materials: An alliance, which leads to more raw materials may lead to a change in process or position innovation due to an ability to ramp up production increasing scale or even scope.

Gain access to resources: This could be related to changes at all levels of the '4Ps' of innovation depending on the resources.

Enhance / retain competitive advantage: It could be argued that any form of alliance may achieve this as any firm would want to achieve this.

On the right hand side of the framework, the reasons for collaborating with technology related firms are considered. Where an alliance for joint R&D is self-explanatory, an alliance for technology transfer occurs when one organisation develops new ideas or technologies that are used or applied by another organisation this can also be linked to the '4Ps' of innovation and identify potential changes the firm is likely to encounter.

Level 5: On the right hand side of the framework identifies the type of organisations that could be involved in technology related alliances. This could be an important factor when considering the benefits of strategic alliances. Each of the different types of organisation has the potential to offer a great number of opportunities that may not be accessible by SJG alone. Some of those opportunities from each sector to be considered could be:

Government: Access to grants, funding, preferential trade laws.

University: Access to laboratories, exchange of ideas and knowledge,
access to spin outs and start ups.

Firms in the private sector: Access to R&D, increased scale and scope of
manufacturing, shared risk, access to markets.

Level 6: The right hand side of the framework considers some of the
potential outcomes from those potential alliances.

The final level of the framework, which has been added to the original
framework, considers the concept of path-dependency and technological
trajectories and how these may be achieved. Each of the preceding elements,
due to strategic alliances, could lead to the acquisition of external knowledge,
an improvement or change in core and dynamic competencies through
product or process innovation or even technology innovation depending on
the alliance. Therefore ultimately leading to a change in path-dependency or
even technological trajectory.

This framework is of course a conceptual framework and can only be used to
support the research element of this project and possibly lead to the
development of an existing or new theory.

Theories

In this final section theories are considered and their role in the management project. As suggested by Fisher (2007) where the conceptual framework generalised about any interactions of the concepts, theories propose hypotheses of the potential outcomes of those processes. Theories attempt to draw wide-ranging findings from detailed instances and are therefore inductive in their nature. Theorising does not necessarily mean inventing a new theory it could just possibly mean adapting and developing existing theories. Therefore, this project will attempt in general terms to consider how any identified phenomena relate to each other or how particular events or actions lead to other actions. As in the previous two sections of this chapter the theories identified are based on the literature review as the research has yet to be carried out and will as a consequence remain a hypothesis or sequence of hypotheses.

When considering the most appropriate theory, which relates to the research question: *What effect will a change in strategic direction have on the technological trajectory of a supplier dominated firm and can that change be driven by path-dependency or strategic goals alone?* It would seem that the theory suggested by Tidd et al is more than likely the most suitable:

Firms' strategies are strongly constrained by their current position and by the specific opportunities open to them in future: in other words, they are path-dependant. At any point in time, two sets of constraints make path-dependency in corporate innovation strategy inevitable: those of the present and likely future state of

technological knowledge, and those of the limits of corporate competence (Tidd et al 2005, p169).

Put simply path-dependency is linked to technological knowledge and the limits of corporate competence; this in turn constrains a firm's strategy. Tidd et al (2005) propose innovation as essentially being a form of change and support that theory in the form of the '4Ps' of innovation as discussed previously in the literature review.

- '*Product innovation*' – changes in the things (products/services), which an organisation offers;
- '*Process innovation*' – changes in the ways in which they are created and delivered;
- '*Position innovation*' – changes in the context in which the products/services are introduced;
- '*Paradigm innovation*' – changes in the underlying mental models which frame what the organisation does. (Tidd et al. 2005, p10)

It is hoped that the research will identify a link or relationship between the chosen theory, the '4Ps' of innovation and the research question.

Where the conceptual framework considers the potential advantages of market related or technology related alliances it is hoped that the theory may go some way in identifying whether or not those advantages will result in the change of path or technological trajectories due to strategic choices.

Research Methods

The purpose of this chapter in the project is to identify the most appropriate research method and approach to be adopted in answering the research question. It would make sense to revisit the research question once again to ensure that the most suitable methodological stance for answering the question is taken:

What effect will a change in strategic management have on the technological trajectory of a supplier dominated firm and can that change be driven by path-dependency or strategic goals alone?

The research question as previously discussed has been developed in an attempt to understand the considerations that a real-time organisation should think about in the management of any strategic change involving the management of its innovation and technology whilst considering entering into strategic alliances.

A great deal of understanding and knowledge supporting the theories relevant to the research question were learnt whilst undertaking the literature review. However that knowledge is already available to us and it is the intention of this project to attempt to expand on that knowledge. There is a need to collect and analyse information in the form of primary research in an effort to achieve that. The research question relates to an existing

organisation that operates in an environment of continual change which can evolve over periods from several months to as little as a few days.

A much more objective empirically detailed understanding of the organisation, how and why they are doing particular things in particular ways, and their future plans is required as part of the research question. An in depth understanding of where they stand in relation to the current literature and existing theories concerning the research question is also required. The only possible way of achieving that is by being involved within the firm through authorised access, which would allow the most suitable choice of research methods to be considered.

According to Fisher (2007) management and business research has an academic and practical element, which makes it somewhat different to many other subjects. Research should academically contribute to a greater understanding of management and practically aid managers in their daily roles. It is therefore important that due to the nature and practicality of the management project that the method and approach can contribute not only to academic knowledge but is also of some use to the organisation's management on which the project is based.

Research approach

Interpretivism has been chosen as the most appropriate approach to the research for this project. According to Fisher (2007) interpretivism is also referred to as phenomenology in many other texts but for the purpose of this project it will only be referred to as interpretivism. Interpretivism can be defined as: "seeking knowledge of the processes by which people in groups and societies make sense of their real worlds. The real world has to be seen through human thought and not seen as separate from it" (Fisher 2007, p 15).

As stated above due to the practical element of this project an academic understanding of the research results alone would be insufficient. Therefore an interpretive approach may yield better results, as Fisher (2007) believes that the interpretive approach allows an indirect link between understanding and action to be established by researchers. The most appropriate actions cannot be achieved by understanding and knowledge alone, any links between understanding and action are achieved through the relationships, values and thinking between people. Knowledge alone cannot offer obvious choices for action but understanding a situation might allow a better choice of action through the use of judgement.

Fisher (2007) goes on to explain that the interpretations of interpretive research are developed through debate and conversations with oneself or

with others in an attempt to establish the scope and complexity of the views taken on the subject of the research. It attempts to identify how meaning is developed through human interaction and how sense is made of the world, structures and processes within it. The interpretative approach considers the individual details of situations and the reality of those situations. It also considers the different accounts people give of problems and issues and people's explanation of the means by which they make sense of the world. This adds weight in support of the interpretative approach and why it may be the most appropriate for the management project. The interpretative approach advocates interaction with people to gain a greater understanding through dialogue so will be the most suitable approach for the chosen research method.

Research method

This element of the project is one of discovery where through primary research things will be found out by means other than literature, which has already been considered. It is important to choose the most appropriate method of gathering any research material relevant to the research question. Fisher (2007) proposes that there are two kinds of discoverer: explorers and surveyors and due to the nature and personal choice of the project, explorer would seem to be the most appropriate choice here. Therefore the research method chosen is going to be an exploratory research method based upon exploration in the form of a single-case study.

The case study is but one of several ways of doing social science research. Others include experiments, surveys, histories and the analysis of archival information. Each strategy has peculiar advantages and disadvantages, depending on three conditions: (a) the type of research question, (b) the control an investigator has over actual behavioural events, and (c) the focus on contemporary as apposed to historical phenomena (Yin 2003, p1).

Based upon that above it would seem that a case study would be an appropriate strategy to adopt as according to the three conditions described by Yin (2003) the research question is certainly asking in one form or another "how" and "why"? Control over behavioural events is not achievable by the investigator and the research does focus on contemporary events.

There are nonetheless circumstances when a specific strategy has a clear benefit and for the case study this is when: "A "how" or "why" question is being asked about a contemporary set of events, over which the investigator has little or no control" (Yin 2003, p9). This supports the choice for using the case study as a suitable method of research for this particular management project.

In further support for the use of the case study as a suitable method of research Eisenhardt & Graebner (2007) state that the reputation of case studies for the building of theory and research strategies has lead to a large quantity of significant studies. Additionally, according to Yin (2003) case studies allow investigators to preserve the holistic and significant traits of real life events such as organisational and managerial processes. However

one should be aware that, according to Yin (2003), case studies have usually been considered “soft” and this might be due to researchers not following logical procedures and Burns (1989) suggests a lack of well accepted designs, methods and criteria for the evaluation of field studies may be to blame.

As mentioned above the choice of gathering primary research material is of the utmost importance and that is of course dependant upon the technique used to collect that information or the source of evidence as referred to by Yin (2003). He identifies six sources of evidence that could be used for case studies and they are: documents, archival records, interviews, direct observation, participant-observation and physical artefacts. For the purpose of this project interviews have been chosen as the most appropriate method of collecting evidence or data. Whilst it is appreciated that the six sources of evidence are complementary and no one method has any added advantage over another only the one method will be used for this project. Fisher (2007) supports this choice by identifying interviews as being the most common method of research at this level of study.

For the purpose of this project the interview questions were conducted in a semi-structured manner. According to Fisher (2007), if the kind of answers from respondents or sources was not known or if new ideas were being sought then the open or semi-structured approach should be used. The semi-structured approach allows the respondent as much scope as required in

answering the questions whilst allowing the interviewer a list of questions to ensure that the main topics and issues are covered. Additionally the questions could be forwarded to the interviewees prior to the scheduled interviews. This was important for two reasons. Firstly, some of the interviewees had tight work commitment schedules and were able to save time by considering their responses in advance. Secondly, it would allow the interviewees the opportunity to clarify any definitions of terminology beforehand. This is covered in more detail later in this chapter.

According to Eisenhardt & Graebner (2007) when any phenomenon is rare or highly irregular interviews may prove to be a highly resourceful means of collecting rich, empirical data. Interviews should not be underestimated in the potential outcome of the primary research phase of the management project, as a great deal of organising and planning can lead to very successful results.

One potential risk of interviews according to Eisenhardt & Graebner (2007) is that they can provoke "knee-jerk" reactions and that any data collected has the risk of bias and being presented as "retrospective sense-making by image-conscious informants". So in an attempt to reduce any bias a combination of real time and retrospective cases should be considered in the collection of data. One thing to bear in mind however when allowing for real time cases is that the data may prove more accurate if those events occurred recently. This appears to be most appropriate for the research being carried

out as the firm in question is operating in real time and the area of research is currently experiencing change. This is as one would expect and is one of the reasons for the research.

The interviewees for the gathering of information and data were all predetermined and selected by the managing director as the most appropriate. Due to the size of the organisation, there are only five members of staff who are at director level, and could be interviewed as being in some way involved in what the organisation is currently doing at a strategic level. This should in no way predetermine any potential value or outcome of such a small number of sources of evidence. Each member of staff is responsible for a different element of the organisation so should have a different opinion and understanding of the research from each other. This was another reason for the decision to use the semi-structured approach for the interviews and to distribute the questions prior to the interviews. There is no one individual responsible for the actual management of innovation however each member of the team is aware of what the company is currently doing, how it has evolved since its inception and what its future plans and aspirations are.

An attempt to prevent the necessity for any follow up interviews due to time constraints and scheduling difficulties was another reason for adopting the semi-structured approach. It not only allowed predetermined semi-structured questions to be considered it also aided in the preparation and planning of the information collection process. As suggested by Burns (1989) prior

knowledge of what will be discussed allows people to prepare for the interview and answer questions more fully during the actual interview. Data collection can be enhanced when the nature of information required by the researcher is understood more clearly and this can be achieved in some cases by sending the proposed interview questions out in advance. One area of unlikely concern that one should however be mindful of is the risk of any form of collaboration between the interviewees once the questions have been sent out and prior to the interviews. The likelihood of this actually happening is of course slim. However, any form of corroboration may, according to Yin (2003), be detected if different interviewees seem to be echoing the same thoughts. This is a minor concern that has to be considered whilst conducting the interviews but it is believed that this will not happen.

An important element of being able to undertake the research project is access to the organisation upon which the project is based. The initial intention was to spend three months working at the firm whilst researching and writing the management project as part of an internship. The reason for this was to achieve as great an insight into the company as possible and to build on what was already known.

After spending three months working for the firm prior to beginning the MBA programme it seemed that the firm would be an ideal subject for some form of research and management project. The firm was continually evolving and changing in what appeared to be a niche sector.

The managing director and part owner of the firm was keen for some form of research to be undertaken that would be of use to the firm, which could hopefully be used to contribute to decision making processes.

The decision not to partake in an internship was taken for two reasons. Firstly it was believed that due to the size and makeup of the firm and the way in which the firm operates little would have been achieved from an observational, ethnographic point of view. Secondly, it was believed that the research and any results may not have had the expected value from the point of view of the firm and so the decision was made not to encroach on the organisation unnecessarily. This is in no way a reflection of how the organisation operates but a personal choice that was discussed at length with and agreed upon by the managing director.

That decision therefore resulted in the choice of research method and approach, which has been described above and will be used for the purpose of this management project.

The only consideration from an ethical perspective is the commercial confidentiality of the information made available that contained in this management project and a request that the managing director was able to review the proposed interview questions prior to the interviews being conducted.

Presentation and Analysis of Findings

This chapter of the management project proposes to interpret the research findings. This will be done by revisiting the Literature Review and conceptual framework to evaluate the research results, with the ultimate goal being the testing of the theory proposed in the Concepts, Conceptual Framework and Theory chapter and its relationship with the research question.

An important element of this chapter is, according to Fisher (2007), the explanation of the interpretive grid used to help in understanding the research material. However, another important element of deciphering the research material is coding and this allows the extraction of any usable material from all of the material collected. Fisher goes on to explain that this process involves identifying themes, dividing the research material into units and allocating those units to the themes. This will be achieved more readily through the processes adopted during the early stages of the project of dividing the literature review and the semi-structured interview questions into themes related to the research question and other associated topics. However, as the project presented is in the form of a case study Fisher (2007) explains that there is no universally acknowledged way of analysing a case study and this ambiguity is unfortunately a characteristic associated with qualitative research. As discussed, the conceptual framework and proposed theory have been used as a guide for the collection of the research material and evidence and will provide the scaffolding for writing up the case

study. The subheadings for this chapter will be drawn from any identified relationships between the concepts and conceptual framework in the account of the case study.

Fisher (2007) acknowledges that there is no right or wrong interpretive grid for analysis of the research material, as it is possible to make different interpretations of some research material but this does not mean that all interpretations are true. Some interpretations may just be incorrect or impractical. The interpretive grid adopted for this project is that of the realist, which will allow concepts also known as universals, to be considered objectively in a real world sense. However, the fact that knowledge may not be a perfectly accurate depiction of reality needs some consideration. Therefore, from a realist perspective, Innovation Strategy, Alliances and Networks, Path-dependency, Technological Trajectories and the '4Ps' of Innovation when considered collectively could sensibly be called Innovation Management. Innovation Management is real and is something that links all of the above. For that reason, the realist approach allows us to write about the subject of innovation management without any ambiguity and assert that changes in path-dependency and technological trajectories could somehow be linked. The realist approach also allows the organisation in question to be studied and allows consideration of whether what it does and how it approaches innovation is a good or a bad thing, certainly in relation to the research question. The most important consideration is that the research material collected is based upon individual's perceptions, opinions, views,

and not necessarily factual tangible objects, and care has to be taken not to claim that the research might be more than it actually is. As discussed, a number of sub headed themes will be used to analyse the research material and evidence that has been collected through the semi-structured interviews.

Innovation management

The management of SJG collectively agree that innovation is a continual ongoing process not only at individual but also at departmental and organisational levels, where contributions can be made by anybody at any level of seniority throughout the organisation. One of the managers who is deeply involved with innovation at product level went some way to corroborate Tidd et al (2005) and their belief that innovation is often confused with invention as invention is only the beginning of a long process. The manager commented that he believed the innovation process was not invention alone but an evolutionary ongoing process. When asked about developing the core product the senior managers all agreed that even without the proposed joint venture with CamelBak the firm would have continued to develop its core product independently and would have continued scanning the horizon for alternative potential alliances that would benefit the firm in a variety of ways.

There is a strong agreement between the senior managers that as an organisation they are extremely innovative. Considering the product alone,

they believe that their strength is definitely in process innovation and they are certainly capable of competing against the strongest and biggest competitors. This is only relevant when considering process innovation at the time of the research being conducted. The firm, as witnessed by myself and corroborated by the management, is extraordinarily flexible from a productivity point of view and is capable of producing high quality standard or custom body armour at short notice with remarkable lead times. This has been demonstrated in the past by the number of third party orders that the firm has received from much larger body armour manufacturers in the United States (US) and European Union (EU). An additional consideration is that the management are aware of the issue of limited resources that currently restricts innovation and R&D at product level and this will be discussed in more detail when considering alliances and networks. When taking into consideration product innovation it has been identified that there is certainly a potential for exploring technology innovation with regard to the make up of the product and the processes of improving the core product. This however as already mentioned is currently restricted to minor improvements and limited R&D due to limited resources, the firm's background and limited scientific knowledge. The encapsulation process that the firm uses in the manufacturing of body armour is being continually developed internally, not only to improve the efficacy of the product itself but also to reduce costs. There tend to be small differences in the process of encapsulation across the industry. The issue for SJG is reliance on the suppliers of the ceramic plates of the hard armour systems, which the body armour manufacturers

encapsulate in the production process, to make up one part the bullet proof jackets. The advancement of the technology in the ceramic plates to make them lighter and cheaper, or even to use an alternative to ceramic plates, is ultimately the domain of large manufacturers and developers of composite materials. Also relevant is the advancement of another core constituent of the product: the Aramid, better known as Kevlar, is what actually stops the shrapnel and bullets from causing 'blunt trauma' and ultimately maiming or killing individuals. Again, any development or replacement of this fabric is reliant upon specialist material manufacturers such as DuPont.

When considering the adoption of ideas external to the organisation there was a strong belief that from an innovation point of view that adopting external ideas was encouraged. This correlates with Cassiman & Veuglers (2006) and illustrates that the firm does not suffer from the 'not invented here' syndrome. There were however some concerns raised about the level of secrecy within the industry and a reluctance to share ideas due the constant risk of any newly advanced products being easily reverse engineered. The adoption of ideas external to the firm lead to the concept of external knowledge acquisition. The general opinion of the management was that external knowledge could only lead to better things. When considering the acquisition of external knowledge, according to Atuahene-Gima & Patterson (1993), strategic considerations such as competitive advantage, market expansion and extending product portfolio are equally as important. The management are acutely aware of this and it will be considered later when

exploring strategic alliances. The sources of external knowledge have been identified as customers, suppliers and competitors. To consider these sources of knowledge individually:

- knowledge from customers is achieved by: developing the core product or developing hybrid or new products for their needs. Working closely with customers in the development of products and meeting their expectations in the delivery and future business needs leads to innovation throughout the firm from the initial contact throughout the life of the relationship.
- Suppliers are seen as an integral part of the product and this will be considered when alliances and networks are discussed.
- Contrary to the discussion relating to secrecy and reverse engineering amongst competitors there is still a great deal of knowledge shared between body armour manufacturers.

The interviews then turned to a discussion of the ongoing alliance from an innovation point of view with HitCo Inc, the US based composites firm that is working with SJG in the development of a light weight, less expensive ceramic plate for a hard armour solution. Some of the management felt that considering the advancement of the technology quite so specifically was an industry specific question that they were unable to answer with much conviction and this might have been due to their role within the firm and field

of speciality and should in no way be considered a lack of product or organisational knowledge. They also felt that the development of the technology related to the hard armour solutions was a strategic level concern and they were unable to comment on other potential considerations in the development of the technology. However some of the management team did identify that the technology can be divided into two broad areas and the adoption of new technologies and advancement of the existing technologies would either come from composite material manufacturers other than HitCo Inc such as current ceramic plate suppliers CoorsTek or the Aramid would follow a similar path. As previously discussed Vyas et al (1995) consider the benefits of intra or inter-industry alliances to produce technology fusion. Considering the ceramic plates and Aramid both are examples of inter-industry alliances and would be deemed technology related in consideration of the conceptual framework. However, the consensus is that it is not possible to identify exactly where the next advancement in the technology might come from. That said considering how the firm approaches innovation, constantly seeking more innovative methods of developing core products and processes and the work it is doing with HitCo Inc fits in with what Man (2001) suggests that innovation should be, not "settling into" one successful strategy but continually seeking to challenge existing successful technologies. This could ultimately lead to improved performance, new designs and methods, adding value and possibly lowering costs.

The issue of SJG having the ability to improve the technology was explored from an innovative perspective and it was felt that the firm could not improve the technology alone due to a number of reasons. Resources in the form of capital and technological knowledge was one reason but more important is the use of technology for the development of raw materials into the constituent materials of the core product. Innovation and innovating the product and processes are very different from developing the technology and the managers are acutely aware of this. An attempt to identify why the core technology has not advanced at a greater pace was considered next and again this lead to the fact that the technology is dependant upon what the suppliers are doing. There was an agreement certainly between the managers responsible for the production of the body armour and associated products that the constituents of the product had reached their limits and, to the best of their knowledge, could not be developed much further. A point was made that the failure of an alternative to the industry standard in recent years might have be a contributory factor for a reluctance to improve the current technology and to not introduce an alternative technology.

The important issue of being a supplier dominated firm was raised whilst discussing innovation management. The general agreement was that without any form of vertical integration the firm would always be supplier dominated as any advancement in the technology of the core constituents of the product were reliant upon being introduced by suppliers. This was supported by the fact that the management are aware that due to the size and available

resources the firm would always be constrained. The managers interviewed understood the concept of being a supplier dominated firm and this will be revisited when considering alliances and networks.

Alliances and networks

Alliances and networks are an important element of the research as early indications suggested that strategic alliances were high on the firm's list of strategic options. There is a strong correlation between strategic alliances and the conceptual framework, and how it might be able to link what the firm is doing, the research question and the theory of innovation management.

The initial area of exploration was that of process innovation and as discussed in the previous section a major competence of SJG. In the opinion of the management, process innovation and their approach to it means that they are one of the best in their industry. A couple of the managers agree that their potential to remain one of the best small firms when dealing with process innovation is due to their ability to manage change. However they are acutely aware that a lack of resources in the short-term may affect this ability, potentially affecting their core competencies and dynamic capabilities which in turn is linked to path-dependency. The fact that they acknowledge the management of change being an important element of process innovation supports the theory of this project and that of Tidd et al (2005),

that innovation is essentially change as presented in the '4Ps' of innovation. The most important point here is that the firm is confident of its abilities and aware of its limitations. One other concern that may be worth some thought is how aware of this the owners of the firm are and any potential effects that it has not only on the firm but its staff and the innovation process overall.

Regarding position innovation and any form of strategic alliance, the general opinion is that SJG could potentially enter into new markets alone but the sustainability of that casts some doubt in the managers' minds. One of the reasons suggested that might allow new market penetration was the network of contacts that one of the owners of the firm had established over the years. More important however were the barriers that would make entry to new markets all the more difficult. The fact that the product is manufactured in Asia might pose some difficulty due to recent problems experienced in other Asian manufacturing countries. Contributing to this is the potential lack of brand recognition and any reputation of the quality of the product. This however is no reason for not attempting to enter new markets but is merely a factor to be considered. Another area that presents a barrier to entry according to one of the managers is that the market has a tendency to be technology or price driven and this can prove to be difficult to overcome, due to scale and scope issues that the firm is faced with. This supports what Radjo (2006) proposes, that due to the demand by customers for more choice and greater speed for technology enabled innovation, the traditional model of innovation where firms financed, invented and promoted their

innovations alone is no longer fit to meet this growing demand, and this identifies a possible need for considering strategic alliances. One of the managers did comment that the establishment of a driven sales team may allow the firm entry to new markets. This however was currently not possible due to a lack of resources and this may identify another reason for developing strategic alliances.

Leading on from position innovation the next consideration is the effect that strategic alliances might have on SJG. An overwhelming agreement by all of the managers interviewed supported that any form of strategic alliance would potentially lead to an increase in market share and an increase in sales. Additional to this and as previously discussed Tidd & Izumimoto (2002) believe that the collaboration of firms occurs for numerous reasons such as the reduction of cost and the risk of technological or market development, which can lead to much faster times to market, and the development of economies of scale. One of the managers suggested that there were two potentials to be considered; firstly, the CamelBak joint venture could introduce more refined marketing skills and a learning process for SJG. Secondly, an alliance with Mehler Vario System, a German body armour manufacturer, would lead to a potential for joint R&D between the two firms. This correlates with the view by Coombs & Hull (1998), that strategic alliances have distinct objectives, such as product development or to enter new markets. However an important consideration as proposed by Bruce et al (1995) is that whilst many firms form alliances to reduce time, cost or risk

of R&D they were not wholly aware of the benefits of the relationship, a fact that SJG should be aware of when considering entering into strategic alliances.

In the context of the conceptual framework the CamelBak joint venture would be market related and could be linked to diversification of the product, a gain in distribution, or even shared risk. An alliance with Mehler Vario System on the other hand would be technology related and would be an alliance for joint R&D. The ultimate goal of any alliance and the desired gain would of course depend on the main reason for the alliance and it is hoped that the conceptual framework would go some way in identifying this and also help in reducing any risk in selecting alliances.

As the CamelBak joint venture is the current hot topic within the firm and most prominent strategic alliance being developed, it is worth gaining a better understanding of how significant this joint venture really is. It is the opinion of all of the managers interviewed that the firm would survive without the joint venture by simply seeking out other potential strategic alliances. It was suggested that SJG's ability to internally innovate was one potential; however, the sustainability of this was questionable primarily because the product is such a niche product. Considering the potential success of the joint venture lead to an overall agreement that market share would be the main outcome of a successful alliance in this instance. This achievement would be due to CamelBak's global presence and network of

distributors, and its brand possessing global recognition. Optimistically, this would lead to the SJG and JMAS brand not only becoming established and recognised but synonymous with quality manufacturing and that quality being associated with Asian manufacturing. Tidd & Izumimoto (2002) state that strategic alliances, joint ventures and innovation networks provide a superior prospect for learning, but go on to say that little research has been carried out on how firms manage learning from international joint ventures, an important element of any alliance.

When considering strategic alliances generally and their significance to SJG, a resounding agreement in favour of some form of strategic alliance was noted. Interestingly one of the managers believes that the firm is continually involved in some form of strategic alliance throughout the supply chain up and down stream through casual and more long-term relationships without which the firm could not exist. Another manager identified that due to the volatility of the body armour market, being an armour manufacturer alone could potentially lead to instability of some form or another. He identified that the majority of the world's larger body armour manufacturers have parent companies that are either materials specialists or composite specialists that can support their subsidiaries during lean times. In some cases, the market share of some armour manufacturers or their size alone allows their survival.

The next area of consideration could possibly be one of the most important elements of the whole research project, which is whether any form of alliance will add to any technological knowledge that SJG currently has. The belief of some of the managers is that SJG does not have any technological knowledge, although they do have a strong product and process knowledge. This considered with the theory presented by Tidd et al (2005) and the theory chosen for this management project may then prove to be contradictory:

Firms' strategies are strongly constrained by their current position and by the specific opportunities open to them in future: in other words, they are path-dependant. At any point in time, two sets of constraints make path-dependency in corporate innovation strategy inevitable: those of the present and likely future state of technological knowledge, and those of the limits of corporate competence (Tidd et al 2005, p169).

On the other hand, the opinion of some of the management that SJG does not have any technological knowledge might be very wrong and way off the mark. The question of technological knowledge seems to have divided some of the managers and their understanding of technological knowledge. Some of the managers that know a great deal more about the industry believe that technological knowledge is more than just the raw materials or core constituents of the core products provided by suppliers. It is more about understanding how to utilise those components in developing and manufacturing an extremely effective reliable product and having the knowledge and the technical ability to achieve that. This links the current state of the firm's technological knowledge and the limits of their corporate

competencies as previously considered by Tidd et al (2005) as they explain competence as what a specific firm is capable of learning and exploiting. They say that any learning process is normally incremental, therefore a firms' learning process is path-dependent and most accumulated competencies are strongly related to existing product bases. From path-dependency comes technological trajectories, whereas competencies limit a firm, technology can be constrained by knowledge limits.

Additional to this and another important element of the research question is the issue of corporate competence but more specifically the effect that a strategic alliance will have on those competencies. The opinion of all of the managers interviewed was that any form of strategic alliance would go some way in contributing to the firm's competencies. One suggestion was that a better understanding from a technological point of view from an alliance with suppliers might be achieved and this is linked to external knowledge acquisition. One manager commented that there is the potential for the firm to become more disciplined through learning from others, leading to the enrichment of the management's capabilities. Another manager believes that strategic alliances in one form or another will allow access to people and knowledge, the pooling of resources and access to networks of distributors, potentially leading to more business in more territories.

Technical advancements aside, product innovation is considered just as important. The proposed CamelBak alliance demonstrates a fusion of both

firms' products to create a single product. The opinion of the management was that this could only be positive for the firm. The areas with the most potential identified were growth in market share, entry to new markets, and improved brand recognition. However, the risk of this particular alliance failing had to be considered so the managers were asked whether they believed if SJG could continue to achieve some form of product innovation without any form of strategic alliance. All of the managers firmly believe that the firm would continue to develop the product with or without an alliance. They do agree that there is still the need to learn from ideas outside of the firm but are adamant that if you consider what the firm has achieved thus far there is no reason to doubt its ability to continue to innovate the product. Pavitt (1990) believes that the innovative opportunities open to a firm are strongly related to the firm's size and core business. He states that innovative small firms are generally specialised in their technological strategies where they concentrate on product innovation for specific products. Technological strategy aside, this seems to reflect what SJG does regarding their core product.

Production innovation apart the continued sustainability and survival of the firm in such an unpredictable industry on its own without any form of alliance is an area of interest. This issue was raised, as it was felt that as the firm appeared to be strongly attracted to a number of strategic alliances it was important to gauge whether the management believed that the firm could indeed survive without any form of alliance. The general consensus is that

the firm would survive, but for how long and in what sort of capacity is a question that the managers are acutely aware of. The issue of survivability as a sole body armour manufacturer with no diversification in products or as being part of a much larger entity as raised by one of the managers previously was again suggested. This uncertainty highlights a truth in what Das & He (2006) say about the importance of strategic criticality, which identifies that the continued viability of a firm may have to rely on a partnership.

Innovation Strategy

When initially considering the strategy of the firm from a general perspective there was a need to identify if there were any links between innovation and strategy or if indeed the firm practiced innovation strategy. The general opinion of the management is that strategic decision making is the domain of one the owners of the firm. They are aware of a continually evolving strategy and identify that a lack of financial resources to fund particular projects may constrain the strategy. It would seem apparent that there is little in the way of sharing any of the strategic aspirations of the firm between the managers so that they are unaware of not only the long-term strategy but also short-term real time strategy.

The proposed joint venture with CamelBak aside, identifying what the management felt would have been the most appropriate strategic move to

consider was explored next. It is believed that the CamelBak joint venture is in reality a small element of what the firm does and is considered as an additional alternative strategy and whilst the joint venture is pursued, the firm continues to operate as normal. The management believe that the firm would continue as they are, to increase distribution and gain market share on a steady basis. There was one suggestion that the firm should consider a merger with or acquisition from a much larger composite or specialist materials company or even another body armour manufacturer. Considering strategy from an innovative perspective that is specific to the product one manager suggested that it was the firm's intention to develop the lightest most cost effective armour solution and get that to market as quickly as possible. This lead to the consideration of whether innovation and strategy were approached separately, in parallel or as one. The consensus is that innovation and strategy are considered separately; in this instance innovation throughout the firm is not specific to any particular activity or process be it product or process innovation. Whilst all of the managers do agree that the firm is extraordinarily innovative, there is a belief that innovation and strategy should be considered together when planning from a strategic perspective. Considering future innovation and the way in which the firm approaches and adopts innovation, it was thought that the most appropriate way ahead would be some form of strategic alliance.

The firm's competencies from a strategic point of view, according to the management, are made up of a combination of management skills, industry

specific knowledge, general experience and flexibility. This in turn has led to efficient operational skills in the manufacturing of high quality products, better, faster, more cost effectively and more reliably than anybody else in the world. The propensity to build networks and relationships that support their aims and to their advantage has also been identified as a competence. The final consideration of how innovative the firm is when dealing with change and specifically in the context of the '4Ps' of innovation, paradigm innovation, the managers are confident of their capabilities. They agree that the firm is more than capable of altering course and changing direction due to there being a limited number of decision makers. The flexible forward thinking attitude of the management and the fact that the firm is still small enough to achieve this is a major contributing factor. This could be associated with discontinuity as presented by Bessant et al (2005) and the fact that whilst firms operate in environments of stability most of the time; there are occasions when something happens to dislocate that stability. These are not every-day events that can disrupt the status quo, but can present new opportunities whilst challenging existing players. This leads to the need and ability to manage innovation under conditions of uncertainty and rapid evolution. Firms in these conditions therefore need to be flexible, agile, with an ability to learn fast and preconceive how things might evolve. SJG need to be aware that any discontinuities or innovation opportunities that arise can lead to significant path and technological shifts. Bessant et al then go on to say that the value lies not in the scale of novelty or dislocation

but the firms' ability to deal with situations that arise outside of its operating abilities; these appear to be areas of capability within SJG.

Therefore, what Sartorius (2006) says about the existence of path-dependency and lock-in restricting the switch from one technological trajectory to another being frequently blocked by considerable barriers may be true and that unfortunately technological change requires the transition from one paradigm to another. So not only is it less likely to occur but it will be associated with higher uncertainty and risk. That said, it appears that SJG are prepared for any form of change and are capable of dealing with the uncertainty that may accompany it. This begs the question of whether they are capable of changing trajectories through strategic decisions alone, through path-dependency, or through the two together.

Finally, an opinion of what strategy the firm should consider was asked of the managers and the general opinion was that growth through strategic alliances would hopefully lead to an increase in market share through better sales and distribution networks. An alternative to this or in conjunction; to, would be some form of vertical integration and diversification which would create sustainability for the firm.

Conclusions and Recommendations

The ultimate goal of this management project has been to identify whether a small, niche Malaysian based manufacturing firm's strategic choices would alter their current technological trajectory as a supplier dominated firm and whether any changes could be due to path-dependency or strategic goals alone.

The development of this management project has been a path of discovery and learning from its inception all the way through to this final chapter of objective reflection. It is intended that the learning is not one sided and indeed the organisation for whom this project is based upon will gain some value from the recommendations and subsequent management report. The ultimate gain of course is more than just an individual or organisational learning process but also a contribution to knowledge. As proposed by Tidd et al (2005) innovation is essentially change and the completion of developing new knowledge, and this has been achieved from an academic and innovative perspective. This chapter aims to consider any conclusions that might be drawn from the presentation and analysis of the research material and evidence, which was collected during the research stage of the management project. Conclusions and any suggested recommendations will be considered together to retain meaningful coherence through the chapter. Finally, the chapter will conclude with some recommendations or thoughts for

any further research relating to the management project or innovation management in general.

According to Tidd et al (2005), path-dependency considers where a firm has come from and the incremental learning process a firm is capable of exploiting; this is considered part of a firm's competencies. SJG's competencies as Tidd et al propose are indeed strongly related to their existing product base but one would argue that their competencies are not accumulated solely around their core product. When a firm is capable of finding new ways of doing something, according to Tidd et al this leads to competitive advantage, which can be maintained by that ability to do things differently. They also suggest that a firm that is limited by its competence or a technology by its knowledge can be applied equally. Therefore, the question of whether SJG's limited technological knowledge of the development of the core constituents of their core products should restrict them, needs to be considered. We know from the research that SJG are extremely capable of product and process innovation and are continually developing their core product to deliver a lighter, more cost effective solution, which contributes to their competencies. So technological knowledge aside, considering path-dependency and SJG's ability to exploit what they do, according to Tidd et al they should be capable of altering paths leading to a change in trajectories.

Considering SJG's approach to innovation, it would be safe to say that they practice incremental innovation, as we know that they deal closely and interact with customers in developing the product when an alternative to the standard product is required. We are also aware that they continually strive to improve upon the quality, speed and cost of the processes involved in manufacturing and developing their product and this overall process is closely monitored and is used as a process of learning. This may raise the question of why they do not practice any form of radical innovation to achieve greater advantage and inroads to new markets. It is proposed that this approach to innovation may prove difficult, due to the product being such a niche product and the manufacturers of body armour having such a specialised group of limited existing or potential customers.

Bessant et al (2005) suggest that successful innovation management is not about doing just one thing particularly well but more about the ability to manage an internal system of innovation with a number of dimensions. From what has been learnt from the research process SJG appear to approach innovation in a way that considers a number of issues that may lead to a competitive advantage. One reason for this could be due to the structure of the organisation, which reflects that of a simple start up. This is demonstrated in their ability to respond to issues in a timely manner, and they appear to have clarity of purpose albeit with some evidence of disorganisation or dysfunction in some areas as observed by one manager. There is certainly a great deal of energy and enthusiasm, this was sensed

when interviewing the managers, and there certainly appears to be some entrepreneurial flair. This is not just evident in one of the owners but some of the managers appear to have entrepreneurial flair or indeed some traits of corporate entrepreneurship. This however is only an observation and cannot be substantially supported in any way as the management project is not specifically considering entrepreneurship. Continuing the contemplation of the firm's organisational structure, there is certainly a degree of creativity at all levels but this was mostly evident at product innovation level.

Allowing for any weaknesses of the simple start up organisational structure, there is certainly a question of long-term stability and growth and this has been highlighted in previous chapters of the management project. The main areas of concern as highlighted by the management are sustainability through growth, entering new markets and resources for further development. The overdependence on key people is an area that needs serious consideration and quite possibly some form of contingency planning and risk assessment. Whilst it is well documented that individuals are not part of the core competencies and hiring an individual with particular skills will not lead to a core competence, consideration should be given to key personnel and any effect their sudden departure may have not only on the innovation of the firm but on the firm as a whole. Another area of consideration is that key personnel may inadvertently have some sort of effect on dynamic capabilities, those processes that have been developing over a long period of time but are linked to processes such as product

development, strategic decision making and possibly the current changes being experienced in the firm such as strategic alliances. It is important to consider that the current strategic alliances have been possible due to certain individuals' abilities. Another weakness to consider that would not normally be associated with the simple start up structure and as already mentioned is the apparent dysfunction, which could lead to poor communication and involvement of personnel across the organisations boundaries affecting core competencies. Considering this the senior management might make any strategic plans more widely and clearly known.

If we consider the five phases of innovation as suggested by Tidd et al (2005), they believe that each phase applies to every type of innovation. When used to reflect upon the approach taken by SJG for different areas of innovation this may lead to a better understanding of what they do or how they do it.

- *Scan and search for opportunities:* the core product aside, SJG and JMAS are acutely aware of the need for a lighter, more cost effective solution to the current body armour. They are continually developing and trialling new techniques in an attempt to reduce the weight and cost of the current solution available. They are aware of this need from closely observing the body armour industry and identifying any changes within the industry. They attend defence shows and seminars to identify what potential

customers are looking for and new products and materials being developed by suppliers and other body armour manufacturers. If they see any potential even if it is unrelated to body armour they will consider its use and in many cases attempt to develop it which may demonstrate where or how the firm identifies potential opportunities in developing their products. This is strongly linked to the firm's attitude of adopting ideas from outside of the firm and learning from external knowledge.

- *Strategically select from this set of triggers:* this is an area of weakness that has already been identified due to a lack of resources and it restricts some of the potential ideas from being developed. Some observers may feel that the approach taken may be crude as it is not necessarily strategic in any form but it seems to be effective and furthermore it appears that a lack of resources in the form of capital drive the innovation process even more so. A couple of examples to be considered are the development of a flexible armour solution, which is not readily available due to the cost of development and manufacturing. The firm believes that they are capable of developing this solution and are working with a number of suppliers one may never have considered. Whilst at a defence show one of the managers found a dense air-grade rubber material used in the aviation industry and he believed that there was some potential in the material. However due to the material being manufactured to aviation standards it is cost prohibitive. Not fazed by this he acquired some of the material, returned to Malaysia, and asked the scientists at the local

university that studies rubber, a commodity of Malaysia, to identify its make up. They did so and were then able to develop the same material at a fraction of the cost. The second material currently under trial is a group of ceramics used in the industrial sector mainly, in the manufacture of abrasive wheels. The make up of the ceramic appears to have similar properties to that of the ceramic currently used in hard armour plates. Whilst they continue to develop the core product in the true sense of innovation with limited resources, they are developing a product that would definitely lead to the development of a competitive advantage.

- *Resource the option:* SJG appear to be quite efficient in this area and this might be closely linked to their flexible approach to management and the knowledge within the firm. The example above identifies how they exploit their knowledge resources and this may be more effective again due to their limited financial resources. It definitely identifies their adoption of external ideas and more importantly knowledge and how they exploit it in an attempt to improve the technology. It may also go some way in demonstrating the responsibility the management take in developing the firm.
- *Implement the innovation:* the firm is currently working very closely with a particular customer in developing a lighter weight solution, which has taken some time to develop and is showing positive signs. If successful, it will certainly be a force to reckon with; however further development will

be required to enable them to present it to a wider market. Product aside, if we consider a new process within the firm such as the manufacturing software recently implemented, as with any organisational change it was fraught with difficulty. However, now that it is on line due to the tenacity of the managers responsible for its roll out and the positive attitude of the staff, this is a perfect example of managing innovation in the form of process innovation, no matter that it is unrelated to product innovation. It also reflects innovation as change in the form of the '4Ps' of innovation and is linked to the incremental learning of path-dependency and its benefit is certainly being exploited.

- *Reflect upon previous phases:* this final optional phase of reflection has been identified in a recent operational process improvement within the manufacturing plant. A pull system of manufacturing has been introduced which has not only streamlined the process but also prevents a backup of raw materials which is important when considering the curing process where backups sometimes lead to waste. This is another example of incremental learning and contributes to the firms competencies.

SJG may not knowingly or strategically follow the five phases of innovation as presented above. However, what they currently do and how they do it is reflected in the five-stage process and may prove to be a tool for future innovation process management. The firm should consider implementing the

five stage process when considering future innovations and it will certainly be recommended in the management report.

We know that a firm's processes identify what they do and how they do it, and regardless of how dysfunctional SJG may appear on the surface through casual observation and comments by the management it is apparent that those processes are not only well managed but continual improvement is always being sought. When considering paths which relate to the strategic alternatives accessible to the firm and the attractiveness of the opportunities ahead we know that SJG are continually looking for the best way to develop the core product and the potential any form of strategic alliance may hold. This allows a brief consideration of core rigidities and it is believed that there is very little risk of any of the firm's competencies becoming core rigidities. This is because of the constant change that it is currently managing. However, core rigidities should not be overlooked as the firm develops and becomes more established and settled over time.

An issue identified by Tidd et al (2005) that they call technological weakness could be related to SJG in the fact that they do not have the ability to fund long-term risky programmes. This then suggests that strategic alliances are an option that will benefit the firm in the long run. In support of SJG seeking strategic alliances Moss Kanter (2006) proposes that firms may miss or hold back innovation when any potential innovations require expertise from different industries or knowledge from different technologies. She goes on to

say that there is a risk of managers not only failing to understand but also feeling threatened by any new ideas. This certainly does not represent SJG and their unique approach to strategic alliances. The research shows that any form of strategic alliance is very well supported by all of the managers interviewed and they seem to share a common belief that strategic alliances are required to enter new markets or learn from ideas external to the firm, and are necessary for the firm's long-term sustainability. One area of consideration that SJG are no doubt aware of and according to Tidd & Izumimoto (2002) is that the creation of a sustainable joint venture is not just about identifying a potential partner with complementary resources and applying good project management techniques but more about establishing strategic goals and how these may be delivered. Consideration needs to be given to any legal or financial details and any potential conflict requires careful thought. Whilst SJG appear to be aware of this and are working closely with CamelBak in achieving it, their awareness of the above needs to be clarified to demonstrate their potential ability in developing strategic alliances. Another area of concern identified by Moss Kanter is that of interpersonal skills and the need to ensure that both parties take advantage of the strengths of various individuals so that things such as tacit knowledge can be communicated successfully whilst the innovation is under development. This will allow the time to develop and build the trust required to spark new ideas. An area that the management interviewed are no doubt aware of is that of the owners' drive to grow the firm, whether it is for long-term sustainability or to make it more attractive for potential acquisition. As

suggested by Anslinger & Jenk (2004) alliances appear to be emerging as part of a number of firms' growth strategies. They believe that alliances enjoy above average returns by allowing partner companies to transform performance and respond to market changes. This was identified throughout the research phase of the project as one of the reasons for considering some form of strategic alliance. Another consideration that could be applied when entering into an alliance of some kind is that there is unlikely to be 'one best way' to manage innovation. Industries vary in terms of sources of innovation and the technological and market opportunities and particular organisational characteristics are likely to weaken any notion of a collective method for successful innovation (Tidd 2001). This is something that SJG has to be aware of when considering alliances with firms in unrelated industries such as the CamelBak joint venture or the potential for vertical integration or diversification discussed during the research phase of the project. This is where the conceptual framework may be beneficial in considering the potential advantages of a particular strategic alliance in helping to identify not only the benefits but also the risks to SJG. It may prove beneficial to carry out a table top exercise using the conceptual framework to identify potential partners for a strategic alliance and identify the benefits and risks the proposed alliances may hold. This may also prevent, as suggested by Bruce et al (1995), the risk of not really understanding the benefits of the relationship of a strategic alliance. Stach (2006) identified some issues that the conceptual framework will not be able to identify and which the firm needs to be aware of and continually reassess throughout any alliance. They

are issues such as power imbalance in terms of size, resources and access to markets, implementation issues, personality conflicts and other non-technical factors. The firm needs to be aware of this and implement communication plans so that both parties are aware as possibly can be of what is happening in each stage of the alliance.

What does seem to be apparent are the reasons for SJG considering some form of strategic alliance and this is reflected in the work carried out by Das & He (2006). They suggest that entrepreneurial firms such as SJG should choose established firms that are motivated to develop technology or products rather than just to meet the threat of any new technology. They need to consider firms that are willing to provide access to manufacturing and marketing functions involving committed middle managers and enthusiastic top managers. It may still be too early to identify whether this will be reflected in the joint venture with CamelBak but all of the managers interviewed appear to support this in identifying the positive elements that CamelBak will bring to the table.

The joint venture with CamelBak aside, Vyas et al (1995) suggest that technology fusion or technology transfer is one reason for strategic alliances. One partner may be able to contribute specific knowledge of a process, which might be critical in achieving competitive advantage. This is certainly the case in the alliance with HitCo Inc. As we are aware they are currently

attempting to develop a much more cost effective lightweight ceramic plate which if successful will certainly give SJG some competitive advantage.

Considering the acquisition of SJG as a by-product of any form of alliance should not be viewed as a failure of the alliance. According to Das & He the acquisition of an entrepreneurial firm would be dependent on the entrepreneurs' expectations.

So in final deliberation of the ultimate objective of this management project we know that SJG are path-dependent as their learning process is incremental and their competencies are related to their core product. It is also evident that due to this and an apparent lack of resources changing paths may be prohibitive. However, from a technological trajectory perspective SJG's technological knowledge is not as was originally thought constrained by their technological knowledge or lack of technological knowledge. It is correct that as a small firm SJG are supplier dominated and they do rely upon manufactures to provide raw materials that have a certain degree of technology in their manufacture and development which is outside of SJG's abilities or control. Nevertheless, the process of manufacturing body armour and ballistic solutions is not provided by their suppliers and they do not rely upon their suppliers to show them how to develop their product. The encapsulation and UV curing process of ceramic plates for hard armour solutions used by SJG is specific to their product and has been developed and perfected by them alone. This is also the case of the process of layering and

stitching Aramid in the soft armour solutions. It would be safe to say that all body armour manufacturers are similar in some way and constrained by the advances in the composite and material technologies used industry wide. It might also be safe to assume that even the subsidiaries of the large composite and materials firms that manufacture body armour are constrained by the same conditions. However, SJG is continually looking for solutions to resolve the weight and cost issues already identified and they do not rely on suppliers, as demonstrated in the work that they are doing with alternative sources of ceramic and encapsulation materials such as the rubber discussed earlier in this chapter.

Considering changes in technological trajectories Table 1 & 2 on page 35 of this management project in the tables developed by Tidd et al (2005) have been consulted for a better understanding. When considering SJG in relation to the categories of small firms their product does involve the integration and adaptation of innovations by suppliers. They have already exploited IT based opportunities in the manufacturing software recently rolled out and the pull method of manufacturing recently implemented has contributed to the success of the new software package and vice versa. In considering the five major technological trajectories in Table 1, SJG's main source of technology is from suppliers but more importantly from product learning. SJG are indeed as proposed by Tidd et al (2005) specialised rather than diversified in their technological competencies and product range. However, technology related product diversification such as the acquisition of the sports goods

manufacturing firm considered earlier uses the same curing technology as the body armour and could therefore lead to new commercial competencies such as new markets unrelated to the body armour industry.

It is possible for SJG, as experienced by many small firms before them, to become a superstar through exploiting a first mover advantage. This could be achieved by taking advantage of learning curves, which lead to reduced production costs, and an accumulation of tacit knowledge both of which through the continuous learning process SJG will and have no doubt started to accrue. The tacit knowledge that they have through the development and manufacture of their core product may lead to a competitive advantage, due to the difficulty of imitating tacit knowledge. This might even be achieved through the successful development of a lightweight solution or even the development of a flexible armour solution using materials from sources other than regular suppliers. This relates to the rubber and ceramic tiles already discussed. If this were to happen and SJG were to become a superstar there is one serious challenge according to Tidd et al (2005) and that is the management of the transition from the original innovator and original innovation and the new product line. However most small firms fall into the category of supplier dominated firms as their main sources of new technology come from the suppliers of their production inputs.

Even with a continual process of developing their competencies avoiding any form of core rigidities due to flexibility and continual learning, changing path

or technological trajectory may ultimately not be possible for SJG. It is believed that this is not solely related to their technological knowledge and their capability to continually improve as a firm through process and product innovation and their ability to handle paradigm innovation. It is also believed that it is not due to a lack of competencies or dynamic capabilities, as we have witnessed one of their dynamic capabilities is the ability to enter into strategic alliances. It is the barriers and the high degree of risk and uncertainty of forging ahead in such a niche specialist, competitive and volatile industry. There is no question of SJG's ability as a firm to continue to develop their products possibly attaining a competitive advantage in some markets. However, the sustainability of those markets and having the ability to enter into much bigger more challenging markets cannot be achieved alone. Even strategic alliances may only create a certain degree of sustainability and competitive advantage much the same as diversification or some form of vertical integration may. To that end being part of a much bigger organisation may not only allow SJG to overcome those barriers but be the contributing factor of a successful and sustainable firm that has access to bigger markets such as the US and the EU. It would allow any doubt about Asian manufacturing to be dispelled whilst maintaining a competitive edge through low cost quality manufacturing with access to global markets through firms with recognised brands and established markets.

Considering what has been learnt through the process of this management project some thought has been given to any further or future research that

would not only add to this management project but also go some way to developing what is already known about innovation management. It is true as identified by Hoffman et al (1998) during the literature review, there has been little research undertaken specifically relating to small firms. This identifies a need not only to attain a greater understanding of innovation within small firms but more specifically small firms in niche industries. Identifying possibilities of the transition from one technological trajectory to another and what enables that change specifically in small firms would not only add to what is already known about technological trajectories but might aid small firms in changing trajectories. Further research into SJG and the outcome of their current endeavours would add to this management project and also allow further consideration of their trajectory and any potential changes. Another area of potential interest is that of strategic alliances and how small niche manufacturers contribute to alliances with much larger global firms and how each firm benefits from the alliance. Finally a much more radical consideration could be the theory of managing change and the theory of innovation being studied in parallel to identify not only corresponding similarities but also the methods employed in achieving the end results.

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Appendices

Appendix 1

What is body armour?

The following information was provided by SJG as a brief explanation of what body armour is, how it works, its construction and the materials that go into manufacturing it. It also briefly considers recent advances in the in the development of body armour.

How does a bullet-proof vest work?

When a handgun bullet strikes body armour, it is caught in a web of very strong fibres. These fibres absorb and disperse the impact energy that is transmitted to the vest from the bullet, causing the bullet to deform or 'mushroom'. Additional energy is absorbed by each successive layer of material in the vest, until such time as the bullet has been stopped. Because the fibres work together both in the individual layer and with other layers of material in the vest, a large area of the garment becomes involved in preventing the bullet from penetrating. This also helps in dissipating the forces, which can cause non-penetrating injuries what is commonly referred to as "blunt trauma" to internal organs. Unfortunately, at this time no material exists that would allow a vest to be constructed from a single ply of material. Today's modern generation of concealable body armour can provide protection in a variety of levels designed to defeat most common low and medium energy handgun rounds. Body armour designed to defeat rifle fire is of either semi rigid or rigid construction, typically incorporating hard materials such as ceramics and metals. Because of its weight and bulkiness, it is impractical for routine use by uniformed patrol officers and is reserved for use in tactical situations where it is worn externally for short periods of time when confronted with higher levels of threat.

Methods of Construction

Typically, concealable body armour is constructed of multiple layers of ballistic fabric or other ballistic resistant materials, assembled into the "ballistic panel." The ballistic panel is then inserted into the "carrier," which is constructed of conventional garment fabrics such as nylon or cotton. The ballistic panel may be permanently sewn into the carrier or may be removable. Although the overall finished product looks relatively simple in construction, the ballistic panel is very complex.

Ballistic fabric is available from a number of manufacturers in various styles and compositions, each type having unique ballistic resistant properties. The body armour manufacturer may construct a given model of ballistic panel from a single fabric style or from two or more styles in combination. The location and number of layers of each style within the multiple-layer ballistic panel influence the overall ballistic performance of the panel. In addition, some manufacturers coat the ballistic fabric with various materials. For example, the manufacturer may add a layer of non-ballistic material for the sole purpose of increasing blunt trauma protection. Even composites of two or more different ballistic materials are available. As a consequence, it is impossible to compare one product with another based solely on the number of fabric layers in the ballistic panel.

The manner in which the ballistic panels are assembled into a single unit also differs from one manufacturer to another. In some cases, the multiple layers are bias stitched around the entire edge of the panel; in others, the layers are tack stitched together at several locations. Some manufacturers assemble the fabrics with a number of rows of vertical or horizontal stitching; some may even quilt the entire ballistic panel. No evidence exists that stitching impairs the ballistic resistant properties of a panel. Instead, stitching tends to improve the overall performance, especially in cases of blunt trauma, depending upon the type of fabric used.

Materials and Technology

Steel, the traditional armouring material of choice because of its strength, is gradually being phased out in favour of lighter materials that are more flexible made possible by advanced materials technologies. Hard materials like steel tend to crack or shatter under pressure. Nanotechnology has had a big impact on new materials, because changing the nanostructure of materials like ceramics can produce a material that is tough, flexible, and resilient. One way companies are adopting this is by blending lightweight and heavier materials into mixtures called alloys and composites.

However, ceramic composites are favourites for body and vehicle armour, along with high quality polymers such as plastic, rubber or other elastic materials. Composites still have a way to go before they compete with the tried and tested strength of steel. However, Analysts say the mixtures available now do not protect as well as steel, but are improving.

Recent Developments of Body Armour

Prior to the late 1990s, body armour was very heavy. Even the "advanced" aluminium oxide armour worn by soldiers in the 1993 operation in Mogadishu, Somalia, weighed an average of 25 lbs for a complete set. This reduced the soldiers' mobility and dramatically increased their fatigue, resulting in decreased fighting capability and an increase in casualties. Although lighter weight ceramic armour was available, the manufacturing costs and therefore purchasing costs were very high.

In 1997, the US Army Manufacturing Technology (ManTech) Programme, a cost sharing research and development initiative embarked on a project to develop processes for the economical mass production of boron carbide (B₄C) and siliconised silicon carbide (Si/SiC) Small Arms Protective Insert (SAPI) armour plates, which were designed to be used in the Interceptor

Body Armour (IBA) system. Initial participants in the project included the U.S. Marine Corps; the U.S. Army Soldier & Biological Chemical Command; Specialty Defence Systems; Simula Inc.; and Cercom Inc., a manufacturer of advanced materials such as B4C and SiC. Other ceramic manufacturers, such as M Cubed Technologies Inc., Ceradyne Inc. and CoorsTek also got involved as the project progressed.

Through the ManTech effort, the cost of B4C plates was reduced from an average of \$850 per plate to \$525 per plate by 2001, and processes were refined to produce functionally equivalent Si/SiC plates at an average cost of only \$350 per plate. By 2002, the cost of Si/SiC plates had been reduced even further. Combined with the soft outer tactical vest (OTV) that comprises the IBA, these new plates brought the total cost of IBA into the \$1500-\$1700 range. Although this was still higher than what the Department of Defence had been paying for conventional aluminium oxide armour, the new plates were about 55 percent lighter, weighing an average of 10 lbs less than the conventional armour materials.

The Interceptor Body Armour system was the first new armour that the Marine Corps and Army have had since Vietnam in the 1960s. Because it is B4C (and, in some cases, SiC) instead of aluminium oxide, it is much lighter. That is the justification for the high price, and the government is more than willing to pay that price because they are beginning to understand the impact of weight on a soldier in the field. The performance of B4C and SiC materials was also improved through the ManTech effort, increasing the IBA's ability to protect soldiers' lives. Multiple hit protection has been the real Achilles heel of ceramic because of its fracture behaviour. You cannot eliminate this behaviour, because it is actually a key energy-absorbing process. However, we do need to limit crack propagation, because the presence of a large amount of cracking reduces the performance of the ceramic from subsequent hits.

In the past, manufacturers tried to overcome this problem by creating a tile mosaic. However, even this solution had drawbacks. Although the tile mosaic design works, it is expensive because the interfaces between the tiles need to be precisely made. Additionally, it is extremely difficult to design a tile mosaic system with uniform performance. Instead, you have to design for the weakest link, so the armour system ends up being heavier than it needs to be. By modifying the microstructure of the ceramic material to better dissipate the energy of the projectile, as well as by using different composite backings, the industry has been able to design better armour with very good multiple hit performance using a monolithic approach.

Companies such as M Cubed Technologies also brought valuable materials expertise to these advances. Reaction-bonded SiC has been made for some time, but there have been alterations made to the microstructure to make it very fine grained for the manufacture of precision-machined components for the semiconductor market, and they are able to demonstrate that the same fine-grained microstructure also resulted in very good ballistic performance in armour applications. By combining that expertise with the ability to make very large, complex shapes and the ability to scale that to large volumes in a manufacturing environment, they have been able to help meet the demand for lightweight, high-performing, cost-effective armour.

By early 2001, the US government had procured more than 30,000 of the new plates and had another 130,000 on contract. It was not long before the new armour was tested in a combat situation. US troops first wore the IBA system in operations in Afghanistan, where it was credited with saving numerous lives. According to one report, some soldiers pinned down in fire fights survived AK-47 and other small-arms fire to their chest and back because of the new vest, and most of the wounds suffered by US troops were in the arms and legs. Many of these same systems have been credited with saving soldiers' lives in Operation Iraqi Freedom.

Aramid

Kevlar

Kevlar, a p-phenyleneterephthalamide, was synthesized in 1965 by Stephanie Kwolek and Herbert Blades at DuPont. The long molecular chains are highly oriented with strong inter-chain bonding. The polymer was commercialised in the early 1970s. The inherent orientation of the bonds give the polymer high tensile strength at low weight, a low elongation-to-break modulus, structural rigidity, and low electrical conductivity. These properties are combined with high chemical resistance, high cut resistance and flame resistance. Kevlar is well recognised as a suitable material for body armour and became the first material used in widespread development of bullet resistant garments. Kevlar is five times stronger than steel on an equal weight basis yet, at the same time, it is flexible. The downside is that the material is not very abrasion resistant, but this can be over-come by putting the Kevlar inside a covering of abrasion resistant material.

Several different grades of Kevlar are available: Kevlar 29, Kevlar 49, Kevlar 149, Kevlar 129, Kevlar Correctional and Kevlar Protera are available. Each of the grades provides different properties and not all are appropriate for use in body armour.

Kevlar 29 was the first generation of bullet-resistant fibres developed by DuPont and helped to make the production of flexible, concealable body armour practical. The second generation of Kevlar debuted in 1988 as Kevlar 129. In 1995, Kevlar Correctional was introduced, which provides puncture-resistant technology to both law enforcement and correctional officers against stabbing threats. Correctional Kevlar uses a superfine fibre that is woven very tightly. When struck by sharp instruments, such as ice picks, awls or prison-made knives, but not including commercially made knives such as stilettos, these fibres not only absorb and dissipate the energy of the penetration, they also prevent the stabbing instrument from pushing the

Kevlar fibres apart to penetrate the armour.

Kevlar Protera is a high-performance fabric that allows lighter weight, more flexibility and greater ballistic protection in a vest design because of the molecular structure of the fibre. Its tensile strength and energy-absorbing capabilities have been increased by the development of a new spinning process. The phenyl rings of adjacent chains easily stack on top of each other making the polymer crystalline and the fibres stronger.

DuPont has announced several expansions of its Kevlar production starting in 2000. Since that time, the company has invested about US\$95million in expanding Kevlar production.

GoldFlex

GoldFlex is a soft armour material that combines Honeywell's Shield Technology with an Aramid fibre. Honeywell's Spectra Shield technology lays parallel strands of fibre side by side and holds the fibres in place with a resin system, creating a unidirectional tape. Two layers of this construction are then cross-plyed at right angles and fused into composite under heat and pressure.

Twaron

Twaron is a p-Aramid sold by Teijin Twaron. The polymer is sold as yarn, fibre, or pulp, and offers a combination of properties such as strength five times as much as steel, low weight, high modulus, good chemical and hydrolysis resistance, and the high temperature expected from p-Aramid materials. It is claimed that the phenyl rings of adjacent polymer chains stack on top of each other easily and make this para-Aramid polymer more crystalline, and the fibres stronger than the Kevlar-type polymer.

Teijin Twaron's para-Aramids are used in numerous applications, such as bullet resistant vests, thermoplastic pipes, optical fibre cables, tyres, ropes,

cables, geotextiles, and protective garments. The Twaron T-2000 microfilament is claimed to be a thinner fourth generation ballistic material that has a softer, more wearable body armour.

Dyneema

Dyneema is an ultra high molecular weight polyethylene produced by Toyobo as a joint venture with DSM in Osaka, Japan and is manufactured by DSM in Heerlen, The Netherlands as well as in Greenville, NC. The high-performance fibre is prepared by dissolving ultra high-molecular weight polyethylene in a solvent and spinning it through small orifices. The spun solution is solidified by successive cooling, which fixes a molecular structure containing a very low entanglement density of molecular chains. It is claimed that this structure gives an extremely high draw ratio and results in high strength. The highly drawn fibre is said to be almost a 100% crystalline structure.

Other desirable features include high strength and high modulus, giving Dyneema SK60 the highest-level value of specific strength among commercialised organic specialty fibres. A one-millimetre diameter rope of Dyneema SK60 can bear up to a 240kg load. The fibre has a low specific gravity and Dyneema SK60 has a density below 1.0, which will allow the fibre to float on water. Due to its high impact strength and good energy absorption characteristics, Dyneema SK60 is suitable for use in the protective apparel market.

The flexibility and abrasion resistance make fabrication into textile applications possible. Dyneema SK60 is claimed to have a high UV stability and chemical resistance; it is said it shows no degradation due to water absorption and demonstrates chemical resistance over a wide PH range.

DSM is investing about US\$50million to expand production of the fibre in Greenville, NC by about 50% and boost production in Heerlen by 10%. This is the fifth time that capacity increases have been announced since 2001.

Ceramic Materials

Armour producers were among the first users of advanced, high-strength, lightweight materials, such as fabrics comprised of para-Aramid fibres, ultra high molecular weight polyethylene, carbon fibres or some composites. The next move was to lightweight hard materials such as boron carbide, titanium, alumina oxide, silicon carbide and metal matrix ceramics. To achieve the desired protective properties, selected materials have often been combined with each other in layer-like fashion.

One of the most successful multilayer materials for use against high-energy impacts, such as those caused by high-velocity rifle bullets, employs a strike-face comprising the hardest available material within weight/cost constraints in a multiple-tile configuration.

The tiles can be made of ceramic, metal, plastic, metal alloys, rapid solidification materials, or metal or ceramic foams. In reality, only a few of the possibilities have made it to the commercial stage.

The use of rigid plates and polyurethane foams are among known trauma reduction methods. Plates used for trauma reduction are generally heavy and uncomfortable, and are not permeable to air or moisture so that a garment can breathe. Early plate technology sometimes produced a plate that broke or deformed under high-energy impact.