CRANFIELD UNIVERSITY

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A SYSTEMATIC REVIEW OF PORTFOLIO MANAGEMENT

SCHOOL OF MANAGEMENT

M.Res. Thesis

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A SYSTEMATIC REVIEW OF PORTFOLIO MANAGEMENT

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Abstract

This systematic review was conducted to provide a broad assessment of the academic and practitioner literature relating to new product portfolio management. The aim is to identify the methods of new portfolio management used within global business to business (B2B) firms with a view to understanding the effectiveness and potential problems of portfolio management in practice.

New product development portfolio management is the business process by which, typically, the senior management of a firm decide upon which new products to invest in to meet the firm's long, medium and short-term business objectives. Generally these would be those products which the senior management believe will most effectively utilise the firm's resources and thereby optimise the return on their investment.

Within the limitations of this systematic review, a significant number of possible gaps in research are *provisionally* apparent. These notably include the absence of suitable research material studying possible differences in practice and emphasis of portfolio management in Japan and Asia compared with the United States and Western Europe. Whilst portfolio management is frequently portrayed as a rational, precise and logical process, evidence emerges from this review suggesting that human aspects, such as team motivation and personal ambition, may also arise which may inhibit the senior managers' effective portfolio decisions. This possibly raises questions as to whether, as a consequence of this phenomena, due consideration is therefore given to portfolio strategies which effectively re-use development efforts in other projects or take advantage of complementing a firm's product portfolio through alliances with other firms.

In summary portfolio management would appear to be an area worthy of significant additional management research.

Contents

Appendix

1.0 Introduction

This M.Res review is centred in the general broad field of maximising the innovation potential of a firm's business performance through research and development expenditure on new product development. This field of study is known as Portfolio Management.

1.1 Academic traditions of innovation and new product development

Innovation is a field of study and in its own right its importance is recognised by several schools of business management. Economists have studied innovation dating back to Schrumpeter (1934), as quoted by Elliott (1980), and his work on creative destruction. Creative destruction occurs because market forces and new technologies unleash beneficial cycles of innovation that destroy old methods of operation and lead to new patterns of growth.

Porter (1980) considers the economic resource based view of the firm in the context of strategy. Hamel and Prahalad (1994) argue both the criticality and importance of the alignment of firms' core competencies with strategic intent. Porter (1980), in his five forces model, recommends three generic strategies for a firm to effectively compete.

Cost leadership.

Market niches and segmentation.

Differentiation. A better/different product or service to earn above average profits.

Innovation and new product development specifically is often an important process in firms' achieving either cost leadership and/or successful market niches. New product development is concerned with how to define superior products that will earn *above average profits* (Porter, 1980). How senior management configure the resources of the firm involved in product development is a critical factor in the performance of innovative firms.

More recently Sheth and Ram (1987) identify and expand the factors which are driving change in many markets and creating the need for more innovation.

- Technological advances.
- Changing customers.
- Intensified competition.
- Changing business environment.

Lieberman and Montgomery (1988) and Chen (1996) remark that the success of a new product is significantly determined by the reactions and moves of competitors. They must react to the threat of first mover advantage. If firms are unable to forecast the "move" they must have the capability to respond quickly to competitive moves.

Griffin (1997), working with the PDMA (Product Development and Management Association), reports that successful US firms have found that more than 50% of their current sales were coming from new products. In the case of the most successful overall firm, Hustad (1996) showed that this figure was over 60%. Today the great importance of a firm's innovation potential can often be expressed in concise financial terms. The evolution of legislation governing Intellectual Property Rights (IPR) from innovations in product development are often litigated, thereby building defendable boundaries with settlements often running to hundreds of millions of dollars. Take for example the billion dollar "Kilby" patent royalties paid during the 1980s and 1990s by Fujitsu, Samsung et al to Texas Instruments for violation of Dynamic Random Access Memory (DRAM) patents.

Iansiti and West (1997) point out that it is not sufficient to merely measure the money spent by a firm on R&D. The critical factor is what the firm gets for the money spent. Consequently considerable effort has been expended studying the product development process in an attempt to increase the profits of firms.

1.2 The product development process

Cooper (1996) stresses the importance of having a systematic NPD process including idea generation, screening, evaluation, development, testing and product launch and advocates the adoption of his Stage Gate product development process.

Griffin (1997), conducting a PDMA (Product Development & Management Association) study of firms engaged in B2B and consumer products and services, reported a 30% reduction on new product development (NPD) cycle times in 1995 compared to 1990, in part due to improvements and adoption of stage gate product development processes.

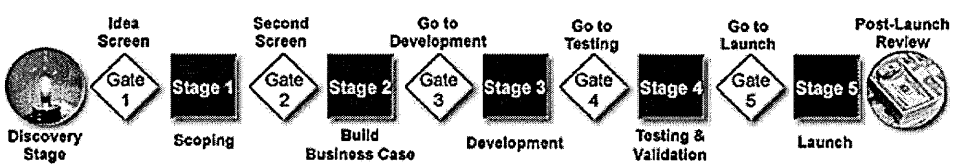

Fig 1.1: Cooper's Stage Gate Process (Cooper, 2001).

Cooper's (2001) Stage-Gate Process (shown in fig1.1) is a conceptual and operational road map for moving a new-product project from idea (Gate 1) to launch (Gate 5). The Stage-Gates split the product development process into distinct time-sequenced stages separated by *management decision* gates. Cooper, Edgett and Kleinschmidt (1998) stress the importance of senior management setting strict requirements at each gate to ensure the project is on track and not letting a project proceed past the gate until these requirements are met. Cross-functional development teams must obtain management approval before proceeding to the next stage of product development.

Stage gates processes do have critics. McGrath (1996) and Ulrich and Eppinger (1999) argue that in practice many new product development projects are not sequential and found that it is often desirable in new product development to have built-in iteration some of which is essential to foster innovation. Software developers such as Microsoft have tended not to use a strict sequential process like the Cooper Stage Gate Process. However, Griffin (1997) found that 68% of US firms use some form of Stage Gate Process.

1.3 Portfolio management

When considering the product development implications across multiple projects each involved in an individual Stage Gate Process the phenomena of portfolio management becomes critical. Cote and Stanmeyer (2001) describe portfolio management by paraphrasing Mark Twain's comment, "Put all your eggs in one basket" and watch that basket.

Cooper, Edgett and Kleinschmidt (1999) define portfolio management as, "the process by which senior management try to select and develop both the winning products and the correct balance of products that they believe will best succeed in the long term and then decide how to most effectively allocate the firm's resources optimising the return on investment (ROI)".

Cooper, Edgett and Kleinschmidt (1999) found that senior management believed there were four almost equally ranked factors why portfolio management was important.

1) Strategic position. 2) Ensuring a competitive position. 3) Efficient resource allocation and 4) Focus the company upon product execution.

1.4 Problems of product development in practice

Despite the high importance of product development indicated by the preceding academics, implementation of product development in practice is often unsuccessful. Cooper (2000) estimated that 46% of the resources that companies devote to new products go to ventures that fail in the marketplace and indeed many products don't ever make it to market. Porter (1990) condemns UK management as having a culture which works against innovation and change.

Because fierce competition erodes the competitive advantage of firms, Christensen (1997) argues that firms must complement their traditional competitive analyses and long term strategic planning with the necessary capabilities to recognise and adapt to changing circumstances. In the extreme, paradigm shifts can occur. IBM's near collapse during the 1980s and 1990s showed that even a financially dominant firm (in main frame computers) and which was acknowledged as the industry leader in developing advanced computing technologies failed to develop simpler technologies to exploit the emerging PC market. Resources allocated to mainframe computer new product development were not re-deployed to PC development until management became convinced that there was a substantial PC market. Conversely in the 1980s a new entrant Compaq, spotting the emerging PC market, allocated its entire development resources to PCs and exploited the opportunity (Moore, 1992).

Indeed such was the technical and market myopia at IBM that Louis Gerstner, CEO and Chairman of IBM from April 1993 until his retirement in 2002, was recruited from non-technical tobacco firm RJR Nabisco to attempt to recover the situation.

Whilst portfolio management might be considered as a process selecting which products firms develop, implicit within the definition is also the requirement for management to decide *what not to do*. Within the stage gate process surely is the assumption that if a new product development cannot successfully pass a gate, the resources working on that project are re-deployed to benefit the total organisation. The project is "killed". However, Cooper, Edgett and Kleinschmidt (1999) report a

strong reluctance of senior management to *make decisions* to "kill" projects. Repenning (2001) argues that portfolio management of multi-project development *is not effective,* finding that random allocation of resources, what he terms fire fighting, is a wide spread management practice. Indeed best selling management authors such as Tom Peters (1988) in his book "*Thriving on Chaos*" even advocate fire fighting as a business virtue.

Despite these conflicting comments there provisionally appears to be a surprising shortage of research on portfolio management, indicating the topic could be suitable for a systematic review.

1.5 External academic practitioner discussion

To verify the provisional literature search a practitioner meeting was arranged with a Vice President of Advanced Research Machines (ARM) in Cambridge and an academic meeting with Prof. Keith Goffin, a prominent European innovation professor at Stuttgart. Prof. Goffin provided the opportunity to gain detailed insight into Agilent (formerly a division of Hewlett Packard). Each of the three sources confirmed the importance and newness of the field. Agilent had only recently started to implement a formal portfolio management process within the last year. All three confirmed the absence of literature material in the field. It would seem that portfolio management would indeed benefit from a systematic review of the literature.

1.6 Systematic review limiting the area of search

Figure 1.2 briefly summarises the preceding narrowing of the literature to portfolio management of multiple projects in the Cooper Stage Gate Process.

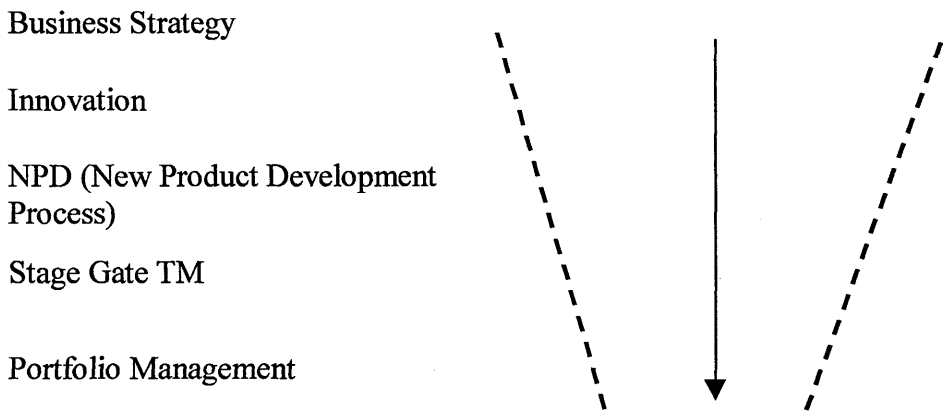

Fig 1.2: Limiting the area of search.

Even having narrowed to this point to enable an effective systematic review it is necessary to try to limit the field of study. Cranfield M. Res. program dictates that a systematic review must be completed by August 2003. 3 months are available for the study, but this time is in competition with other rigorously assessed courses.

1.7 Language

Though the author conducting the systematic review speaks some French it is at very low level. No other languages are spoken. Given the time constraint it is unrealistic to conduct a systematic review in any other language but English.

1.8 Geographic location of firms

The initial proposal was to study literature relating to firms based in the UK and US, however the review panel discussed in section 2 recommended that the systematic review should consider global studies.

1.9 Firm product market type

Griffin (1997) classifies and differentiates between firms involved in developing products and those involved in developing services. Griffin (1997) also differentiates between firms involved in business to business and consumer markets. This systematic review proposes to focus on firms manufacturing *products* for *Business to Business (B2B)* markets. This review excludes *consumer* firms and firms providing *services.*

This decision to de-limit the search clearly has limitations. There is a vast and rich literature relating to consumer markets which, it may be argued by some, may be lost from the review. Equally the work by de Brentani (1995) on scenarios for success and failure in industrial service firms showed that many of the cases for business services firms are actually similar to firms involved in products. Equally this is a logical classification of firm market involvement widely recognised by the academic community and practitioners alike. Ultimately it is recognised that the dominant factor in this decision is due to the severe constraint of the time available to do the systematic review.

Section 2.0

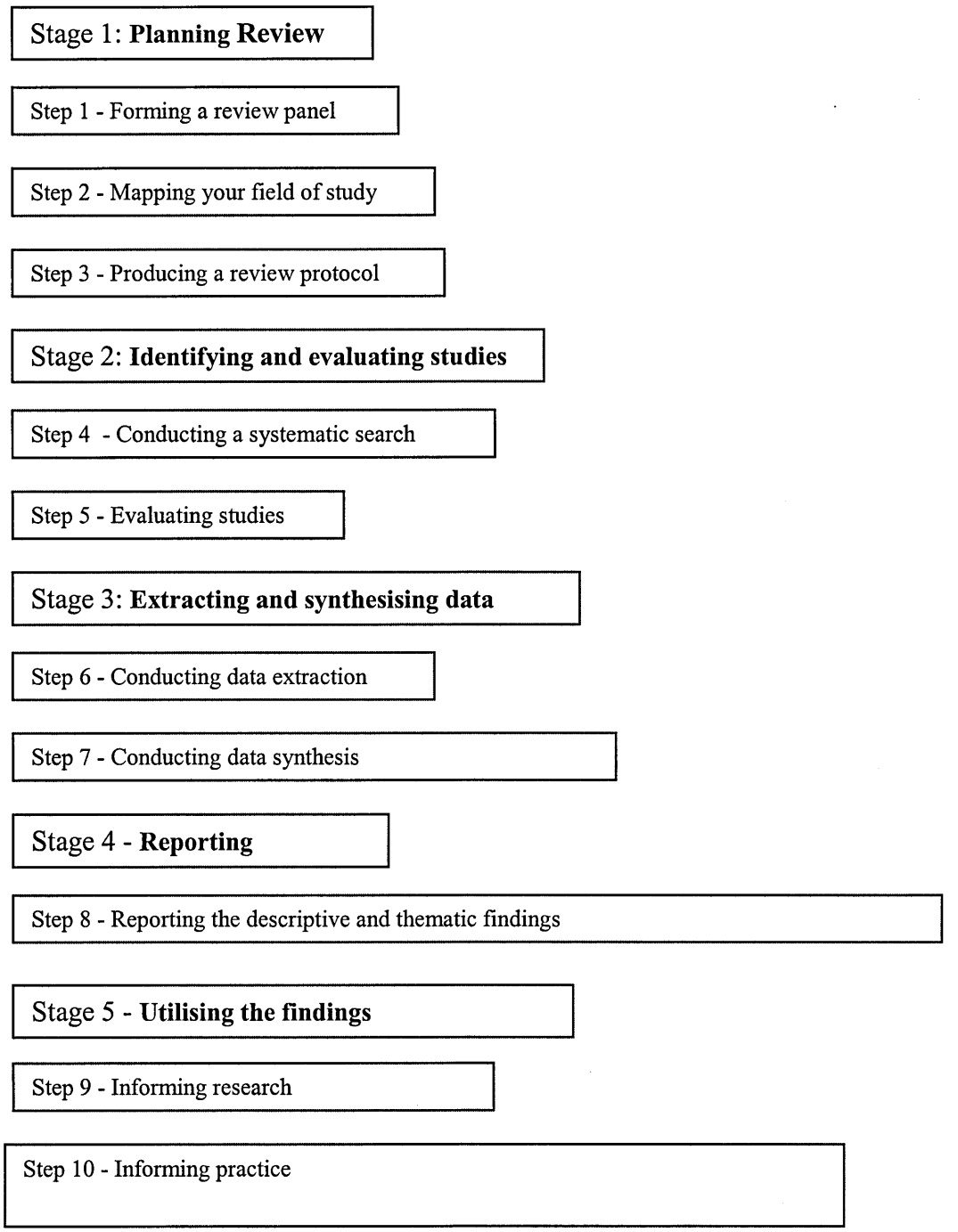

Fig 2.1: 10 step systematic review (Tranfield, Denyer and Smart, 2003).

2.1 Aim of the systematic review

The aim of this research project is to conduct a systematic review to understand the portfolio management practices used in firms to make product portfolio decisions.

Specifically the aim of this systematic review is to:

1. Identify the methods of new product portfolio management used within the business-to-business industries manufacturing products.

2. Review the research relating to the effectiveness of portfolio management methods used in the business to business industries.

2.2 The reduction of possible bias and repeatability

A systematic review is a highly structured process for reviewing the literature surrounding the chosen topic. Greenhalgh (1997) describes a systematic review as "an overview of primary studies which contains an explicit statement of objectives, materials, and methods and has been conducted according to an explicit and reproducible methodology". The intent of adopting a rigorous approach is to attempt as far as possible to remove sources of potential bias, such as preferences for research methodologies, geography etc. which might otherwise appear in a conventional literature review. The systematic review attempts to make an assessment of the literature as objective as possible. A key phase of the systematic review process is to recognise and declare potential sources of potential bias.

My employer, Texas Instruments, is a major high technology US microchip company and may be interested in sponsoring a Ph.D. based on the outcome of this systematic review. It is recognised that this possible "incentive" could introduce possible bias into the systematic review. My positivist physics and electronics background historically dominates my personal perspective. Similarly my managerial perspective has been positivist. My Myers-Briggs Type Indicator is ENTJ. Though the intuitive component manifests itself in a preference for generation of ideas and model creation compared to data collection, my tendency is to be driven by the thinking and judging components to make decisions on the basis of "logic", using an analytical and "objective" approach.

I recognise the existence of substantial criticism of the positivist position, indeed I think physicists, contrary to popular belief, have been increasingly self-critical. Nobel Lauriate Richard Feynman (1969) told a U.S. science teachers' convention that, "Science is the belief in the ignorance of experts". I would accept that the positive approach tends to focus upon social order and is less effective explaining social change. Kuhn (1962) describes the existence of paradigm, the belief system that underpins science. I share Kuhn's view that paradigm has generally limited physicists to working within an established and accepted field and therefore developments in theory have tended to be incremental rather than breakthrough improvements.

Though undoubtedly a positivist, my view of social reality is also heavily pragmatic. I view the practical consequences of ideas, considering theories, principles and so called laws as working hypotheses rather than as binding axioms. As a pragmatist I identify with Popper (1963) that unlike "hard line" positivists, where the hypothesis must come from observable data, it doesn't especially matter where the hypothesis comes from (including qualitative scholars or methods) providing the hypothesis is credible and testable. Consider that even the paradigm shift of Einstein's (1916) "General Theory of Relativity" only gained greater acceptance following experiments based on a solar eclipse in 1919 which confirmed Einstein's theoretical predictions.

I would like to believe that this pragmatic component to some extent provides some level of balance to my positivist traditions, but additionally recognise that pragmatism coupled with the possible interests of my employer perhaps also introduces its own source of bias.

These possible sources of bias are considered during the systematic review, especially in the key areas of paper selection, quality assessment, and reporting of gaps. To try to minimise the bias of my 20-year new product development career experience at Texas Instruments, a deliberate attempt was made to compare the literature with other companies. Through consultation with sources external to Cranfield, the academic and practitioner meetings with ARM, Agilent and Professor Goffin reported in section 1.5, I have further sought to attempt to acquire a bias free perspective on how to conduct the systematic review. Reflection on possible bias is substantially considered during the limitations of the review.

2.3 The process adopted to conduct this systematic review

Fig 2.1 outlines the 10 step 5 stage systematic review process, Tranfield, Denyer and Smart (2003) propose for adoption during the Cranfield M.Res. dissertation. In April 2003 a M.Res. review was generated outlining the intent to conduct this systematic review. An academic review panel consisting of two Innovation academic experts, Tranfield and Denyer (2003) confirmed that the portfolio management topic was worthy of study. During the review a systematic review protocol was to be submitted to and approved by the panel.

The panel made several recommendations. The aims of the systematic review were "tightened" (see section 2.1). The study was advised to be global rather than US/UK (see section 1.7). It was recommended that the detailed key word protocol and search engine analysis was be submitted for approval, (see section 2.5). These changes are comprehended in this report.

2.4 The systematic review search strategy

2.41 Key words

Commonly occurring key words relating to portfolio management and methods which forms the basis of this systematic review were extracted from the academic papers used to generate the M.Res. and the frequency of their occurrence within the papers calculated. These keywords appeared logically to form 4 groups. These were:-

1. Innovation
Innovation, (New) Product (s), Project, Winning products

2. Portfolio management *"process"*
Portfolio management, Portfolio planning, Product portfolio,
Senior management, Decision, Risk , Resource(s) allocation , Kill projects
Go no Go

3. Business-to-Business

Business to Business and B2B

4. Portfolio Methods
Portfolio methods, ROI, Return on Investment, Resource allocation

2.42 Frequency of portfolio management key words

The frequency of occurrence of the key words within the existing search of the portfolio management literature (shown in fig 2.2) was calculated to determine which key words to include in the search strings. Due to time constraints the search strings have been limited to 12. * Note that *portfolio,* though occurring only 5 times, is

included because it occurs 98 times in portfolio methods, portfolio management and portfolio planning.

Key word	Frequency	Key word	Frequency
Portfolio	5	Portfolio planning	8
Decision	5	Product portfolio	8
Go No Go	4	Resource(s) allocation	16
Kill	4	Risk	6
New product	17	Return on investment	15
Portfolio management	78	Senior management	8
Portfolio method (s)	12	Stage-Gate	3
Project(s)	21	Others	48
R&D	14	*Total*	272

Fig 2.2: Frequency of key words.

2.5 Search strings

The frequency of the top 6 keywords made up 60% of the total, portfolio management alone made up 29%. From the analysis shown in fig 2.3 and fig 2.4 the following search strings were constructed:-

1. Portfolio management
2. Portfolio methods
3. R&D AND Portfolio
4. Return on investment AND Portfolio
5. Resource allocation AND Portfolio
6. New products AND Portfolio
7. Projects AND Portfolio
8. R&D AND Business-to-Business
9. New products AND Business-to-Business
10. Resource allocation AND New product
11. Resource allocation AND R&D

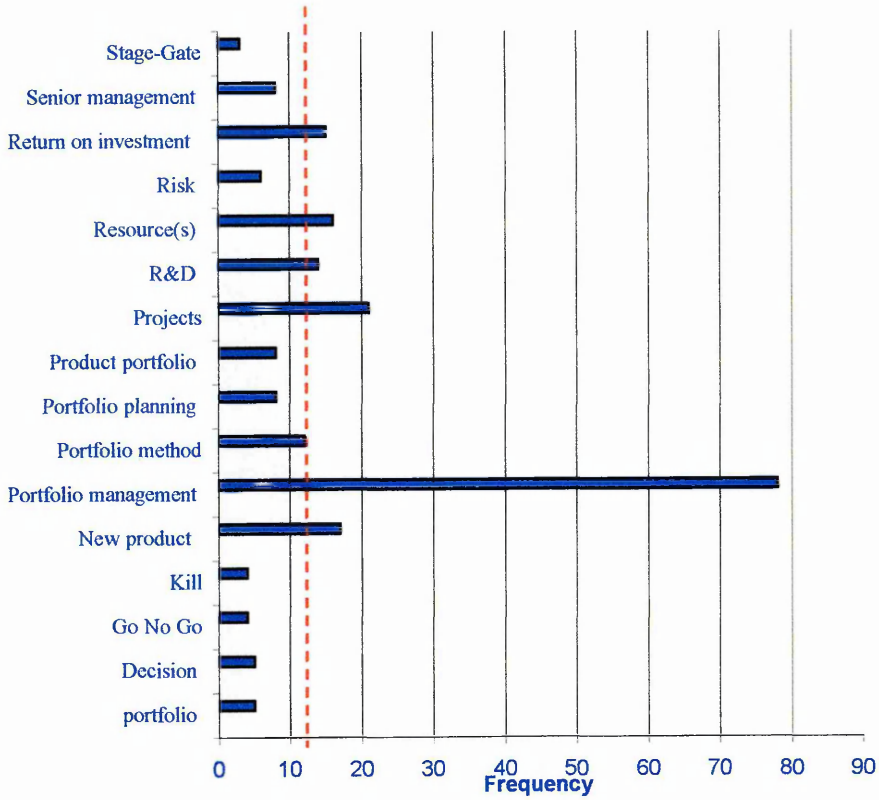

Fig 2.3: Frequency of keywords.

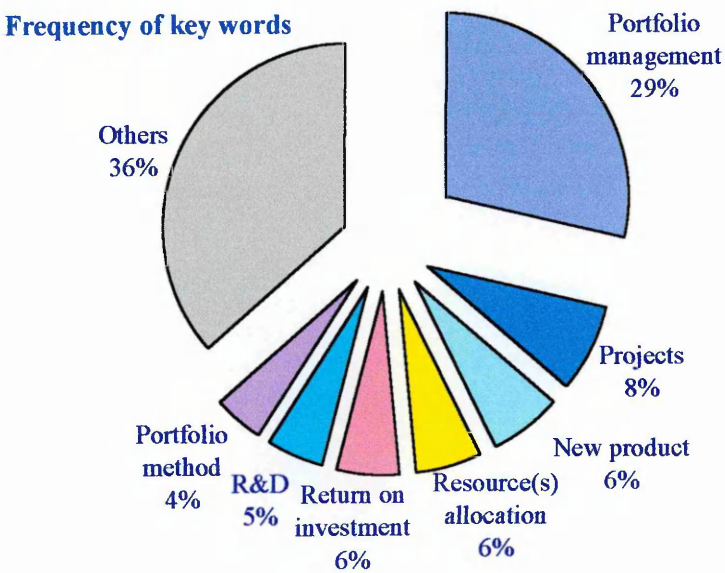

Fig 2.4: Percentage distribution of key words.

2.6 Inclusion exclusion criteria

2.61 Inclusion criteria

2.61 Inclusion criteria

Nos	**Criteria**	**Comments - Reason for inclusion**
1	High quality academic papers	See quality criteria
2	High quality practitioner	See quality criteria
3	B2B	Discussed in section 1.8
4	Products	Discussed in section 1.8
5	Quantitative studies	
6	Qualitative studies	
7	** From 1980	
8	* Global studies	(Provided) written in English section 1.6, 1.7

* Recommendation from review panel as a method to generate more quantitative studies within the search results.

** Though not formally insisted upon by the panel, it was suggested that papers prior to 1980 could enhance the systematic review. During the systematic review the inclusion criterion *papers after 1980* was removed.

2.62 Exclusion criteria

Nos	**Exclusion criteria**	**Comments - Reason for exclusion**
1	Papers not in English	Discussed in section 1.6
2	Not relevant to the field of study	For example stock market * see below
3	Services sectors	Discussed in section 1.8
4	Overtly technical & non – management	For example *(some)* IEEE articles etc. technical experts only
5	Consumer sectors	Discussed in section 1.8
6	**Papers before 1980	
7	Low quality assessment	See quality criteria section 2.8

* *Search exclusion of the stock market.* Portfolio management of new product development within the innovation field, which is the focus of this study, unfortunately uses similar terminology and nomenclature to that used within literature relating to the management of stock portfolios traded on the global stock markets. The management of stock portfolios on the stock market is categorically not the focus of this systematic review. Therefore the exclusion of the stock market literature was specifically discussed and approved by the review panel, and entered into the exclusion criteria.

** Though not formally insisted upon by the panel, it was suggested that papers prior to 1980 could enhance the systematic review. During the systematic review the exclusion criterion *papers before 1980* was removed.

2.7 Search methods

2.71 Search engine selection

Time constraints dictated that the systematic review was to be limited to two search engines. To determine which search engines to use, the search string "Portfolio

management" was chosen for a "pilot" search engine test due to the high occurrence frequency (shown previously in fig 2.4). Acting on the suggestion of the Cranfield library, thirteen of the twenty-two available search engines were selected for the pilot test.

The search string was run in each of the thirteen engines and the total number of results of each recorded. The stock market literature, as previously discussed in **section 2.62** was heavily considered during the trial. It was important to get a "good yield" of innovation literature within the total literature.
The yield of each search, the number of relevant results to the innovation field of study and the percentage that these formed of the total results obtained were recorded. The results of the pilot test are shown in fig 2.5

Engine	Raw result	Disqualified Stock Mkt.	Yield		Comment
Pro-Quest	50	46	(14)	8%	Unable to differentiate from stock market
ESBCO (Raw)	1478	28 of sample of 30	(2)	7%	
ESBCO Innovation field set	13	2	(11)	84%	
PDMA	196	0 of sample 30		100%	But low on inc/exc
Web-Cat	15	13	(2)	13%	
Blackwell	43	34	(9)	21%	
Synergy	5	5	0	0%	
Science Direct	63	37	(26)	41%	Also AND NOT
Emerald					
Wiley Science	51	47	(4)	8%	
Swets Wise	41	38	3	7%	
Ingenta	469	25 of sample 30	5	16%	
Ingenta select	1	1	0	0%	AND Product

Fig 2.5: Pilot test search results.

2.72 Conclusions of pilot study

Based on the results of the pilot study (shown in fig 2.5), **Science Direct** and **ESBCO** were chosen as the academic search engines. Science Direct appeared to have a high yield of relevant papers. Whilst ESBCO had a low yield of relevant papers, the multiple of the yield and the raw results exceeded the other options. The **PDMA** was recommended by practitioners, (TI, Agilent and ARM), as a high quality source of practitioner papers. Regretfully the PDMA, though having back papers available on their web site, did not have a full electronic search capability, thus necessitating a "manual" paper search which entailed looking through all the back copies of the magazine.

2.73 Search engine, key words, title and abstract versus full text

Portfolio management was entered into **Science Direct** to compare search results with full text, abstract, key words and or title. The results were:-

	Full Text	Abstract	Key words	Key words abstract and title
Science Direct	800 Articles Found	30 Articles Found	21 Articles Found	62 Articles Found

In conclusion, 800 articles from just one of eleven search strings would suggest that a full search would produce several thousand results, which would have been far beyond the scope of this study. The search would be conducted for keyword, abstract and title. (Not full text)

2.8 Quality assessment

Different quality assessment tools were considered for the systematic review, including Rose's ABCDE framework (Rose, 1982). Without question Rose's framework was very comprehensive and especially useful at formatting qualitative material into logical steps (Rose, 1982). One disadvantage of Rose's method was that it was very time consuming to use (Rose, 1982). Upon evaluating other tools a screen used by the Journal of Occupational and Organisational Psychology appeared to be a good compromise between the advantages of Rose's Method and ease of use (Rose, 1982). The model was then adapted to use simple 5-point scale shown in fig 2.6. The principle modification to the model was to add an additional category of relevancy to the systematic review.

	Score/rating				
Criteria	1	2	3	4	5
Contribution	None	Low	Medium	High	Excellent
Method	None	Low	Medium	High	Excellent
Data analysis	None	Low	Medium	High	Excellent
Findings	None	Low	Medium	High	Excellent
Relevance **(to the S.R.)**	None	Low	Medium	High	Excellent

Fig 2.6 Quality assessment criteria

Each of the main headings of Contribution, Method, Data analysis and Findings separates into the following sub categories:-

Contribution

- Appropriateness of method
- Epistemological integrity
- Theoretical considerations

Method

- Sampling
- Data collection technique
- Researcher situation interface
- Conceptualisation

Data Analysis

- Framework
- Audit ability
- Derivation of categories
- Use of transcripts
- Credibility
- Alternative explanations

Findings

- Research reflexivity
- Consistency
- Theoretical considerations
- Transferability
- Utilisation

2.90 Stage 2: Identifying and evaluating studies

2.91 The search and selection and process

The overall process adopted for the search selection process is outlined in fig 2.7.

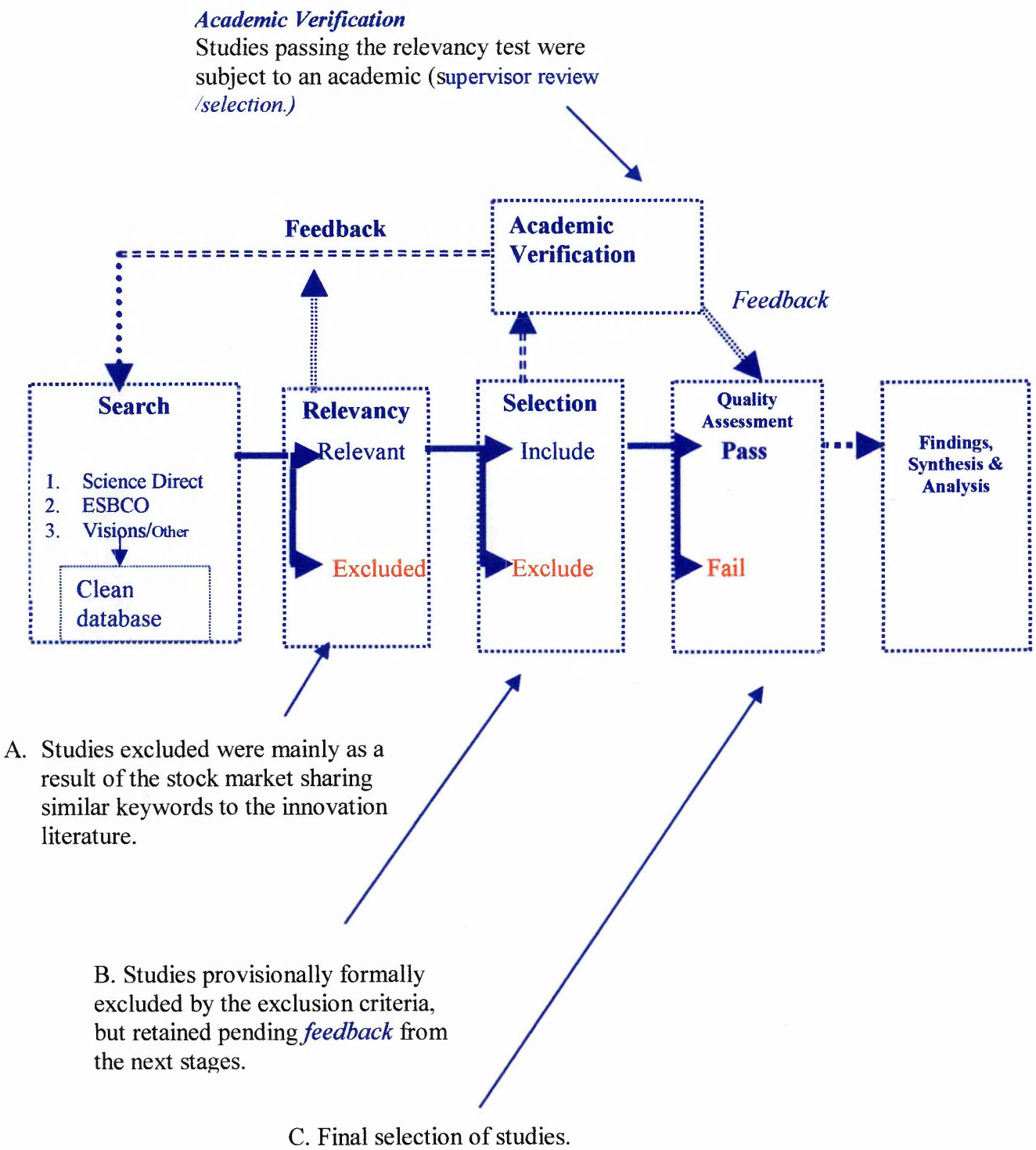

Fig 2.7: Five stage process search selection process.

There were 5 main stages in the search and selection process. Search, relevancy, selection, academic verification and quality assessment. The output from the process, the findings, synthesis and analysis are reported in section 3.

2.92 Search

The literature search was conducted between May and July 2003. 643 total search raw results were obtained. The totals of papers retained at each stage of the process are shown in fig 2.8.

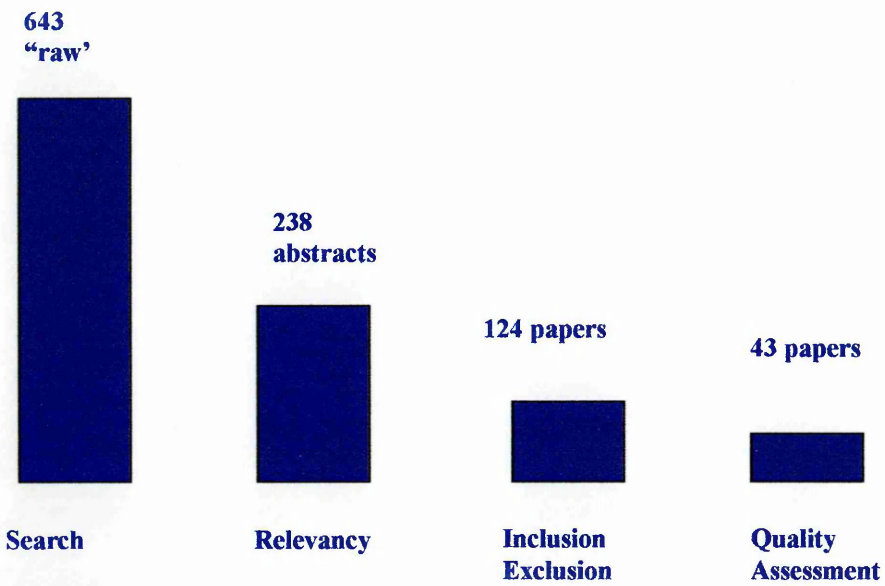

Fig 2.8: Number of results retained by stage.

2.93 Relevancy

A "clean" database was generated. Many papers could be eliminated at the title stage, for example, news wire releases recommending stocks to add to stock portfolios such as "add Microsoft (NASDAQ MSFT) to your stock portfolio". Though Science Direct had a facility to remove duplications in its search basket ESBCO had captured multiple duplications, for example in the case of Cooper et al (1999) five copies. Combining the Science Direct and ESBCO search results in Procite created yet more duplications. The Procite facility to compare identical and or similar papers was used to eliminate the duplications. From the 643 papers 405 were eliminated, leaving 238 papers in the "clean" database, listed in Appendix 1, which were provisionally considered as possibly being relevant.

The 238 papers, listed in Appendix 1, were consolidated into a print out of authors and abstracts using Procite. With the additional information provided by the abstract, and after a brief review of the abstracts, 114 could be eliminated as not relevant. 124 papers listed in fig 2.9 below were identified to progress to the formal selection stage.

Author Date (abbreviated)

Anderson et al (1987)
Archer and Ghasemzadeh (1999)
Armstrong and Brodie (1994)
Ausura (2003)
Ayal and Rothberg (1986)
Bardsley (2001)
Basso and Peccati (2001)
Bernstein and Macias(2002)
Bhoovaraghavan et al (1997)
Blackman (1973)
Blattberg and Deighton (1974)
Boddington (2002)
Bond and Houston (2003)
Braunstein et al (1994)
Brown (1991)
Buxton and Hanney (2000)
Cabral (1994)
Cardozo and Wind (1985)
Chapman et al (1985)
Cooper, K. et al (2002)
Cooper et al (1997)
Cooper et al (1998)
Cooper et al (1999)
Cooper (2000)
Cooper et al (2001)
Cote and Stanmeyer (2001)
De Maio et al (1994)
Deeds et al (2000)
Duysters and de Man (2003)
Elonen and Artto (2003)
Engwall and Jerbrant (2003)
Ferns (1991)
Firth and Narayanan (1996)
Foster (1996)
Fox et al (1984)
Ghasemzadeh and Archer (2000)
Gluck and Rumelt (1981)
Gokhale and Bhatia (1997)
Graves and Pennings (1992)
Graves and Pennings (2000)
Griffin (1997)
Griffin (2002)
Gupta (1987)
Hambrick and MacMillan (1982)
Harmsen (2000)
Heartland (2002)
Heidenberger and Kurt (1999)
Heidenhain (2001)
Helfat (1989)
Hemmerick (1997)
Hendriks et al (1999)
Heung and Yu (1998)
Hout (1997)
Hugunin and Wilemon (1992)
Hung, Liang and Liu (1996)
Islei et al (1990)
Jacob and Kwak (2003)
Jandourek (1996)
Jiang and Klein (1999)
Jolly (2003)
Jones (1971-1972)
Khurana and Rosenthal (1998)
Kim and Srivastava (1998)
Kirchhoff and Merges (2001)
Kuczmarski (1997)
Kumar and McCaffrey (1997)
LaPlaca (1997)
Leung (1997)
Liberatore (1987)
Lint and Pennings (2001)
Lint and Pennings (1998)
Linton et al (2002)
Loch (2000)
Loch and Bod-Greuel (2001)
Locke (1972)
Luehrman (1998)
Lumsden (1997)
MacMillan and McGrath (2002)
Mandakovic and Souder (1990)
Markham et al (1991)
McMillan (2001)
Meadows (1999)
Mikkola (2001)
Morris (2002)
Nagpau (1985)
Narula (2001)
Newton (2001)
Nihtila (1999)
Nijssen and Lieshout (1996)
Payne and Turner (1999)
Perigrim (2000)
Platje et al (1994)
Prichard and Pullan (1997)
Purdue and McAllister (1999)
Regan and Holtzman (1995)
Repenning (2001)
Roberts (1969)
Roetheli and Pesenti (1986)
Rosenau (1999)
Scherer and Harhoff (2001)
Schiavina (1979)
Segelod (2002)
Sharpe and Keelin (1998)
Shenhar (2000)
Shenhar (2001)
Sirbu (1978)
Smith (1993)
Snee and Rodebaugh (2002)
Souitaris (2002)
Spital (1979)
Spradlin and Kutoloski (1999)
Sundbo (1996)
Thakkar et al (1998)
Tieleman (1981)
Tritle et al (2000)
Van Arnum (1998)
Verma and Sinha (2002)
Walsh (2001)
Wang (2002)
Webber et al (2002)
Whetstone (2002)
Wilhelmsson (1999)
Winkofsky (et al 1981)
Zahra (1996)

Fig 2.9: Papers selected for formal selection.

Analysis of the source of publication

Publication / number of papers	Publication / number of papers
Academy of Management Journal	Journal of Business Venturing
Across the Board	Journal of Economic Dynamics & Control
American Water Works Association	Journal of High Technology Management
Baseline	Research
Benefits Canada	Journal of Law and Economics
Best's Review	Journal of Management Information
Buyouts	Systems
California Management Review	Journal of Operations Management
Chemical Engineering	The Journal of Product Innovation
Chemical Market Reporter	Management
Chief Executive	Long Range Planning
Computers & Industrial Engineering	Management Review
Computerworld	Management Science
Decision Support Systems	Marketing Intelligence & Planning
The Economic Journal	Marketing News
Engineering Management Journal	National Productivity Review
European Journal Of Operational Research	National Real Estate Investor
Financial Planning Fortune	PDMA- Visions
Harvard Business Review	Pensions & Investments
Hewlett-Packard Journal	Pharmaceutical Executive
IEEE Transactions Engineering Management	Project Management Journal
Industrial Marketing Management	Quality Progress
Industry Week	Quarterly Journal of Business and
Information & Management	Economics
InformationWeek	Quarterly Journal of Economics
Interfaces	The Quarterly review of Economics and
International Journal of Management	Business
International Journal of Management Reviews	R & D Management
International Journal of Operations &	Research Management
Production Management	Research Policy
International Journal of Production Economics	Research Technology Management
International Journal of Production Research	Science
International Journal of Project Management	Sloan Management Review
International Journal of Research in Marketing	Technology Analysis & Strategic
Ivey Business Journal	Management
Journal of Applied Psychology	Technovation
The Journal of Business & Industrial Marketing	Venture Capital Journal
Journal of Business Strategy	

Fig 2.10: Systematic search publication list. (70 sources)

Fig 2.10 shows the publications from which the 124 documents were sourced.
The systematic search generated results from seventy publications from which seventeen had multiple occurrences and fifty-seven provided a single paper. The analysis of the top 10 journals is shown in table 2.11.

2.94 Selection and academic verification

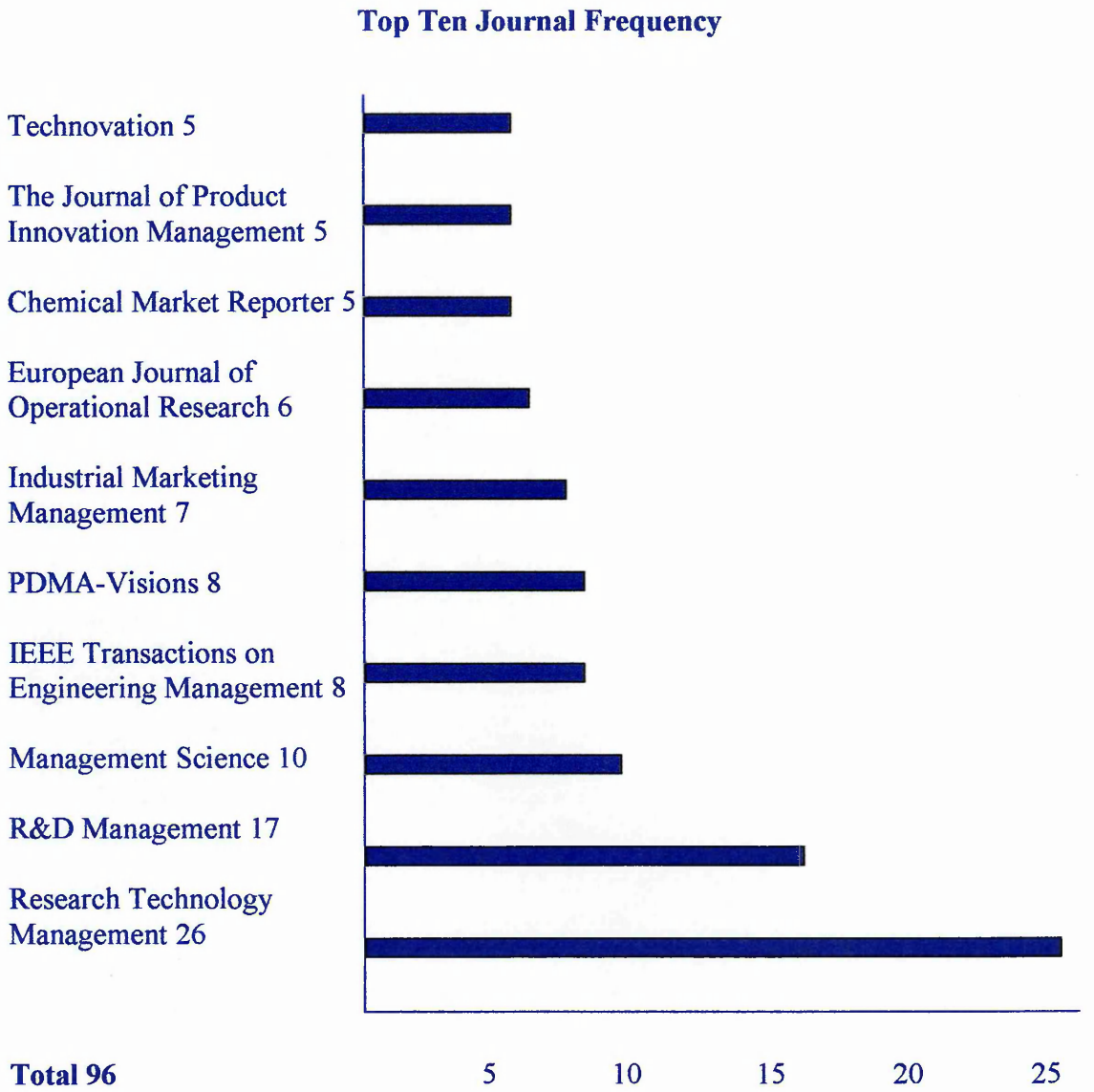

Fig 2.11: Top 10-journal frequency of the systematic search selected papers.

The 124 full papers underwent inclusion/exclusion selection by myself. In addition, as shown in fig 2.12, a parallel independent 2-part academic verification process was undertaken with my supervisor.

Verification step 1

The first part of the verification consisted of reviewing the analysis of the publications shown in fig 2.10 and 2.11. There was considerable surprise that as many as sixty-nine publications were sourced by just two search engines. (PDMA Vision was a separate source). This was far more extensive than expected and no obvious innovation publications appeared to be left out of the analysis. It would have been preferable to introduce a third search engine at this stage, as the use of two search

engines is a limitation of this systematic review *(see section 2.71)*. In the event that any omissions had been discovered, journal specific searches would have been undertaken to complement the database.

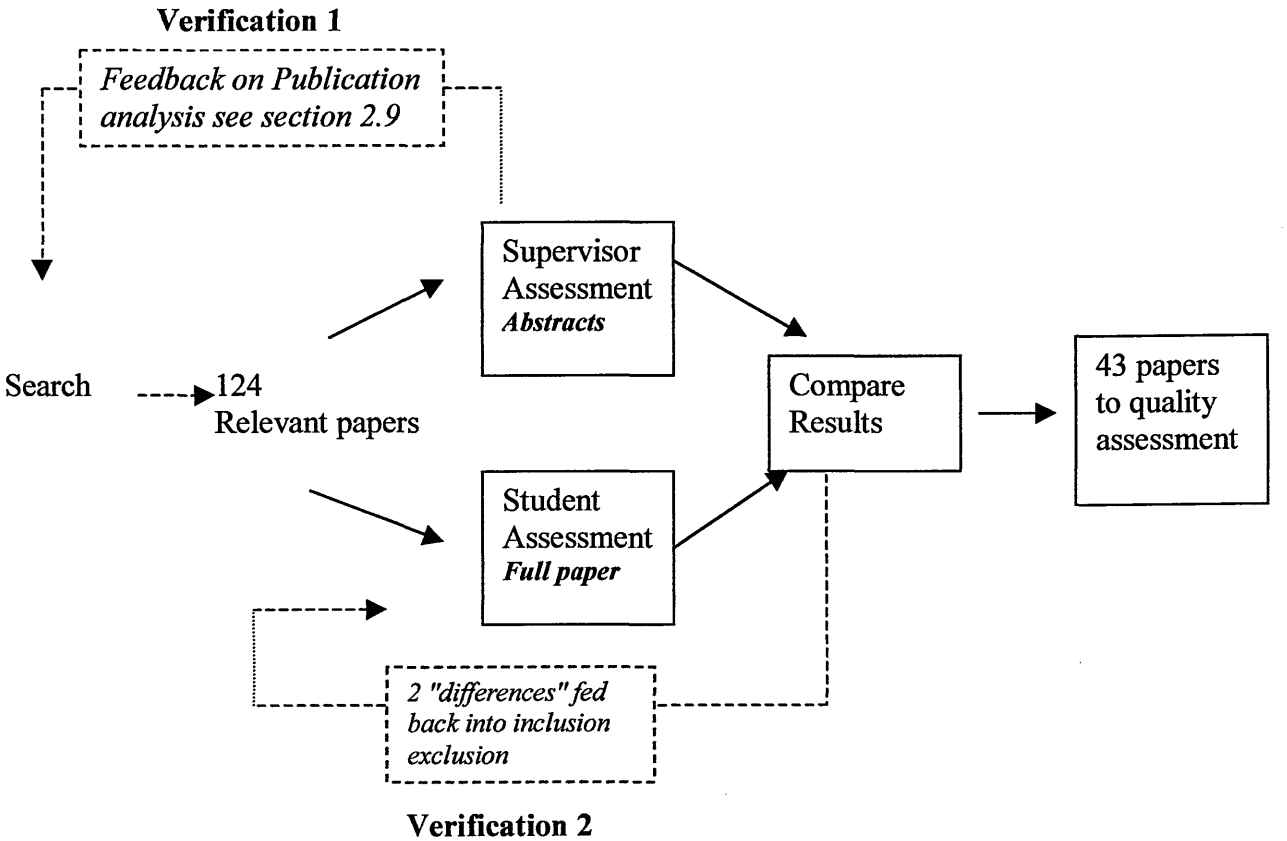

Fig 2.12: Academic verification.

Verification step 2

A consolidated printout of all 124 references and their abstracts, sorted alphabetically by author/date was presented to the supervisor with a request to mark papers worthy of inclusion. The supervisor returned a list of 44 papers, which was compared with the 42 selected papers in my own full paper analysis.

The supervisor had marked 2 papers not included in the results of my full paper analysis. These were fed back into the full paper analysis and re-screened for inclusion and exclusion. As a result of the verification one of the two papers, Meadows (1999) was accepted as being relevant and that its omission was an error on my part. One paper, (Maas, 1998) was again rejected. The reason this paper was rejected was that abstracts did not provide sufficient data for the supervisor to have made a full judgement. Maas (1998) "Portfolio Management for New Products" was actually a "publicity" summary of the work by Cooper et al (1998), but the abstract made it appear that she had made the contribution.

2.95 Excluded papers

As a consequence of the inclusion, exclusion and verification process the 81 papers shown in fig 2.13 were excluded from the systematic review.

Fig 2.13: List of excluded papers.

Author Date	Exclusion	Exclusion comments
Anderson et al (1987)	5	Channel management
Archer and Ghasemzadeh (1999)	4	Overtly technical
Armstrong and Brodie (1994)	2	Marketing
Bardsley (2001)	2	Project management
Basso and Peccati (2001)	2	Finance
Bernstein and Macias (2002)	5	Consumer pricing
Blackman (1973)	6	Tech forecasts
Blattberg and Deighton (1974)	5	Customer equity test
Boddington (2002)	5	Power industry
Buxton and Hanney (2000)	3	Health industry
Braunstein and Salsamendi (1994)	2	Not focused on R&D
Brown (1991)	2	Marketing
Chapman et al (1985)	5	Project management
Deeds et al (2000)	2	Finance
Duysters and de Man (2003)	3	Services
Engwall and Jerbrant (2003)	2	Project management
Ferns (1991)	2	Program management
Foster (1996)	2	R&D effectiveness
Gluck and Rumelt (1981)	2	Project tracking methods
Gokhale and Bhatia (1997)	2	Project tracking methods
Gupta (1987)	2	Product marketing
Hambrick and MacMillan (1982)	2	Product market (BCG)
Heidenberger (1999)	2	Literature review
Helfat (1989)	2	Finance
Heartland (2002)	5	Health care
Heidenhain (2001)	3	Tech insurance risks
Hemmerick (1997)	4	Pensions
Heung and Yu (1998)	4	Computer model
Hout (1997)	2	Competition strategy
Hugunin and Wilemon (1992)	2	Integration of Mkt and R&D depts
Hung et al (1996)	4	Arbitrage pricing
Islei et al (1990)	4	Planning IS systems
Jacob and Young (2003)	2	Finance
Jandourek (1996)	2	Platform development
Jiang and Klein (1999)	4&3	IS services
Jones (1971-1972)	6	Obsolete
Khurana and Rosenthal (1998)	2	Development practices
Kim and Srivastava (1998)	2	Purchasing management
Kirchhoff et al (2001)	4	Systems programs
Kuczmarski (1997)	2	Risk management
Kumar and McCaffrey (1997)	2	Production engineering
LaPlaca (1997)	2	Marketing strategy
Leung (1997)	2	Project management
Loch and Bode-Greuel (2001)	2	NPD practices
Loch (2000)	2	NPD practices
Locke (1972)	2	NPD practices
Lumsden (1997)	2	Consultant workshop
Maas (1998)	2	"Publicity" see 2.94
McMillan (2001)	4	Technical

Markham et al (1991)	2	R&D management
Morris (2002)	3	Services
Nagpau (1985)	2	Project management
Narula (2001)	2	Make or buy decisions
Newton (2001)	2	Uncertainty management
Nihtila (1999)	2	Cross functional organizations
Nijssen and Lieshout (1996)	2	Project management
Payne and Turner (1999)	2	Disruptive technologies
Perigrim (2000)	2	Disruptive technologies
Prichard and Pullan (1997)	2	Innovation
Regan and Holtzman (1995)	4	S systems
Roberts (1969)	2	Technology forecasting
Roetheli et al (1986)	2	Control of R&D budgets
Scherer and Harhoff (2000)	2	Technology policy
Schiavina (1979)	2	Economics
Segelod (2002)	2	Finance
Sharpe and Keelin (1998)	2	Competing managers
Shenhar (2000)	2	Risk management
Shenhar (2001)	2	Project management
Sirbu (1978)	2	Government initiative
Smith and Jan (1993)	2	Finance
Snee and Rodebaugh (2002)	2	6 sigma
Souitaris (2002)	2	Greek investment strategy
Sundbo (1996)	2	People management
Thakkar et al (1998)	2	Mkt. strategy
Tieleman (1981)	2	R&D management
Walsh (2001)	2	Reported as Linton &Walsh
Wang (2002)	2	Risk
Webber et al (2002)	4	Manufacturing
Whetstone (2002)	2	Mkt. strategy
Wilhelmsson and Mcqueen (1999)	2	Operations
Winkofsky et al (1981)	2	Decision theory
Zahra (1996)	2	Venture capital

2.96 Included papers

The 43 papers selected for inclusion are listed in fig 2.14 together with the inclusion criteria listed in section 2.61.

	Inclusion criteria							
Author Date	**1**	**2**	**3**	**4**	**5**	**6**	**7 ***	**8**
Ausura (2003)	x	x	x	x		x	x	x
Ayal and Rothberg (1986)	x		x	x		x	x	x
Bhoovaraghavan et al (1997)	x		x	x	x		x	x
Bond and Houston (2003)	x		x	x	x		x	x
Cabral (1994)	x		x	x	x		x	x
Cardozo and Wind (1985)	x		x	x		x	x	x
Cooper, K et al (2002)		x	x	x		x	x	x
Cooper et al (1997)	x		x	x	x		x	x
Cooper et al 1998.	x		x	x	x		x	x
Cooper et al (1999)	x		x	x	x		x	x
Cooper (2000)	x		x	x	x		x	x
Cooper et al (2001)	x		x	x	x		x	x
Cote and Stanmeyer (2001)		x	x	x		x	x	x
De Maio et al (1994)	x		x	x		x	x	x
Elonen and Artto (2003)	x		x	x	x		x	x
Firth and Narayanan (1996)	x		x	x	x		x	x
Fox et al (1984)	x		x	x	x		x	x
Ghasemzadeh and Archer (2000)	x		x	x	x		x	x
Graves and Ringuest (1992)	x		x	x	x		x	x
Graves et al (2000)	x		x	x	x		x	x
Griffin (1997)	x		x	x	x		x	x
Griffin (2002)	x		x	x	x		x	x
Harmsen et al (2000)	x		x	x	x		x	x
Hendriks et al (1999)	x	x	x	x		x	x	x
Jolly (2003)	x		x	x	x		x	x
Liberatore (1987)	x		x	x		x	x	x
Lint and Pennings (1998)	x		x	x	x		x	x
Lint and Pennings (2001)	x		x	x	x		x	x
Linton et al (2002)	x	x	x	x		x	x	x
Luehrman (1998)	x		x	x	x		x	x
MacMillan and McGrath (2002)	x		x	x	x		x	x
Mandakovic and Souder (1990)	x		x	x	x		x	x
Meadows (1999)		x	x	x		x	x	x
Mikkola (2001)	x		x	x		x	x	x
Platje et al (1994)		x	x	x		x	x	x
Purdue and McAllister (1999)		x	x	x	x		x	x
Repenning (2001)	x		x	x	x		x	x
Rosenau (1999)	x	x	x	x		x	x	x
Spital (1979)	x		x	x	x		x	x
Spradlin and Kutoloski (1999)		x	x	x	x		x	x
Tritle et al (2000)		x	x	x	x		x	x
Van Arnum (1998)		x	x	x		x	x	x
Verma and Sinha (2002)	x	x	x	x		x	x	x

x denotes inclusion.
* Inclusion criteria 7, papers from 1980 removed as discussed in section 2.6, therefore all papers met time requirements.

Fig 2.14: Inclusion criteria.

2.97 Quality assessment

The quality assessment tool described in section 2.8 was applied to the papers included in the systematic review and the results listed in fig 2.15.

Quality Assesment	Score					
Author Date	Contribution	Method	Analysis	Findings	Relevance	Total
Ausura (2003)	2	2	2	2	3	11
Ayal and Rothberg (1986)	3	3	3	3	3	15
Bhoovaraghavan et al (1997)	4	3	3	3	3	16
Bond and Houston (2003)	3	3	3	3	3	15
Cabral (1994)	4	3	3	4	4	18
Cardozo and Wind (1985)	3	4	3	3	3	16
Cooper, K. et al (2002)	2	2	2	2	2	10
Cooper et al (2001)	*4*	*4*	*3*	*4*	*4*	*19*
Cooper (2000)	3	3	3	3	3	15
Cooper et al (1999)	5	4	5	5	5	24
Cooper et al (1998)	*4*	2	3	4	4	17
Cooper et al (1997)	3	3	3	3	3	15
Cote and Stanmeyer (2001)	2	2	2	2	2	10
De Maio et al (1994)	3	4	3	2	2	14
Elonen and Artto (2003)	3	3	3	2	3	14
Firth and Narayanan (1996)	4	3	3	4	4	18
Fox et al (1984)	3	3	3	3	4	16
Ghasemzadeh and Archer (2000)	*3*	*3*	*3*	*3*	*2*	14
Graves and Ringuest (1992)	2	3	3	3	4	15
Graves et al (2000)	3	2	3	3	4	15
Griffin (1997)	4	4	4	4	3	19
Griffin (2002)	4	4	4	4	3	19
Harmsen et al (2000)	*4*	*4*	*4*	*4*	*4*	20
Hendriks et al (1999)	*3*	*2*	*3*	*4*	*4*	16
Jolly (2003)	*3*	*3*	*4*	*3*	*4*	17
Liberatore (1987)	3	2	3	3	3	14
Lint and Pennings (1998)	3	3	3	4	4	17
Lint and Pennings (2001)	3	3	3	4	4	17
Linton et al (2002)	4	3	3	3	3	16
Luehrman (1998)	3	2	2	2	3	12
MacMillan and McGrath (2002)	3	3	3	3	4	16
Mandakovic and Souder (1990)	2	2	2	2	3	11
Meadows (1999)	2	2	2	2	3	11
Mikkola (2001)	4	4	4	4	4	20
Platje et al (1994)	3	3	3	3	4	16
Purdue and McAllister (1999)	3	2	2	2	2	11
Repenning (2001)	4	3	3	4	4	18
Rosenau (1999)	3	3	3	2	3	14
Spital (1979)	4	3	3	4	4	18
Spradlin and Kutoloski (1999)	3	3	3	3	4	16
Tritle et al (2000)	2	2	3	2	2	11
Van Arnum (1998)	3	1	1	1	4	10
Verma and Sinha (2002)	3	4	3	2	3	15

Fig 2.15: Quality assessment score.

2.98 Practitioner ranking

The authors' scores in the quality assessment were ranked as shown in fig 2.15. It was apparent that the ranking appeared to "favour" academics.

In the first quartile no practitioners made the list. In the second quartile, 2 practitioners were represented though 2 did assist academics, in the third quartile there were no practitioners, though 2 assisted academics. In contrast, in the lowest quartile 6 practitioners were present and one practitioner assisted an academic.

This introduced a dilemma. This systematic review was deliberately scoped to consider the views of practitioners. As discussed in section 2.2 practitioner views are an essential part of the strategy to counter any possible bias of my own practitioner experience. The dilemma was further compounded when considering individual papers. Several of the lower ranked papers, for example the lowest overall ranked paper, Van Arnum (1998), had substantial findings and relevancy in respect to the use of real options in pharmaceutical portfolios, but very low scores for method and analysis. As a consequence the contribution, which as discussed in section 2.8, is determined by, appropriateness of method, epistemological integrity and theoretical considerations was also low. Deeper investigation of real options pricing more fully discussed in section 3 reveals that Van Arnum's point may well have substance. Cooper et al (1999), coincidentally the highest ranked paper in the assessment, McMillan and McGrath (2002) and Luehrman (1998) all discuss the use of real options. Indeed Purdue and McAllister (1999) specifically report that Westinghouse use real options in portfolio management. Could it be that Academics write in a rigorous format which is required for acceptance to academic journals, whilst practitioners may be discouraged from doing this for practitioner journals? Alternately the practitioner might simply be incorrect.

Several steps were considered. Most radically, should the quality assessment criteria be replaced for example by Rose's model? (Rose, 1982). However Rose's model would produce a similar result (Rose, 1982). Should there be two different assessment models used for academics and practitioners? This is certainly a possibility, but for what purpose? It was decided that it was important to capture any possibility of difference of opinions between academics and practitioners as this in itself may provide a possible research gap. Indeed, providing the practitioner findings were reasonable, gaps in the rigor of method and analysis might lead to providing research opportunity. Ultimately all the practitioner papers as previously discussed and even the lowest ranked Van Arnum (1998) were considered to be relevant to the systematic review. However it was felt important to maintain an audit trail. The findings reported in section 3 would be clearly labeled as academic, practitioner or both. Additionally in the "possible gap" analysis shown in Section 5 the quality assessment score was reported so that "evidence" could be treated with some "caution", if the reader desired.

.

Author Date	Practitioner	Contribution	Method	Analysis	Findings	Relevance	Total
Cooper et al (1999)		5	4	5	5	5	24
Harmsen et al (2000)		4	4	4	4	4	20
Mikkola (2001)		4	4	4	4	4	20
Cooper et al (R 2001)		4	4	3	4	4	19
Griffin (2002)		4	4	4	4	3	19
Griffin (1997)		4	4	4	4	3	19
Cabral (1994)		4	3	3	4	4	18
Firth and Narayanan (1996)		4	3	3	4	4	18
Repenning (2001)		4	3	3	4	4	18
Spital (1979)		4	3	3	4	4	18
Jolly (2003)		3	3	4	3	4	17
Lint and Pennings (1998)		3	3	3	4	4	17
Lint and Pennings (2001)		3	3	3	4	4	17
Cooper et al (1998)		4	2	3	4	4	17
Bhoovaraghavan et al (1997)		4	3	3	3	3	16
Cardozo and Wind (1985)		3	4	3	3	3	16
Fox et al (1984)		3	3	3	3	4	16
Hendriks et al (1999)	pa	3	2	3	4	4	16
Linton et al (2002)	pa	4	3	3	3	3	16
MacMillan and McGrath (2002)	p	3	3	3	3	4	16
Platje et al (1994)		3	3	3	3	4	16
Spradlin and Kutoloski (1999)	p	3	3	3	3	4	16
Ayal and Rothberg (1986)		3	3	3	3	3	15
Bond and Houston (2003)		3	3	3	3	3	15
Cooper et al (1997)		3	3	3	3	3	15
Cooper (2000)		3	3	3	3	3	15
Graves and Ringuest (1992)		2	3	3	3	4	15
Graves et al (2000)		3	2	3	3	4	15
Verma and Sinha (2002)	pa	3	4	3	2	3	15
Elonen and Artto (2003)		3	3	3	2	3	14
Ghasemzadeh and Archer (2000)		3	3	3	3	2	14
Liberatore (1987)		3	2	3	3	3	14
Rosenau (1999)	pa	3	3	3	2	3	14
De Maio et al (1994)		3	4	3	2	2	14
Luehrman (1998)		3	2	2	2	3	12
Ausura (2003)	pa	2	2	2	2	3	11
Mandakovic and Souder (1990)		2	2	2	2	3	11
Meadows (1999)	p	2	2	2	2	3	11
Purdue and McAllister (1999)	p	3	2	2	2	2	11
Tritle et al (2000)	p	2	2	3	2	2	11
Cooper, K et al (2002)	p	2	2	2	2	2	10
Cote and Stanmeyer (2001)	p	2	2	2	2	2	10
Van Arnum (1998)	p	1	1	1	3	4	10

Notes
p denotes practitioner
p.a. denotes practitioner and academic

Fig 2.16: Ranking by occupation (practitioner /academic).

2.10 Stage 3 Extracting, disseminating and synthesising the data

2.11 Descriptive and thematic findings

Each of the 43 papers was disseminated and its descriptive details captured. A set of 43 descriptive tables, an example of which is shown in fig 2.17, was generated listing by author, date and title of paper the key details of the paper. The table shows whether the author(s) was an academic, practitioner or both, the type of study and the country in which the subject of the study *(not necessarily the researcher)* resided. Details of the study, for example the numbers of firms in the study, their names and size are also listed. The key findings of the study were then summarised and reported in landscape format. (See section 3.2).

Upon completion of the 43 descriptive tables, the component data was consolidated and reported in the general findings. (see section 3.1) This provided consolidated information.

- Analysis of the countries where the studies were conducted.
- Ratios of quantitative and qualitative research methods.
- Ratios of academic and practitioner research.
- Analysis of studies by industry/business sector.
- Names of firms featured in the systematic review.

The Agilent portfolio management material was "quarantined" from the descriptive tables and reported separately in section 3.3 exactly as summarised by Agilent. This will be used during the discussion of findings, discussed in section 2.14 to offer both a practitioner's real life example and potentially to act as a measure to attempt to reduce possible bias. Additional information, such as a summary of the major portfolio methods firms used to conduct portfolio management, the popularity of these methods, and "high level" perception of the satisfaction with these methods is shown in section 3.4 and 3.5.

Fig 2.17: Key findings. *(Example).*

Author date paper	Country of study	Details of study	A/P	Findings
Firth and Narayanan (1996) "New Product Strategies of Large, Dominant Product Manufacturing Firms: an Exploratory Analysis."	USA	18 large companies (multi billion dollar) 459 new products introduced during a 5-year period. Merk. Rohr, Abbott IFF, Mobil, Varian Medrtronics, Helen Curtis Tonka, Joostents Maytag, Clorox Deere, Sun, Scott Wang, AMP	A	Three dimensions of new product introductions, newness of embodied technology, newness of market application, and innovativeness in the market. Identifies 5 strategies. 1 Innovators, who produce innovative products by using their existing resources. 2 Investors in Technology, who focus on expanding their technological base. 3 Searching for New Markets, firms that venture into unfamiliar markets by introducing products closely aligned with those in their existing portfolios.

				4 Business as Usual firms that rely on existing technologies and products to serve existing markets. 5 Middle-of-the-road, firms content to introduce new products rated as low to moderate along all three dimensions of the strategic profile. Firms that emphasised market innovativeness in their new product enjoyed higher returns than less innovative firms. They gained this advantage without an accompanying increase in risk. Continual innovation might provide a large firm with the means for achieving higher returns without higher risk!

2.12 Thematic analysis

Whilst disseminating the 43 papers to determine the descriptive details and findings, each paper was grouped into themes. Many, in fact most papers, had multiple themes. On completion of the full exercise, 17 major themes had emerged. These themes were then reconsidered, and upon reflection, 7 were considered to be subsets of other main themes and consolidated back into these groups.
Upon completion of the exercise these were grouped into 10 major themes.

These were :-

Risk
Technology
Re-use (Platform)
Market
Finance
Size of company
People management
Level of innovation
Strategy
Competition
Investment/resource allocation (Agilent verification)

Academic and practitioner verification

These themes underwent academic verification. This was essentially a supervisor review. The conclusion of the academic verification was that the themes extracted adequately covered the systematic review.

Additional verification of the 10 themes was undertaken using Agilent as a reference. Via Prof. Goffin, Agilent had provided 50 foils describing their portfolio management process and their philosophy towards portfolio management. Amongst these was a single page summary checklist of critical questions Agilent raised when making their final portfolio decisions (reported in section 3.3). This checklist was compared against the 10 themes. An additional theme of investment/resource allocation decisions was found to be present. Cooper et al (1997) might suggest that, as they believe strategy only begins when money is invested, this could be grouped with the existing strategy theme or perhaps other themes. A decision was taken to include the theme. The rationale for this decision was that Agilent was part of my strategy to eliminate my own possible bias or preconceptions reported in section 2.2. ARM

provided an additional verification cycle, confirming the themes looked "reasonable" but did not wish to make public their proprietary checklist or process.

Having decided on the major themes, the sub themes were captured in excel and ultimately a word file adopting a similar "What we know?" format to that used in a Loughborough, Psychology PhD thesis (Tranfield, 2003). In the case of portfolio management this was frequently in reality a statement as to what we *may* know?

An example is the study shown in fig 17, "New Product Strategies of Large, Dominant Product Manufacturing Firms an Exploratory Analysis" (Firth and Narayanan, 1996). It should be apparent from the descriptive table on page 41 that the paper is referring to large companies, resources (including people), technology and the innovation risk advantages the authors believe they may have over smaller companies. On page 41 it is stated that;

*"Continual **innovation** might provide a **large** firm with the means for achieving higher returns without **higher risk.**" "Firms that emphasised **market innovativeness** in their new product enjoyed higher returns." "Investors in **technology**, who focus on expanding their **technological base**". "**Innovators**, who produce **innovative** products by using their existing **resources**"* (Firth and Narayanan, 1996).

The component sub theme, "Risk portfolios *may* be more appropriate for ***large*** innovative firms", was captured as shown in fig 18 with the supporting comments. Note that the example has several other references which are also themes, technology, innovation, market and large. These sub themes were also captured as shown in fig 2.19 for comparison with other authors comments.

Fig 2.18: Example of sub theme.

Risk	
What we know	**Comments/reference**
Risk portfolios *may* be more appropriate for ***large*** innovative firms.	*Large innovative firms enjoyed higher returns than less innovative firms, without an accompanying increase in risk. Continual innovation might provide a large firm with the means for achieving higher returns without higher risk!! Firth* and *Narayanan (1996).*

Fig 2.19: Summary of authors and dates of the major themes listed.

Theme	**Author**
Risk	Bond and Houston (2003) Cabral (1994) Cardozo and Wind (1985) Cooper et al (1997) Cooper et al (1998) Cooper et al (1999) ***Firth and Narayanan (1996)*** Ghasemzadeh and Archer (2000) Graves et al (2000) Lint and Pennings (2001) Tritle et al (2000)

	Van Arnum (1998)
Technology	Cooper et al (1999) ***Firth and Narayanan (1996)*** Jolly (2003) Mikkola (2001) Verma and Sinha (2002) Mandakovic and Souder (1990) Purdue (1999)
Market	Boovaraghavan et al (1997) Cooper et al (1999) Cote and Stanmeyer (2001) ***Firth and Narayanan (1996)*** Griffin (1997) Griffin (2002) Spital (1979)
Size of company	Cooper et al (1998) Cote and Stanmeyer (2001) ***Firth and Narayanan (1996)*** Hendriks et al (1999) Platje at al (1994)
Level of innovation	Bhoovaraghaven et al (1997) ***Firth and Narayanan (1996)*** Griffin (1997) Griffin (2002) Spital.(1979)
Investment/Resource allocation	DeMaio et al (1994) Elonen and Artto (2003) ***Firth and Narayanan (1996)*** Ghasemzadeh and Archer (2000) Hendriks et al (1999) Liberatore (1987) Meadows (1999) Platje at al (1994) Repenning (2001) Rosenau (1999) Tritle et al (2000) Van Arnum (1998)

2.13 Synthesis

The conceptual process used for synthesis, reporting and possible gap analysis is shown in fig 20. Upon completion of the thematic tables the author's theme could be compared and contrasted with other themes and sub themes. These in turn could be considered against the descriptive analysis and tables shown in section 3.

To illustrate for example in the large company sub themes, Cote and Stanmeyer (2001) suggest that large companies can leverage their brand strength to form alliances that complement the product portfolio. (Generally supporting the point that large firms *may* have an advantage managing their portfolios). However Bond and Houston (2003) suggest that, in large companies, internal competitions exist for limited resources, technology capabilities, and control of market charters. Further that communication and cultural barriers exist between functional units. These *may* (or may not) offset the advantages which Firth and Narayanan (1996) and Cote and Stanmeyer (2001) are considering. Other authors' findings may then be added to the synthesis, to inform discussion and consider the implications to other themes.

In the context of risk, Agilent's summmary check list included "Do we have at least one bold move?".

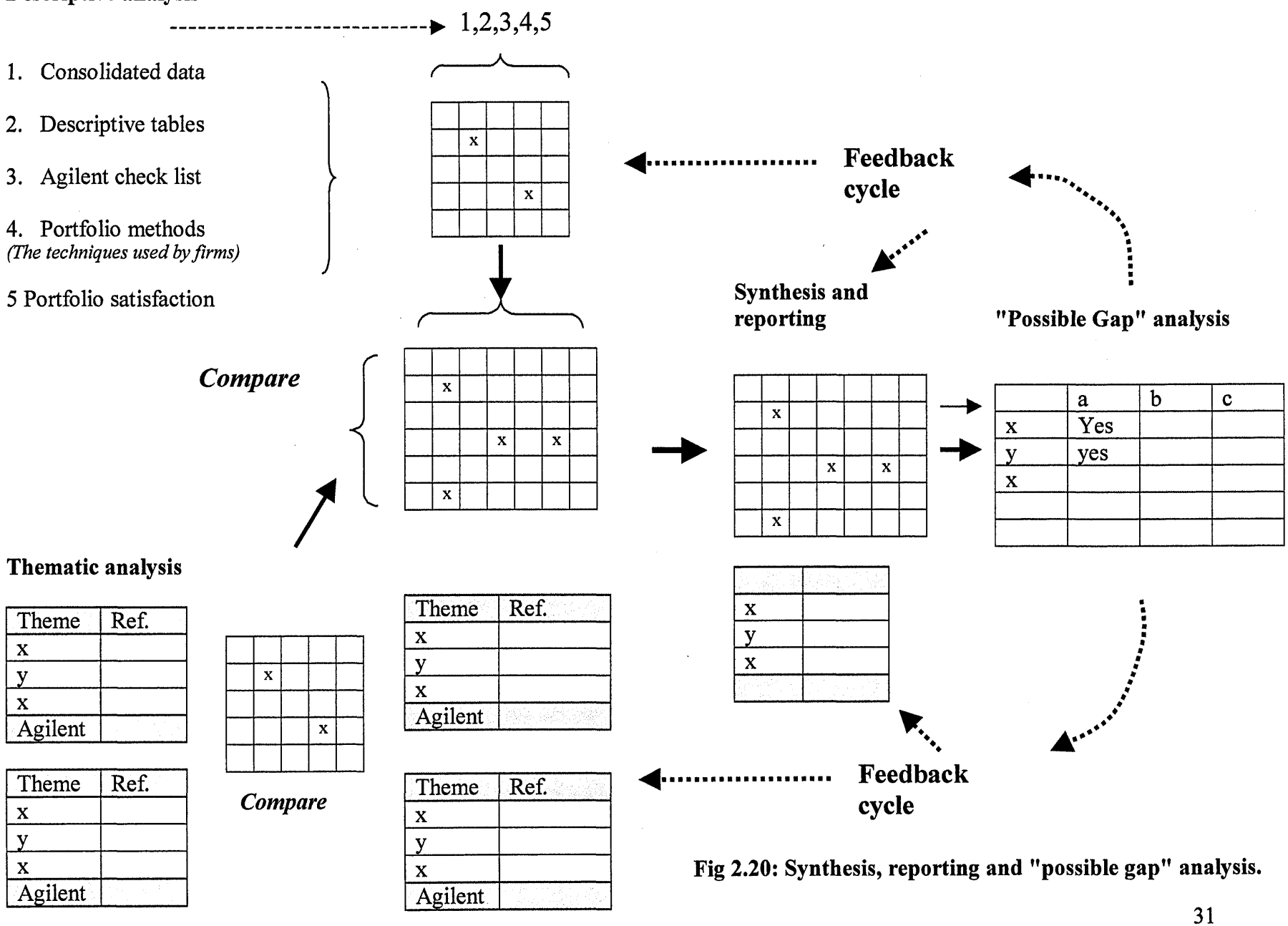

Fig 2.20: Synthesis, reporting and "possible gap" analysis.

As shown in fig 2.20, the results of the thematic comparison could then be compared with the descriptive analysis. More data on the size of company can be pulled from the descriptive tables. For example Section 3.1 Fig 3.8 lists the companies named in the studies. These are:-

Abbott	Deere	Maytag	Scott
Aiwa	Dodge	Medrtronics	Seagate
AMP	English clay	Merk	Sharpe
Bank of	Ford	Mobil	Sony
Canada	Gillette	Philips	Sun
Bell Labs	Helen Curtis	Reilly	Texas
Chrysler Ely	Hoechst	Industries	Instruments
Lilly	Hughes	Rohr	Tonka
CISCO	IFF	Royal Oak	Varian
Clorox	Joostents	Sanyo	Wang
			Westinghouse

From section 3.1, fig 3.7 it is seen that almost 50% of the studies are high tech or pharmaceutical firms.

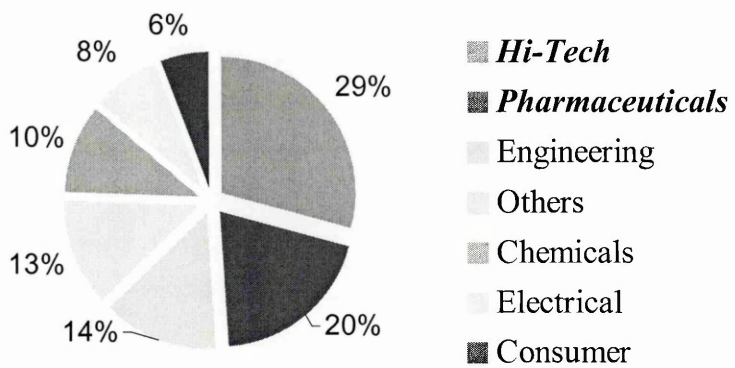

Fig 3.7 Study sector.

"Possible gap" analysis of the systematic review

Theme Z		Type of study			Region			Source		
Author date	Industry studied	Survey	Case	Other	US	Euro	Other	Quality score	P	A
A	Hi. tch	1			1			24		1
B	Pham	1					1	10	1	
C	Hi tech			1			1	12		1
D	Eng.			1	1					1
E	Auto				1					1
F	Chem			1	1					1
Total		1			4		2		1	5
Possible gap?		3	yes	3		yes				

Fig 2.21: "Possible gap" analysis.

The dissemination of the descriptive data enabled the construction of "possible" gap analysis tables, the format of which is shown in fig 2.21. Multiple "possible gap" analysis tables grouped by each major theme were used to capture high level details from the descriptive analysis. Details such as; the author and date, the type of study, categorised as survey, case study or other, the industry studied, and the region categorised as US, Euro or Other, in which the firm which was the subject of the study resided. The quality assessment score was recorded and also whether the researcher(s) were academics, practitioners or both.

Upon completion of the full possible gap analysis of all the themes the consolidated results were compiled for high level discussion of possible gaps. The additional insight offered by the "possible gap" analysis, as described in fig 2.20, could then be fed back into the descriptive and thematic analysis to interrogate whether additional information could be obtained from the source databases. In turn this might produce additional material to be included in the descriptive, thematic and gap analysis tables. This essentially set up a multiple feedback loop as described in fig 2.20.

2.14 Reporting and Discussion

Fig 22 shows a simplistic and abbreviated example of the format used to report and discuss the findings in section 4. The top of the form gives an executive summary of the number and types of studies which were found in the systematic review and in which region etc. This is referenced back to the full gap analysis tables shown in fig 2.21 and also, if the reader desires, back to the descriptive analysis, an example of which is shown in fig 2.17. The major points emerging from the synthesis are then discussed. Immediately below the discussion is a brief summary of Agilent's practices to enable a real life practitioner perspective to be compared with the discussion. This also enables some level of possible bias screening to occur, as discussed in section 2.2. In the event that there are any possible future research requirements emanating from the discussion, these are tabulated at the end of the format. Upon completion of the discussion a consolidation of all the future research requirements are carried forward for discussion in section 5.

Studies	**Type of study**			**Region**			**Pract//Acad**	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.21 Market	1	2	5	8	***yes***	2	4	6

*** possible gap**

Discussion

Integrated organisations promote synergy (Griffin, 2002).Cooper (2000) mainly agrees, but has a different emphasis on ...etc.

Practitioner comparison	**Check list** ***Reference section 3.3***
	Do we focus on the right strategic customers?

Possible future research requirement	
4.5 Markets	1. Absence of Europe regional study
	2. Etc
	3. Etc

Fig 2.22: Reporting format. *(Abbreviated example)*

2.15 Synthesis of "possible research" ideas

Upon completion of the report forms shown in Fig 2.22 Reporting format, 17 research ideas emerged from the systematic review discussion in section 4. These were then combined with the consolidated "possible gap analysis" reports (see fig 2.21) for synthesis and further discussion as reported in section 5.

Though each of the research ideas appeared to present good research ideas in their own right, an additional step was taken to try a) to select the highest potential ideas, and b) provisionally to assess if any potential synergy might exist between the ideas. Each research idea was * ***compared*** against the other and the results presented in the format shown in fig 2.23. Each pair of ideas was labelled to represent the likelihood of possible synergy existing between them, then labelled as either (1 = low, 2 = med 3 = high).

Reference				**4.5**			**4.7**		**4.8**			**4.9**					
Ref.	**4.2**	**4.3**	**4.4**	***A***	***B***	**4.6**	***A***	***B***	***A***	***B***	***C***	***A***	***B***	***C***	**4.10**	**4.11**	**4.12**
4.2	**0**	3	3	3					3	3			3	3	3	3	3
4.3	3	**0**			3								3				
Etc	3		**0**							3						3	
Total		X	Y	z													

Fig 2.23: Possible synergy existing between the potential research areas.

Upon completion of the exercise, each column was totalled and then ranked. The top 4 research ideas were then selected for a further level of synthesis. The results of this together with the 17 original research ideas were then recommended for additional investigation to determine their suitability for further research.

***Important note**, originally this comparison was planned to be conducted with an independent practitioner from ARM. Unfortunately it had not been possible to conduct the exercise in the time allowed for the thesis submission. The exercise was therefore conducted with the support of an individual from my employer. Though the support came from an extremely experienced practitioner, it is recognised that this might be considered to have introduced possible bias into the exercise. This is further discussed in section 6 as one of the limitations of the systematic review.

3.1 General descriptive findings

Country of firm studied	Frequency
North America (USA and Canada)	27
Holland	4
Europe	2
Denmark	2
USA/Japan	2
Finland	1
USA/Chile	1
USA/Israel	1
USA/Portugal	1
USA/UK	1
France	1
Total	43

Fig 3.1: Country of study.

The systematic search appears to suggest that the leading US academics and practitioners significantly influence the field of portfolio management. The dominant number of studies were conducted in the North America market, in fact half the studies were conducted with firms based in the USA and Canada. Furthermore the quality assessment scores of most of these North American papers, as discussed in section two, were also significantly higher than the Non US papers.

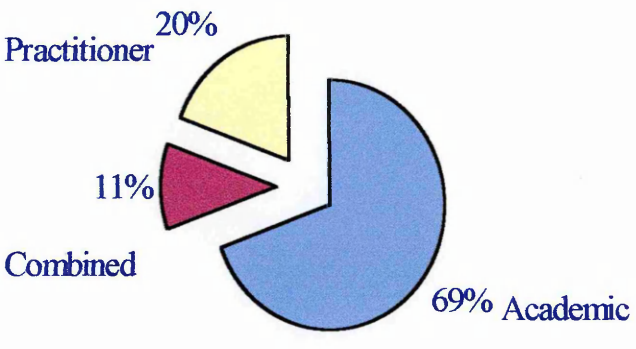

Fig 3.2: Paper/authors.

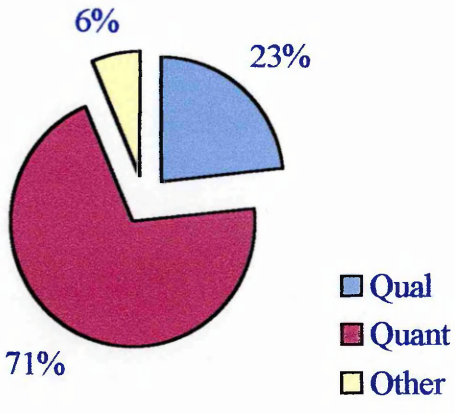

Fig 3.3: Type of study.

The findings highlighted a strong preference for authors to use quantitative methods. In fact studies using quantitative methods made up over two thirds of the total studies included in the systematic review, as shown in fig 3.3.

This was especially the case with the US studies included in the systematic review, as shown in fig 3.4, where almost all the US academic papers were written using a substantially quantitative approach. Practitioners largely wrote the US qualitative papers. Academics were substantially involved in the portfolio management field. Academics authored over two thirds of the studies and participated with practitioners

in a further 11% of the studies as shown in fig 3.2. Europe and the other regions, though also showing a preference for quantitative studies, had more than twice the percentage of US qualitative papers (as shown in figure 3.5). One third of the papers were qualitative.

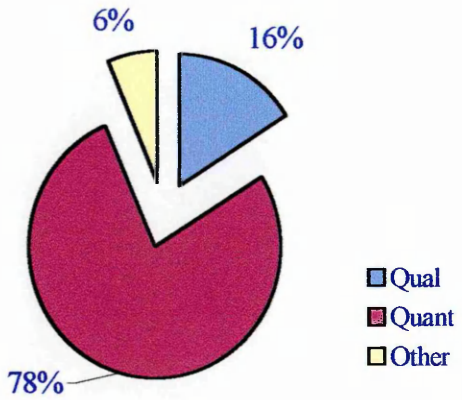

Fig 3.4: North America.

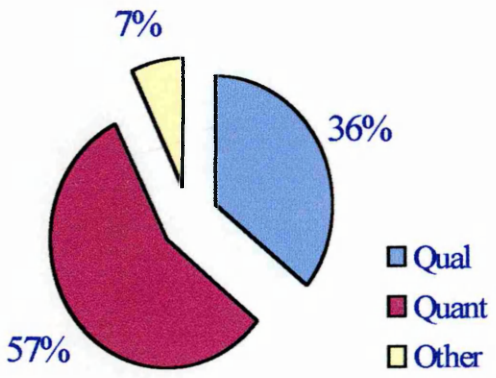

Fig 3.5: Europe/Others.

The subjects of the studies included in the systematic review were drawn from several diverse industries (see fig 3.6 & 3.7), but it is also apparent that the high technology and pharmaceutical industries combined accounted for half of the studies. The individual companies named are listed in fig 3.8.

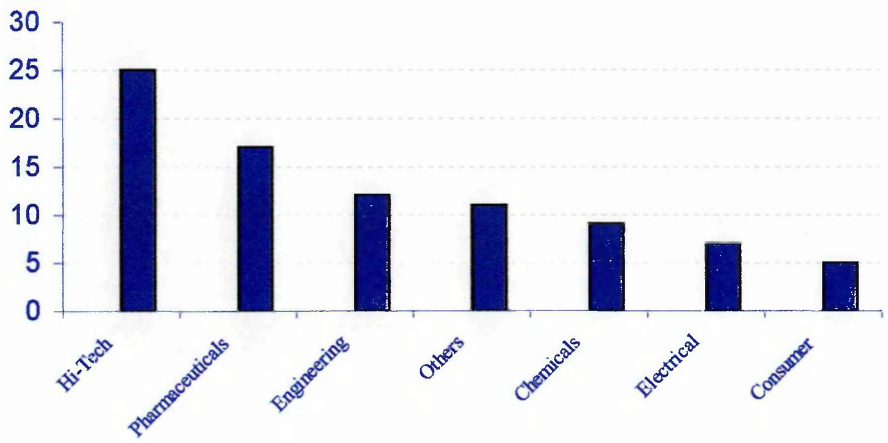

Fig 3.6: Study sector analysis.

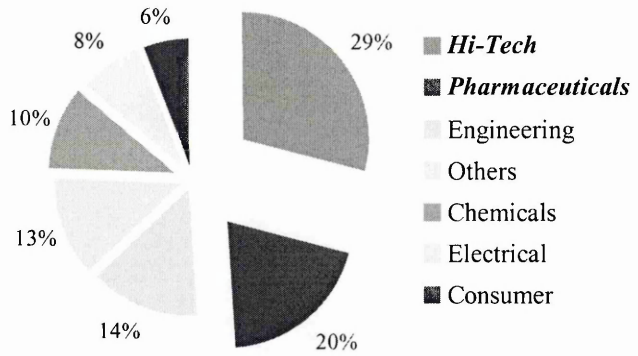

Fig 3.7: Study sector.

Abbott	Deere	Maytag	Scott
Aiwa	Dodge	Medrtronics	Seagate
AMP	English clay	Merk	Sharpe
Bank of	Ford	Mobil	Sony
Canada	Gillette	Philips	Sun
Bell Labs	Helen Curtis	Reilly	Texas
Chrysler Ely	Hoechst	Industries	Instruments
Lilly	Hughes	Rohr	Tonka
CISCO	IFF	Royal Oak	Varian
Clorox	Joostents	Sanyo	Wang
			Westinghouse

Fig 3.8: Companies named in the studies.

3.2 Description and Findings

Author Date Title	Country region	Business Sector	Academic/ Practitioner	Findings :
Ausura (2003) "Recapturing 'True' Life Cycle Portfolio Management; The Path to More Successful Product Development."	USA	High-tech	Academic Practitioner	Product development professionals should take a more holistic view of portfolio management. An *almost fanatical obsession with "new product development"* and "product innovation" has driven companies, academics and consultants *to focus exclusively on the new product area* as to almost totally ignore portfolio life cycles. This has driven *wrong behaviours* in portfolio management.
Ayal and Rothberg (1986) "Strategic Control of R&D Resource Allocations in Diversified Businesses."	USA (Israel)	Hospital Equipment Chemical (Parent Company)	Academic	A distinction between *effectiveness* and *efficiency* of R&D spending. Most companies over control such allocations in terms of tactical detail or efficiency considerations, and under control in terms of strategic significance or effectiveness. Effectiveness of allocations requires that management assess the linkage between R&D spending and the attainment of overall corporate goals.
Bhoovaraghavan et al (1997) "Resolving the Process Vs. Product Innovation Dilemma: A Consumer Choice Theoretic Approach."	USA/ Japan	High tech	Academic	Compares global American and Japanese firms. Argues against the success of the Japanese being due to their emphasis on *process innovation* rather than *product innovation* and views the two types of innovation as being two ends of a continuum. American firms, due to their firm/supply orientation, have focused on product innovations and have tended to ignore uncertainty associated with product adoption. As a result, many product innovations have high degrees of uncertainty at the time of adoption by customers. Japanese firms, having taken a customer/demand orientation, tend to develop products incrementally, resulting in less uncertainty at the time of adoption.
Bond and Houston (2003) "Barriers to Matching New Technologies and Market Opportunities in Established Firms."	USA	High tech	Academic	Research and development (R&D) allocations in high tech industries are greatly dependent on forecasts of the R&D projects estimated. The resource allocation decisions are difficult, as both markets and technology are likely to be highly uncertain. Internal competition exists for limited resources, technology capabilities, and control of market charters. Communication and cultural barriers exist between functional units. Notes language barriers are more difficult within the high technology sector.
Cabral (1994) "Bias in Market R&D Portfolios."	USA/ Portugal	Pharmaceutical	Academic	Economics argument that Market competition implies an equilibrium level of risk which is too low. Divergence between private and social marginal benefits from R&D is greater the greater the probability of discovery by the rival firms;

				and this probability is therefore higher for lower risk projects.
Cardozo and Wind (1985) "Risk Return Approach to Product Portfolio Strategy."	USA	Anonymous B2B	Academic	Risk-return portfolio analysis, can be applied to product-line decisions. However estimates of return often *lack explicit treatment of risk.* By accommodating risk, organisations can better apply risk return portfolio analysis to their product portfolio decisions.
Cooper, K. et al (2002) "Learning to Learn, From Past to Future."	USA/UK	Hughes, P.A. consulting	Practitioner	Systematically extracting and disseminating lessons learnt during project execution. Stresses the value of project commonality and the importance of rework cycles.
Cooper et al (1997) "Portfolio Management in New Product Development: Lessons From the leaders."	North. America	35 various 5 "in depth" case studies High tech Seagate English clay US div of Hoechst Bank of Canada	Academic	Study of portfolio management practices in industry reveals 3 goals: 1. Maximising the value of the portfolio, 2. Achieving the right balance and mix of projects, and 3. Linking the portfolio to the business's strategy. Maximising the portfolio's value is achieved by means of various financial models, including the Expected Commercial Value method and the Productivity Index. Strategic scoring models are also used to maximise the value of the portfolio. Achieving a balanced portfolio is difficult. Recommend the use of bubble diagrams and other visual models. Reluctance to kill projects. Finds that "resource commitments are quite firm" and " the human side, team morale, commitments and not "jerking around" the project team or leader is more important."
Cooper et al (2001) "Portfolio Management for New Product Development: Results of an Industry Practices Study."	North America	Survey of 205large diverse. See Fig 3.9 Section 3.4 Page 49	Academic	Portfolio management is critical to new product success. Financial methods, although the most popular and rigorous, yield the worst results overall, while top performing firms rely more on non-financial approaches strategic and scoring methods. Surveys of the details of how some of these more popular methods are employed by firms to rate and rank development projects are also provided.
Cooper (2000) "Winning with new products, Doing it right."	North America	Builds on Cooper et al (1997; 1999).	Academic	46% of the resources that companies devote to new products go to ventures that fail in the marketplace and indeed many products don't ever make it to market. Focuses on product selection and product innovation and on how to manage new products. Factors that can make a product successful; Adoption of a stage-gate new-product process; Goals in portfolio management. Build in the voice of the customer. High quality marketing produce double the product

				success rate and 70% higher market share than those products with poor marketing. Ideally there is a balance between high risk and low risk, short term versus long term, genuine new products versus product improvements and extensions.
Cooper et al (1998) "Best Practices for Managing R&D Portfolios."	North. America	Diverse (Not specified but quotes surveys etc from previous study)	Academic	Senior management believed there were four almost equally ranked factors why portfolio management was important. Strategic position, ensuring a competitive position, efficient resource allocation and (company) focus upon product execution. Many companies are struggling with portfolio management, but some organisations are achieving better results, achieving high-value portfolios, cycle time, and portfolio balance. *The leaders are using a hybrid approach* that combines different traditional approaches; *they rely far less on financial methods* for portfolio management, and have an explicitly and *established approach to portfolio management with management buy-in and support.*
Cooper et al (1999) "New Product Portfolio Management: Practices and Performance."	North. America	205 U.S. companies	Academic	Effective portfolio management is about making strategic choices-re which markets, products, *and technologies the business* should invest in. It is about resource allocation focused on selected projects *achieving a balance between the right numbers of projects to do and the available resources.* Some firms face major problems in portfolio management. Businesses are grouped or clustered into four groups Cowboys, Crossroads, Duds, and Benchmark businesses. *(See section 3.5 & Fig 3.11)* Major differences exist between the best and the worst performers. Benchmark businesses employ a much more formal, explicit method for managing their portfolio of projects. They rely on clear, well-defined portfolio procedures; they consistently apply their portfolio method to all projects. Management buys into the approach. Financial approaches are the most popular and dominate the portfolio decision. *(see section 3.4) b*ut dubious results achieved via "only" using financial approaches. Benchmark businesses place less emphasis on financial approaches and more on strategic methods, and use multiple strategic methods, along with scoring approaches, which yield the best portfolios; financial methods yield poorer portfolio results.
Cote and Stanmeyer (2001) "Integrating Alliances and Other	USA	High tech CISCO Sideware	Practitioner (Price Waterhouse	Firms offer diversified products and services. Companies must take into account alliances and develop integrated strategies for managing their existing product and service offerings together with their new product whilst, at the

Business Structures Into Good Portfolio Management."			Coopers)	same time, co-ordinating alliances and new channels. Companies should consider their alliance relationships and channels as part of their portfolios.
De Maio et al (1994) "A Multi-Project Management Framework for New Product Development."	Europe	Diverse	Academic	One of the main causes of project management failure is the need to manage project interdependencies assuring their mutual compatibility at portfolio level and focus on resource interdependencies. Proposes an interpretative model that explains firms' dynamic behaviour in multi-project management of new project development that could be used to support the processes of project selection, resource allocation, risk management, priority management, and ongoing control.
Elonen and Artto (2003) "Problems in Managing Internal Development Projects in Multi-Project Environments."	Finland	Employed organisation-specific interviews, surveys, workshops & two cases	Academic	Identifies 6 problems in managing multiple internal development projects: 1 Inadequate project level activities. 2 Lacking resources, competencies and methods. 3 Lacking commitment, unclear roles and responsibilities. 4 Inadequate portfolio level activities. 5 Inadequate information management. 6 Inadequate management of project-oriented organisation.
Firth and Narayanan (1996) "New Product Strategies of Large, Dominant Product Manufacturing Firms: an Exploratory Analysis."	USA	18 large companies 459 new products introduced during a 5-year period, Medrtronics Helen Curtis Tonka Joostents Maytag Clorox Deere AMP	Academic Merk Rohr Abbott IFF Mobil Varian Sun Scott Wang	Three dimensions of new product introductions: - newness of embodied technology, newness of market application, and innovativeness in the market. Identifies five archetypes of new product strategy: - 1 Innovators, who produce innovative products by using their existing resources. 2 Investors in technology who focus on expanding their technological base. 3 Searching for new markets, firms that venture into unfamiliar markets by introducing products closely aligned with those in their existing portfolios. 4 "Business as Usual" firms that rely on existing technologies and products to serve existing markets. 5 Middle-of-the-road firms content to introduce new products rated as low to moderate along all three dimensions of the strategic profile. Firms that emphasised market innovativeness in their new product enjoyed higher returns than less innovative firms. They gained this advantage without an accompanying increase in risk. *Continual innovation might provide a large firm with the means for achieving higher returns without higher risk!*
Fox et al (1984).	USA	Theoretical	Academic	Present Value (PV) interactions may exist between in R and D projects even

"Economic models for R&D project selection in the presence of project interactions."				though traditionally interactions are assumed to be absent. Study shows that ignoring PV Interactions can result in both non-optimal project selections and resource allocations.
Ghasemzadeh and Archer (2000) "Project Portfolio Selection Through Decision Support."	North America/ Canada	Laboratory tests on commerce "students"	Academic	Project portfolio selection is a crucial decision but the appropriate distribution of investment is complex, due to varying levels of risk, resource requirements, and interaction among the proposed projects.
Graves and Ringuest (1992) "Choosing the Best Solution in an R&D Project Selection Problem With Multiple Objectives."	USA	Theoretical	Academic	Many R&D project selection models have been based on linear programming, leaving the decision maker with the requirement to optimise based on a single objective, when the manager is normally dealing with multiple objectives. Recommend multiple objective linear programming, a technique which overcomes this objection but generates a problem of its own multiple solutions from which the decision-maker must now choose.
Graves et al (2000). "Formulating Optimal R&D Portfolios."	USA	Large unnamed pharmaceutical	Academic	Method for designing optimal R&D portfolios that minimises risk for a given level of return. Assumes that the relevant decision-makers are risk-averse. Compares probability of success with ROI.
Griffin (1997) "PDMA Research on New Product Development Practices: Updating Trends and benchmarking Best Practices."	USA	PDMA survey 1995	Academic / PDMA & Ed Journal Innovation	Conducting a PDMA (Product Development & Management Association) study of firms engaged in B2B and cons, products and services reported a 30% reduction on new product development (NPD) cycle times in 1995 compared to 1990 in part due to improvements and adoption of product development processes. Advocates strong marketing and product development links. Integrated organisations desirable to promote synergy.
Griffin (2002) "Product development cycle time for business-to-business products."	USA	Built on 1997 study of US PDMA members	Academic / PDMA & Ed Journal Innovation	Survey data re-used from Griffin (1997). 68% of US firms use some form of Stage Gate Process similar to Cooper's Stage Gate Process. Differentiates between Firms involved in developing *products* and those involved in developing *services.* Firms involved in *business to business* and *consumer* markets. Four different types of innovation • *New-to-the-world* • *New-to-the-firm*

				• *Next generation* • *Incremental improvements* Advocates strong marketing and product development links. Integrated organisations desirable to promote synergy.
Harmsen et al (2000) "Company Competencies As a Network: the Role of Product Development."	Denmark	513 Danish production companies Small ($6m net revenue) Top managers Perceptions	Academic	Product development ranks behind sales, market responsiveness, and production management. ***A low impact on overall company success*** is found for product development proficiency. Product development enables product differentiation and is considered to be a central competence. .
Hendriks et al (1999) "Human Resource Allocation in a Multi-Project R&D Environment: Resource Capacity Allocation and Project Portfolio Planning."	Holland	Industrial & electrical Eng.	Academic & Practitioner	In a large R&D organisation it was found that a breakthrough in the allocation method could be made by introducing the project scatter factor and the resource dedication profile. The study claims that these indicators significantly simplified the resource allocation process improved project and business results.
Jolly (2003) "The Issue of Weightings in Technology Portfolio Management."	France	High-Tech (Panel of technical experts evaluation.)	Academic	This research explores the underlying components of technological competitiveness and technological attractiveness. 32 criteria 16 are used for depicting technological competitiveness and 16 are used for describing technological attractiveness. The attractiveness of a given technology depends mainly on the potential impact of this technology on the competitive issues, the market volume and the span of applications it opens, its performance relative to other technologies, the competitive intensity of the technical area and, finally, the barriers to imitation. Results show that technological competitiveness depends above all on the value of the 'applied research' and the 'development' teams' competencies, the relatedness of the technology to the company's core business and the time advantage vis-à-vis the competition.
Liberatore (1987) "An Extension of the Analytic Hierarchy Process for Industrial R&D Project."	Europe	Scientific Eng.	Academic	The research and development (R&D) project selection decision must address the allocation of resources to a set of proposals for scientific and engineering activities. Cost-benefit analysis and integer programming can assist in the resource allocation decision. Using microcomputer-based software, such as Expert Choice, can form the basis of an expert support system for R&D project

				selection and resource allocation.
Lint and Pennings (1998) "R&D as an option on market introduction."	Holland	Philips case	Academic	Updated by Lint and Pennings (2001).
Lint and Pennings (2001) "An Option Approach to the New Product Development Process: a Case Study at Philips Electronics."	Holland	Philips case	Academic	Considers the product development process as a series of (real) options with reducing uncertainty over time, providing insight into the product development process at Philips Electronics. Criteria are developed to decide on speeding up or delaying the development process. Demonstrates how, in the R&D phase, any particular project may be assigned within a 2×2 matrix of uncertainty versus R&D option value. The matrices support portfolio management throughout the different phases of development and enable management to decide on an appropriate point at which to abandon individual projects.
Linton et al (2002) "Analysis, Ranking and Selection of R&D Projects in a Portfolio."	USA	Technology Division of Bell Laboratories	.Academic & practitioners	An objective multi-criteria decision making method, Data Envelopment Analysis (DEA), be used to split a portfolio of projects into accept, consider further and reject subgroups. The approach allows for obvious decisions to be automated and complex decisions to be given careful consideration, an approach that is more consistent with how practising managers actually make select/reject decisions. Bell Laboratories report favourable results.
Luehrman (1998) "Strategy As a Portfolio of Real Options Source."	USA	Hypothetical	Academic	Considers strategies as portfolios of related real options and explains how to get from conventional discounted-cash-flow (DCF) value to option value for a typical *project.* By building option pricing into a framework designed to evaluate hard assets but also opportunities, financial insight earlier rather than later into strategy.
MacMillan and McGrath (2002) "Crafting R&D Project Portfolios."	USA (Japan)	Sanyo Gillette Texas Instruments	Academic	Managing different types of real options that can produce a portfolio of research and development projects. Technique in estimating the level of market uncertainty. Conditions in which positioning projects are appropriate. Applications of scouting options and assembling strategic research and development portfolio.

Mandakovic and Souder (1990) "Experiments With Microcomputers to Facilitate the Use of Project Selection Models."	USA Chile	High Tech	Academic	Examining existing R&D project selection models, it was concluded that integrative approaches are the most effective project selection processes. Microcomputers aid the application of integrated approaches and can be a significant tool to assist R&D project selection and resource allocation decision making.
Meadows (1999) "Advanced Workshop: Portfolio Management."	USA	Diverse US industry attendees of 1999 PDMA workshop	PDMA	Advanced Workshop, PDMA's International Conference notes re portfolio management. Portfolio management is a new practice not understood by senior management. Opportunity frequently exceeds resource allocation.
Mikkola (2001) "Portfolio Management of R&D Projects: Implications for Innovation Management."	Denmark	Hi tech Aiwa Sony Sharpe Dodge Ford Chrysler	Academic	Globalisation of markets and new business practices are prompting high-tech firms to reconsider their competitive strategy. Increasing complexity of technologies in addition to shorter product life cycles are also forcing firms to rely on R&D as a source of strategy. Firms are inclined to evaluate their technologies from a portfolio's perspective in relation to R&D projects. R&D Project Portfolio Matrix is used as a tool for analysing a portfolio of R&D projects by linking competitive advantages of a firm to benefits these projects may provide to customers.
Platje et al (1994) "Project and Portfolio Planning Cycle Project-Based Management for the Multiproject Challenge."	Holland	Industrial equipment	Academic/practioner	In a multiproject organisation, resource allocation is a complex process of balancing the (often conflicting) interests of multiple participants' concept of portfolio management that is based *on delegation and communication* required in the multiproject organisation. The planning and control cycle of individual projects needs to be traded off against the interests of project leaders and department heads in a team effort. Proposes a framework, the project-breakdown structure and organisation-breakdown structure are linked.
Purdue and McAllister (1999) "Valuation of R and D Projects Using Options Pricing and Decision Analysis Models."	USA	Westinghouse Science and Technology Centre. 13 embryonic research projects pilot test.	Practitioner	A combination of options-pricing techniques and decision-analysis tools forms a practical process for evaluating R and D projects in a way that correctly values the impact of decision flexibility. The inevitable technical and commercial project-selection decisions can be radically different from those developed using the standard net-present-value financial rule. Decision-analysis tools simplify data acquisition. Method now applied to Westinghouse's complete portfolio of research projects.

Repenning (2001) "Understanding Fire Fighting in New Product Development."	USA	General theory	Academic	A principal source of difficulties in R&D is the phenomenon of fire fighting, the unplanned allocation of resources to fix problems discovered late in a product's development cycle. Fire fighting is a common occurrence in many product development organisations. Fire fighting can be a self-reinforcing phenomenon and multi-project development systems are far more susceptible to this. The current methods for aggregate resource and product portfolio planning, while necessary, are not sufficient to prevent fire fighting and the consequent low performance.
Rosenau (1999) "Portfolio Management & Planning Conference." (PDMA conference summary)	USA	Diverse	PDMA Conference Academic & Practitioner	Importance of projects *relative priority*. Choke points in critical skills/equipment constrain projects causing slippage. Primarily these are human, but managers think of resources financially.
Spital (1979) "An Analysis of the Role of Users in the Total R&D Portfolios of Scientific Instrument Firms."	USA	Survey Analytic Instruments 9 product Dept. in the scientific instrument	Academic	Few new products represented a major advance in functional performance. Most offer only incremental performance improvement; many 'new' products were direct copies of competitors. Users involved in the innovation process, the innovation for either a major functional improvement or a minor improvement but not for response to competitors. The decision of a manufacturer to commercialise an innovation was unrelated to the level of user activity in the prior stages of the innovation process.
Spradlin and Kutoloski (1999) "Action-Oriented Portfolio."	USA	Pharmaceutical Ely Lilly	Practitioner (Ely Lilly)	Presents a method for structuring and managing research and development (*R*&D) portfolios. Effective management of *R*&D activity; steps for building and evaluating *R*&D portfolios.
Tritle et al (2000) "Resolving Uncertainty in R&D Portfolios."	USA	Reilly Industries Royal Oak	Practitioner C.E.O. Royal Oak	Examines the importance of uncertainty when prioritising or allocating limited resources to a portfolio of research and development (R&D) projects. Overview of the methods and techniques employed to assist decision-makers in allocating R&D resources. Identification of uncertainty differences when comparing projects in various phases.
Van Arnum (1998) "Drug Makers Look to New	USA	Pharmaceuticals	Practitioner	Resource allocation is crucial in the *(US)* pharmaceutical industry. The cost of developing a new drug estimated at $250 million to $350 million, yet there are thousands of unsuccessful drugs. Four alternatives are evaluated for each drug.

Strategies in Portfolio Management."				1. A current plan. (Project activity remains unchanged). 2. A buy-up option. (Project spending increases). 3. A buy-down option. (Project spending decreases). 4. A minimal plan. (Project funding ends). Possible value realised for current/ future use.
Verma and Sinha (2002) "Toward a Theory of Project Interdependencies in High Tech R&D Environments."	USA	High Tech Fortune 500	Academic practitioner	Critical for high technology firms to manage multiple-concurrent (R&D) projects with constrained resources. Must understand the interdependencies between projects and their relationship to project performance in a multiple-concurrent R&D environment. Recommends data envelopment analysis (DEA).

Section 3.3 Agilent portfolio management checklist

Fig 3.9 contains the final checklist used by Agilent Senior management to decide and approve their product portfolio. See section 2.12 (page 28), Thematic analysis and section 2.14 (page 33), Reporting and discussion.

Market, wave, customer portfolio

- ❑ Are we playing offensive making the rules?
- ❑ What is the biggest threat to our portfolio?
- ❑ Do we have "seed" or emerging (A) business?
- ❑ Do we focus on the right strategic customers?
- ❑ How focused are our risks by markets, products, customers?
- ❑ Do we have at least one bold move?
- ❑ Do we achieve growth, profit and target market position in each segment?

Product portfolio

- ❑ How is our product portfolio balanced in terms of attractiveness vs risk?
- ❑ How is our product portfolio balanced in terms of time to market?
- ❑ How are we balanced in terms of competitive differentiation and market leadership. Do we play, improve, set the rules?
- ❑ What are the product priorities short and longer term to win our customers and markets? do we recognize/utilize disruptive technology?

Competence, skills, ability

- ❑ Do we manage our B-Business appropriately?
- ❑ Are we confident that we execute successfully?
- ❑ Are we making the best use of our competencies?
- ❑ Do we develop or acquire new competencies?
- ❑ Do we have the right structure, size, flexibility?

Investment portfolio

- ❑ Do we have the right balance between short term and long term?
- ❑ What is the right balance between HW, SW, solution divisions?
- ❑ What are our investment priorities?
- ❑ How much do we spend in which market/segment, wave?

Fig 3.9: Agilent portfolio management checklist.

3.4 Summary of methods portfolio management

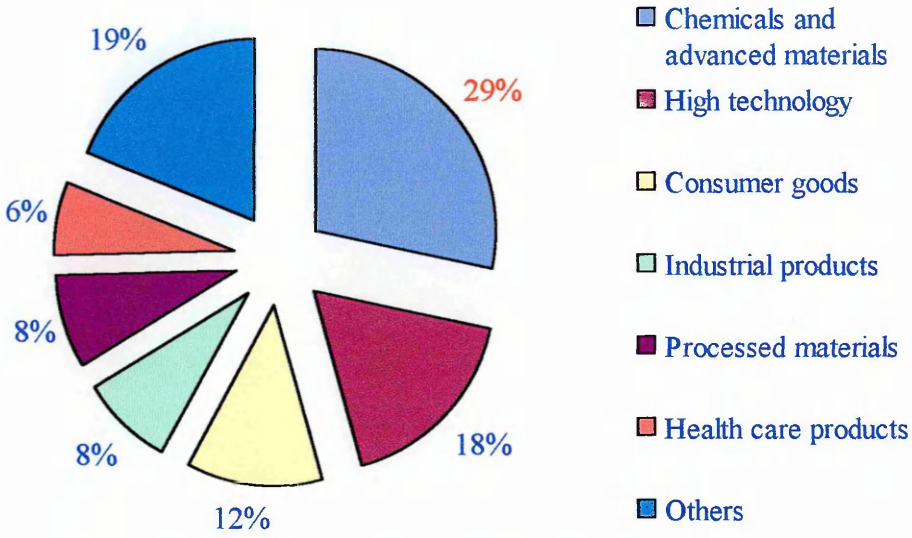

Fig 3.10: Business sectors (Cooper et al, 1999).

Cooper et al (1999) conducted a portfolio management study of Senior Managers from 205 (182 participated) large *US* firms (NR $2B-$7B) engaged in the broad base of businesses segments shown in the pie chart of Fig 3.10.

The survey produced the following eight methods used by respondents in conducting portfolio management: -

1. Financial models and financial indices.

Net present value (NPV), internal rate of return (IRR), and payback method etc.

2. Probabilistic financial models.

For example decision trees and more sophisticated software based solutions, for example Monte Carlo Simulation.

3. Options pricing theory.

Myers (1977) proposed that company value results from assets in place and opportunities to purchase real assets at potentially favourable prices in the future.

Options pricing is a relatively new methodology adopted/investigated by: Kodak (Cooper et al, 1999), Philips (Lint and Pennings, 2001), Bell Labs (Linton et al, 2002), (Luehrman, 1998), Sanyo, Gillette (McMillan and McGrath, 2002), Westinghouse (Purdue and McAllister, 1999) and in the Pharmaceutical industry (Van Arnum, 1998).

See discussion in section 4.2.

4. Strategic approaches.

Product portfolio and deployment of resources is largely driven by the business strategy.

5. Scoring models and checklists.

Projects are rated and scored on qualitative questions, which can capture "proven" drivers of new product success such as product advantage, market attractiveness, leveraging core competencies.

6. Analytical hierarchy approaches.

These are decision tools based on paired comparisons of both projects and criteria. (Models such as *Expert Choice).*

7. Behavioural approaches.

Tools designed to bring managers to a consensus include methods such as Delphi and Q-Sort and are useful for the early gates.

8. Mapping approaches or bubble diagrams.

Essentially extensions of Boston Consulting Group (BCG) portfolio models (stars, cash cows, dogs, wildcats) and the GE/McKinsey model.

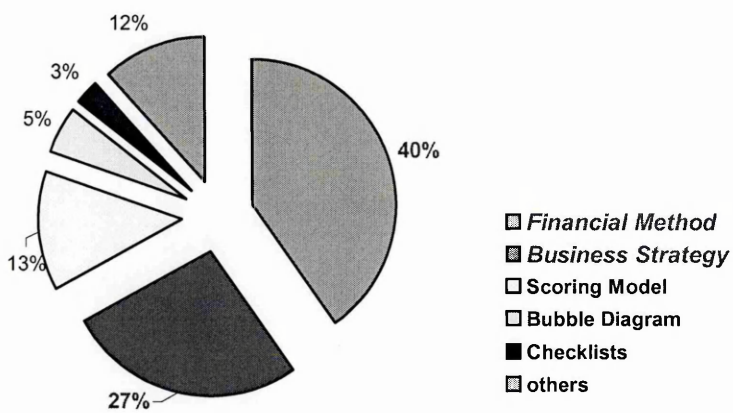

Fig 3.11: Percentage Portfolio Methods Used (Cooper et al, 1999).

The survey by Cooper et al (1999) analysed the different techniques (shown in Fig .3.11). Cooper et al (1999) found that financial methods dominated the portfolio management with 40% of respondents using them. Business strategy methods were nearly 30%.

3.5 Portfolio management satisfaction (Cooper et al, 1999).

Cooper et al (1999) map *four clusters of firms* on a perception/satisfaction map (See Fig 3.12).

- ***Benchmarks***, portfolio methods are high quality and fit management well.
- ***Cowboy businesses***, informal (or no) portfolio management, but fits management's style well.
- ***Crossroads businesses*** high-quality portfolio approach, but does not fit management well. Portfolio management seen as inefficient and ineffective!
- ***Duds*** portfolio management poor on almost every metric.

Though there are 76 benchmark firms where senior management rate their portfolio methods as excellent and effective there are 106, cowboys, duds and crossroad businesses who do not rate their portfolio methods as excellent and/or effective.

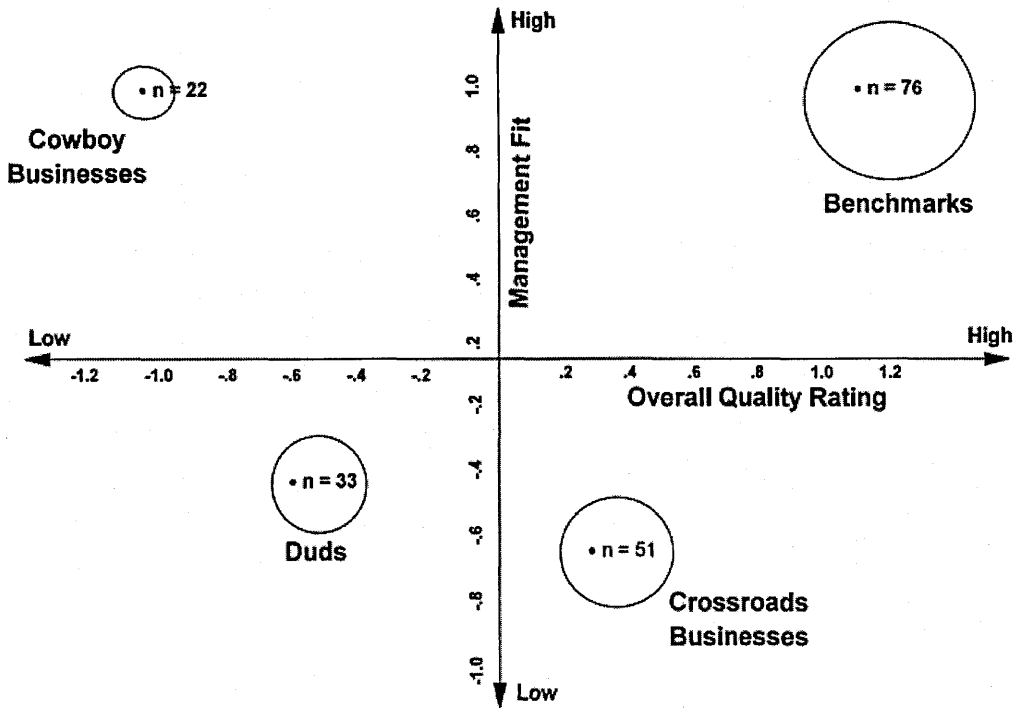

Fig 3.12: 4 Sector Cluster Map (Cooper et al, 1999).

Thematic Tables

3.6 Risk	
What we know	**Comments/reference**
The importance of risk assessment in the portfolio management process.	By accommodating risk, organisations can better apply risk return portfolio analysis to their product portfolio decisions (Cardozo and Wind, 1985). Importance of risk (Cooper et al, 1997; 1999). The importance of uncertainty (Tritle et al, 2000)
Risk substantially complicates the portfolio management process.	Project portfolio selection and the distribution of investment is complex, due to varying levels of risk and resources (Ghasemzadeh and Archer, 2000). Ideally there is a balance between low risk and high risk projects in a portfolio (Cooper et al, 1997; 1999).
Types of risks; competition project execution, market and technology.	The probability of competition from rival firms ***may*** be higher for lower (execution) risk projects (Cabral, 1994). The uncertainty of both markets and technology in resource allocation decisions (Bond and Houston, 2003). 46% of the resources that companies devote to new products go to ventures that fail in the marketplace and indeed many products don't ever make it to market (Cooper, 2000). Project failure (Cooper et al, 1997; 1998; 1999).
(some) Firms underestimate risk	Though risk-return portfolio analysis is important, calculations often *lack explicit treatment of risk* (Cardozo and Wind, 1985).
Risk portfolios *may* be more appropriate for ***large*** innovative firms.	Large innovative firms enjoyed higher returns than less innovative firms, without an accompanying increase in risk. Continual innovation *might provide a large firm with the means for achieving higher returns without higher risk* (Firth and Narayanan, 1996).
The need to stop product development if risks are too high.	The importance of "killing" projects (Cooper et al, 1997; 1998; 1999). Graves et al (2000) assume that decision-makers are risk averse. Management use real options to decide on an appropriate point at which to abandon individual projects (Lint and

	Pennings, 2001). Van Arnum (1998) reports "buy down" options and minimal plans to exit the market in the pharmaceutical industry.
Agilent comparison.	❑ How focused are our risks. Markets, products, customers? ❑ Do we have at least one bold move? ❑ How is our product portfolio balanced in terms of attractiveness vs risk? ❑ Are we confident that we execute successfully?

3.7 Technology	
What we know	**Comments/reference**
Importance of comprehending technology in portfolio management.	Cooper et al (1999) survey data. Firms evaluate their technologies from a portfolio's perspective in relation to R&D projects (Mikkola, 2001)
Different types of portfolio /strategy decisions re investment in technology.	*Investors in technology*, focus on expanding their technological base. *Business as usual*, firms that rely on existing technologies and products to serve existing markets. To introduce new technologies or market applications, business as usual firms tend to acquisition from external sources (Firth and Narayanan, 1996).
Integrating technology selection into R&D portfolio decisions.	Examining existing R&D project selection models, it was concluded that integrative approaches are the most effective project selection processes (Mandakovic and Souder, 1990). Options-pricing techniques and decision-analysis provide a practical process for evaluating Westinghouse R and D projects in a way that values the impact of decision flexibility and the inevitable technical and commercial project-selection (Purdue and McAllister, 1999).
Technological competitiveness is built on competencies.	Technological competitiveness depends on the value of the 'applied research' and the 'development' teams' competencies, the relatedness of the technology to the company's core business, the time advantage vis-à-vis the competition (Jolly, 2003).
Technology competition.	Intensity of competition of high technology firms (Verma and Sinha, 2002).
Agilent comparison.	□ What are the product priorities short and longer terms to win our customers and markets? Do we recognize/utilize disruptive technology?

3.8 Platforms (re-use)	
What we know	**Comments/reference**
The importance of the project interdependencies and methods.	The importance of the project interdependencies. Stresses the value of Project commonality and rework cycle (Cooper, K. 2002). Present value (PV) interactions may exist between R&D projects even though traditionally interactions are assumed to be absent. Study shows that ignoring PV Interactions can result in both non-optimal projects selection (Fox et al, 1984).
Methods of assessing project interdependencies.	Selections and resource allocations (Fox et al, 1984). Resource dedication profile and scatter factor (Hendriks et al, 1999).
Reuse and exit plans.	Even minimal plan when the project funding ends enables value to be realised for current/ future use (Van Arnum, 1998). Senior management reluctance to "kill products" (Cooper et al, 1997; 1998; 1999).
Agilent comparison.	❑ Are we making the best use of our competencies?

3.9 Market	
What we know	**Comments/reference**
Market involvement in product development & portfolio management.	Advocates strong marketing and product development links. Integrated organisations desirable to promote synergy (Griffin, 1997; 2002). New products closely aligned with their core markets and technologies (Firth and Narayanan, 1996).
Importance of alliances as an extension of a firm's portfolio.	To successfully manage their portfolios, companies should consider their alliance relationships and channels as part of their portfolios. Indeed, best practices in each of these areas can inform portfolio management. At the same time, effective portfolio management techniques will improve alliance and channel management (Cote and Stanmeyer, 2001). In the event that "business as usual" wish to introduce new technologies or market applications, they *(often)* turn to acquisition from external sources (Firth and Narayanan, 1996).
User (customer involvement).	Users were involved in the majority of the innovation process when the innovation had not been initiated as a direct response to a competitor's product introduction. However the decision of a manufacturer to commercialise an innovation was ***unrelated*** to the level of user activity in the prior stages of the innovation process (Spital, 1979). The Stage Gate Process (Cooper, 1996). (Described in Section 1.2). Build in the voice of the customer. High quality marketing produce double the product success rate and 70% higher market share than those products with poor marketing (Cooper, 2000).
Demand orientation and regional differences (Japan/US).	Japanese companies appear to have a disposition towards a market orientation, whilst American companies tend towards a supply (product) orientation (Bhoovaraghavan et al, 1997).
Agilent comparison.	**Market, Wave, Customer Portfolio** ❑ Do we have seed or emerging (A) business? ❑ Do we focus on the right strategic customers? ❑ How focused are our risks -> Markets, products,

	customers? ❑ Do we achieve growth, profit and target market position in each segment? ❑ ❑ What are the product priorities short and longer term to win our customers and markets? Do we recognize/utilize disruptive technology? ❑ Do we manage our B-Business appropriately? ❑ How much do we spend in which market segment/ wave?

3.10 Finance	
What we know	**Comments/reference**
Portfolio management is about optimising return on investment.	Cooper et al (1999) define portfolio management as, "the process by which senior management try to select and develop both the winning products and the correct balance of products that they believe will best succeed in the long term and then decide how to most effectively allocate the firm's resources optimising the return on investment."
Product development can require substantial financial investment.	The cost of developing a new chemical entity estimated at $250 million to $350 million. For every blockbuster drug like Viagra, there are thousands of unsuccessful drug candidates absorbing the revenues of pharmaceutical companies (Van Arnum, 1998).
Financial portfolio methods are the most popular.	Financial methods dominated the portfolio management methods used by 205 large US firms with 40% of respondents using them (Cooper et al, 1999).
Dangers of over controlling R&D through financial methods.	Firms need to apply a distinction between *effectiveness* and *efficiency* of R&D spending. Most companies over control such allocations in terms of tactical detail or efficiency considerations, and under control in terms of strategic significance or effectiveness. Effectiveness of allocations requires that management assess the linkage between R&D spending and the attainment of overall corporate goals (Ayal and Rothberg, 1986). Critical choke points (Rosenau, 1999). Firefighting (Repenning, 2001). Benchmark companies *rely far less on financial methods.* Strategic methods, along with scoring approaches, yield the best portfolios; financial methods yield poorer portfolio results (Cooper et al, 1999).
Different results between traditional financial methods and real options.	Options-pricing techniques and decision-analysis tools form a practical process for evaluating Westinghouse R and D projects in a way that values the impact of decision flexibility. The inevitable technical and commercial project-selection decisions that can be radically different from those developed using the standard net-present-value financial rule (Purdue and McAllister, 1999).
Portfolios management using real options.	Respondents list real options as a potential method of portfolio management (Cooper et al 1999). (Survey data) Managing different types of real options can produce a portfolio of research and development projects (MacMillan and McGrath, 2002).

	A combination of options-pricing techniques and decision-analysis tools forms a practical process for evaluating R and D projects in a way that correctly values the impact of decision flexibility and the inevitable technical and commercial project-selection decisions that can be radically different from those developed using the standard net-present-value financial rule (Linton et al, 2002). Building option pricing into a framework designed to evaluate hard assets and opportunities can provide earlier financial insight (Luehrman, 1998). Westinghouse complete portfolio of research projects now use a combination of options-pricing techniques and decision-analysis tools forming a practical process for evaluating R&D projects (Purdue and McAllister, 1999).
Agilent comparison.	❑ Do we achieve growth, profit and target market position in each segment? ❑ How is our product portfolio balanced in terms of attractiveness vs risk? ❑ How is our product portfolio balanced in terms of Time to Market? ❑ How are we balanced in terms of competitive differentiation and market leadership-> play, improve, set the rules?

3.11 Size of company	
What we know	**Comments/reference**
Large firms are the principal subjects of this systematic review.	Survey of 205 large multi-billion dollar US firms (Cooper et al, 1999). The firms are named in the findings Section 3.
Large firms may have advantages over smaller firms.	Large companies typically maintain broader portfolios of products and have easier access to capital markets. Continual innovation might provide a large firm with the means for achieving higher returns without higher risk (Firth and Narayanan, 1996). Value of alliances to complement the product portfolio and leverage the brand (Cote and Stanmeyer, 2001).
Large firms may also encounter difficulties.	Internal competition exists for limited resources, technology capabilities, and control of market charters. Communication and cultural barriers exist between functional units. Notes language barriers are more difficult within the high technology sector (Bond and Houston, 2003). In a multiproject organisation, resource allocation is a complex process of balancing the (often-conflicting) interests of multiple participants. Portfolio management needs to be based on delegation. Communication is required in the multi-project organisation. The planning and control cycle of individual projects needs to be traded off against the interests of project leaders and department heads in a team effort. Proposes a framework, the project-breakdown structure and organisation-breakdown structure are linked (Platje et al, 1994).
Agilent comparison.	❑ Are we making the best use of our competencies? ❑ Do we develop or aquire new competencies? ❑ Do we have the right structure, size, flexibility?

3.12 People management structure/issues	
What we know	**Comments/reference**
Portfolio management emanates from senior management.	Portfolio management is "the process by which senior management try to select and develop both the winning products and the correct balance of products that they believe will best succeed in the long term and then decide how to most effectively allocate the firm's resources optimising the return on investment (ROI)" (Cooper et al, 1999).
(some) Senior managers may not be entirely comfortable "managing" product portfolio decisions.	Portfolio management is a new practice not understood by senior management (Meadows, 1999). Some firms believe they have a weak portfolio management process (Cooper et al, 1999). A strong reluctance of senior management to *make decisions* to "kill" projects (Cooper et al, 1999). Reluctance to kill projects. Finds that "resource commitments are quite firm and "the human side": team morale, commitments and not "jerking around" the project team or leader is more important (Cooper et al, 1997). Elonen and Artto (2003) identify problems in managing multiple internal development projects include:- • Lacking resources, competencies and methods. • Lacking commitment, unclear roles and responsibilities. • Inadequate management of project-oriented organisation. One of the main causes of project management failure is the need to manage project interdependencies assuring their mutual compatibility at portfolio level and focus on resource interdependencies (De Maio et al, 1994).
Internal competition may exist for limited resources.	Internal competition exists for limited resources, technology capabilities, and control of market charters. Communication and cultural barriers exist between functional units. Language barriers are more difficult with technology (Bond and Houston, 2003). In a multi-project organisation, resource allocations are a complex process of balancing the (often-conflicting) interests of multiple participants. The planning and control

	cycle of individual projects needs to be traded off against the interests of project leaders and department heads in a team effort (Platje et al, 1994).
Agilent comparison.	❑ Do we have the right structure, size, flexibility? ❑ Do we have seed or emerging (A) business? ❑ Do we have at least one bold move? ❑ Do we have the right balance between short term and long term?

3.13 Level of innovation	
What we know	**Comments/reference**
Different levels of innovation.	Griffin (1997; 2002) identifies four different types of innovation : - • *New-to-the-world.* • *New-to-the-firm.* • *Next generation improvements.* • *Incremental improvements.*
Innovation and risk.	Ideally there is a balance between high risk and low risk, genuine new products versus product extensions (Cooper et al, 1999; Cooper, 2000). Large innovative firms enjoyed higher returns than less innovative firms, without an accompanying increase in risk. Continual innovation might provide a large firm with the means for achieving higher returns without higher risk! (Firth and Narayanan, 1996).
Competition influence.	Only a few new products represented a major advance in functional performance. Most new products offered only incremental performance improvement, and many 'new' products were direct copies of competitors' offerings (Spital, 1979).
Other options.	CEOs and managers must develop integrated strategies for managing their existing product and service offerings together with their new product whilst, at the same time, co-ordinating alliances and new channels (Cote and Stanmeyer, 2001).
Possible regional differences. Japanese firms compared to US firms.	Japanese firms, having taken a customer/demand orientation, tend to develop products incrementally, resulting in less uncertainty at the time of adoption (Boovaraghavan et al, 1997).

3.14 Strategy	
What we know	**Comments/reference**
Product development portfolio is/should be *(generally)* linked to overall corporate goals.	Most senior management thinks product portfolio management is important as it assists the firm's Strategic position (Cooper et al, 1999). (Survey data). Effectiveness of allocations requires that management assess the linkage between R&D spending and the attainment of overall corporate goals (Ayal and Rothberg, 1986). Strategy (only) begins when you spend money (Cooper et al, 1997). Globalization of markets and new business practices, increasing complexity of technologies in addition to shorter product life cycles are also forcing firms to rely on R&D as a source of strategy (Mikkola, 2001).
Product portfolio could include products from alliances and new channels.	CEOs and managers must develop integrated strategies for managing their existing product and service offerings together with their new product whilst at the same time, co-ordinating alliances and new channels (Cote and Stanmeyer, 2001). Opportunity frequently exceeds resource allocation. PDMA conference note (Meadows, 1999).
Portfolio techniques/tools to align with strategy.	Strategic scoring models are also used to maximise the value of the portfolio. Recommend the use of bubble diagrams and other visual models (Cooper et al, 1997). But also : - Considers strategies as portfolios of related real options (Luerhman, 1998). Managing different types of real options that can produce a portfolio of research and development projects. Applications of scouting options; and assembling strategic research and development portfolio (Macmillan and McGrath, 2002).
Possible regional differences (Japanese firms).	Japanese firms, having taken a customer/demand orientation, tend to develop products incrementally, resulting in less uncertainty at the time of adoption (Boovaraghavan et al, 1997).
Agilent comparison.	❑ Do we have seed or emerging (A) business?

	❑ Do we focus on the right strategic customers? ❑ Do we develop or acquire new competencies? What are the product priorities short and longer term to win our customers and markets? Do we recognize/utilize disruptive technology? ❑ What are our investment priorities? How much do we spend in which market segment, wave?

3.15 Investment/Resource allocation	
What we know	**Comments/reference**
Portfolio management is important to provide efficient resource allocation.	Senior management believed portfolio management was important to provide efficient resource allocation (Cooper et al, 1999). Resource allocation is crucial in the pharmaceutical industry (Van Arnum, 1998). Opportunity frequently exceeds resource allocation. PDMA conference note (Meadows, 1999).
Investment/Resource allocation. Complicated by uncertainty and risk.	Project portfolio selection is a crucial decision but the appropriate distribution of investment is complex, due to varying levels of risk, resource requirements, and interaction among the proposed projects (Ghasemzadeh and Archer, 2000). Examines the importance of uncertainty when prioritizing or allocating limited resources to a portfolio of research and development (R&D) projects (Tritle et al, 2000).
Tools.	Cost-benefit analysis and integer programming can assist in the resource allocation decision (Liberatore, 1987). Portfolio management is about resource allocation and deciding which NPD projects to support ***based on their relative priority*** (Rosenau, 1999). Project scatter factor and the resource dedication profile, significantly simplified the resource allocation process and improved project and business results (. Hendriks et al, 1999).
Fire fighting.	A principal source of difficulties in R&D is the phenomenon of fire fighting, -the unplanned allocation of resources to fix problems discovered late in a product's development cycle. Fire fighting is a common occurrence in many product development organisations. Fire fighting can be a self-reinforcing phenomenon and multi-project development systems are far more susceptible to this (Repenning, 2001).
Resources have "choke points."	Resources have "choke points," analogous to operational bottlenecks. In many cases the critical individual or piece of equipment may be otherwise assigned, causing slippage (Rosenau, 1999).
Internal competition exists for limited resources.	Opportunity frequently exceeds resource allocation. PDMA conference note (Meadows, 1999). The need to manage project and resource inter-dependencies (De Maio et al, 1994). Problems in managing multiple development projects.

	Lacking resources competencies and methods (Elonen and Artto, 2003). Internal competition exists for limited resources, technology capabilities, and control of market charters. (Platje et 1994). Fire fighting (Repenning, 2001). Resources constrain product strategy (Firth and Narayanan, 1996).
Agilent comparison.	❑ How is our product portfolio balanced in terms of attractiveness vs risk? ❑ How is our product portfolio balanced in terms of time to market? ❑ How are we balanced in terms of competitive differentiation and market leadership-> play, improve, set the rules? ❑ What are the product priorities short and longer terms to win our customers and markets? Do we recognize/utilizes disruptive technology? ❑ What is the right balance between HW, SW, solution divisions? ❑ What are our investment priorities? How much do we spend in which market segment, wave?

3.16 Competition	
What we know	**Comments/reference**
Competition influences many firms' decisions on portfolio management.	Senior management believed that portfolio management was important to ensure a competitive position (Cooper et al, 1999). Globalization of markets and new business practices are prompting high-tech firms to reconsider their competitive strategy. Increasing complexity of technologies in addition to shorter product life cycles are also forcing firms to rely on R&D as a source of strategy (Mikkola, 2001). Most new products offered only incremental performance improvement, and many 'new' products were direct copies of competitors ' offerings (Spital, 1979). Intensity of competition of high technology firms are challenged with the task of managing multiple-concurrent research and development (R&D) projects with constrained resources (Verma and Sinha, 2002).
Competition influence is significant.	The probability of competition from rival firms ***may*** be higher for lower (execution) risk projects (Cabral, 1994). The measure of technology is determined by the advantage over competition (Jolly, 2003).
Agilent comparison.	❑ Are we playing offensive making the rules? ❑ What is the biggest threat to our portfolio? ❑ How are we balanced in terms of competitive differentiation and market leadership. Play, improve, set the rules?

"Possible Gap" Analysis Tables

3.17 Risk

Theme Risk		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Bond and Houston (2003)	High technology			1	1			15		1
Cabral (1994)	Pharmaceutical			1	1	1		18		1
Cardozo and Wind (1985)	B2B			1	1			16		1
Cooper et al (1997)	Diverse	1			1			14		1
Cooper et al (1998)	Diverse	1			1			15		1
Cooper et al (1999)	Diverse	1			1			24		1
Cooper (2000)	Diverse		1		1			15		1
Firth and Narayanan (1996)	Diverse			1	1			18		1
Ghasemzadeh and Archer (2000)	Students			1	1			14		1
Graves et al (2000)	Pharmaceutical /Theory			1	1			15		1
Lint and Pennings (2001)	Philips		1			1		17		1
Tritle et al (2000)	Riley			1	1			11	1	
Van Arnum (1998)	Pharmaceutical			1	1			10	1	
Total		3	2	8	12	2			2	11
Possible gap							yes			

"Possible Gap" Analysis

3.18 Technology

Theme Technology		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Cooper et al (1999)	Diverse	1			1			24		1
Firth and Narayanan (1996)	Diverse			1	1			18		1
Jolly (2003)	High technology			1		1		17		1
Mandakovic and Souder (1990)	High technology			1	1		1	11		1
Mikkola (2001)	High technology			1		1	1	20		1
Purdue and McAllister (1999)	High technology		1		1			11	1	
Verma and Sinha (2002)	High technology		1		1			15	1	
Total		1	2	4	5	2	2		2	5
Possible gap?	No									

"Possible Gap" Analysis

3.19 Re-use (Platform)

Theme Re-use (Platform)		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Cooper, K. et al (2002)	High technology (Hughes)		1		1	1		10	1	
Cooper (2000)	Diverse		1		1			15		1
Fox et al (1984)	Theoretical			1	1			16		1
Hendriks et al (1999)	Industrial equipment.			1		1		16	1	1
Van Arnum (1998)	Pharmaceutical			1	1			10	1	
Total			2	3	4	2			3	3
Possible gap?		yes								

"Possible Gap" Analysis

3.20 Market

Theme Market		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Bhoovaghavan et al (1997)	High technology			1	1		1	16		1
Cooper (2000)	Diverse		1		1			15		1
Cooper et al (1999)	Diverse	1			1			24		1
Cote and Stanmeyer (2001)	High technology			1	1			10	1	
Firth and Narayanan (1996)	Diverse			1	1			18		1
Griffin (1997)	PDMA	1			1			19		1
Griffin (2002)	PDMA	1			1			19		1
Spital (1979)	Scientific Inst.	1			1			18		1
Total		4	1	3	8		1		1	7
Possible gap?						yes				

"Possible Gap" Analysis

3.21 Finance

Theme Finance		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Ayal and Rothberg. (1986)	Diverse			1	1		1	15		1
Cooper et al (1998)	Diverse	1			1			15		1
Linton et al (2002)	High technology (Bell Labs)		1		1			16	1	1
Luehrman (1998)	Hypothetical			1	1			12		1
MacMillan and McGrath (2002)	Diverse			1	1		1	16		1
Purdue and McAllister (1999)	High technology /Scientific Inst.		1		1			11	1	
Rosenau (1999)	PDMA			1	1			14	1	1
Van Arnum (1998)	Pharmaceutical			1	1			10	1	
Total		1	2	5	8		2		4	6
Possible gap?						yes				

"Possible Gap" Analysis

3.22 Size of company

Theme **Size of company**		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Cooper et al (1998)	Diverse	1			1			15		1
Cote and Stanmeyer (2001)	Diverse			1	1			10	1	
Firth and Narayanan (1996)	Diverse			1	1			18		1
Hendriks et al (1999)	Industrial equipment			1		1		16	1	1
Platje et al (1994)	Industrial equipment		1			1		16		1
Total		1	1	3	3	2			2	4
Possible gap?							yes			

"Possible Gap" Analysis

3.23 People management

Theme People management		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Bond and Houston (2003)	Industry studied			1	1			15		1
Cooper et al (1999)	High technology	1			1			24		1
De Maio et al (1994)	Diverse			1		1		13		1
Elonen and Artto (2003)	Diverse	1	1			1		14		1
Harmsen et al (2000)	Diverse	1				1		20		1
Meadows (1999)	PDMA			1	1			11	1	
Platje et al (1994)	Pharmaceuticals		1			1		16		1
Total		3	2	3	3	4			1	6
Possible gap?							yes			

"Possible Gap" Analysis

3.24 Level of innovation

Theme Level of innovation		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Bhoovaghavan et al (1997)	High technology			1	1		1	16		1
Cooper (2000)	Diverse		1		1			15		1
Firth and Narayanan (1996)	Diverse			1	1			18		1
Ghasemzadeh and Archer (2000)	Students			1	1			14		1
Griffin (1997)	Diverse	1			1			19		1
Griffin (2002)	Diverse	1			1			19		1
Spital (1979)	Scientific Inst.	1			1			18		1
Total		3	1	3	7		1			7
Possible gap?						yes			yes	

"Possible Gap" Analysis

3.25 Strategy

Theme Strategy		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Ayal and Rothberg (1986)	Diverse			1	1		1	15		1
Cooper et al (1997)	Diverse		1		1	1		14		1
Cooper et al (1999)	Diverse	1			1			24		1
Cote and Stanmeyer (2001)	Diverse			1	1			10	1	
Luerhman (1998)	Hypothetical			1	1			12		1
Macmillan and McGrath (2002)	Diverse			1	1		1	16		1
Meadows (1999)	PDMA			1	1			11	1	
Mikkola (2001)	High technology			1		1	1	20		1
Total		1	1	6	7	2	3		2	6
Possible gap?	No									

"Possible Gap" Analysis

3.26 Investment/Resource allocation

Theme Resource allocation		Type of study			Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
De Maio et al (1994)	Diverse			1		1		13		1
Elonen and Artto (2003)	Diverse	1		1		1		14		1
Firth and Narayanan (1996)	Diverse			1	1			18		1
Ghasemzadeh and Archer (2000)	Students			1	1			14		1
Hendriks et al (1999)	Ind./Elect. Eng.			1		1		16	1	1
Liberatore (1987)	Scientific Inst.			1		1		14		1
Meadows (1999)	PDMA			1	1			11	1	
Platje et al (1994)	Industrial Equipment		1			1		16	1	1
Repenning (2001)	Automotive			1	1			18		1
Rosenau (1999)	PDMA			1	1			14	1	1
Tritle et al (2000)	Riley/Oak			1	1			11	1	
Van Arnum (1998)	Pharmaceutical			1	1			10	1	
Total		1	1	11	7	5			6	9
Possible gap?							yes			

"Possible Gap" Analysis

3.27 Competition

Theme Competition					Region			Quality assessment	Practitioner/ Academic	
Author date	Industry studied	Survey	Case	Other	US	Euro	Other		P	A
Cabral (1994)	Pharmaceutical			1	1	1		18		1
Jolly (2003)	High technology			1		1		17		1
Mikkola (2001)	Diverse			1		1	1	20		1
Spital (1979)	Instruments	1			1			18		1
Verma and Sinha (2002)	High technology		1		1			15	1	1
Total		1	1	3	3	3	1		1	5
Possible gap?										

3.28 Consolidation of "Possible Gaps"

Theme	Type of study			Region			Practitioner /Academic	
	Survey	Case	Other	US	Euro	Other	P	A
3.17 Risk	3	2	8	12	2	yes	2	11
3.18 Technology	1	2	4	5	2	2	2	5
3.19 Re-use	yes	2	3	4	2	yes	3	3
3.20 Market	4	1	3	8	yes	1	1	7
3.21 Finance	1	2	5	8	yes	2	4	6
3.22 Size of firm	1	1	3	3	2	yes	2	4
3.23 People man	3	2	3	3	4	yes	1	6
3.24 Innovation	3	1	3	7	yes	1	yes	7
3.25 Strategy	1	1	6	7	2	3	2	6
3.26 Resource	1	1	11	7	5	yes	6	9
3.27 Competition	1	1	3	3	3	1	1	5

Section 4.0 Discussion

4.1 Introduction

The systematic review has produced a myriad of methods of new product portfolio management used by Business-to-Business firms involved in manufacturing products. The survey by Cooper et al (1999) of 205 large US firms reports the importance of portfolio management. Whilst all authors in this systematic review, whether academic or practitioner are agreed on the importance of portfolio management, accounts of the effectiveness of the portfolio management in practice differ considerably. For example, whilst Hendriks et al (1999) and Verma and Sinha (2002) find that portfolio methods improved business results, Repenning (2001) reports that portfolio methods are *often* not able to prevent fire fighting which results in low firm performance.

Debate surrounds the effectiveness of the portfolio management processes. Accounts of the relationship between the innovation, product development and portfolio management processes also vary. Cooper et al (1997; 1999) strongly recommend that adoption of a rigorous product development process (Cooper Stage Gate) is a prerequisite to successful portfolio management. In practice Griffin (1997) finds that 32% of US firms do not have a rigorous product process. Ausura (2003), whilst recognising that rigorous processes in new product development are highly important, warns that over emphasising processes has driven what he terms wrong behaviours in portfolio management. McGrath (1996) warns that in software development overly rigorous Stage Gate processes may stifle innovation. Boovaraghavan et al (1997) view process innovation and product innovation as actually being two ends of a continuum, rather than distinct phenomena.

Portfolio management has a reputation for very high complexity. Verma and Sinha (2002) state that the intensity of competition in high technology requires that firms must manage multiple-concurrent development projects, however Repenning (2001) expresses concerns that portfolio methods may break down when applied to multiple projects. Graves and Ringuest (1992) criticise project selection models for only optimising decisions based on a single objective, rather than the multiple objectives, which in reality management is normally facing. Graves et al (2000) suggest that most portfolio methods in fact deal with the portfolio selection by essentially evaluating individual projects. Graves et al (2000) point out that, whilst this assessment may well have selected individually good products, the combination of these individually good projects does not necessarily constitute the optimal portfolio.

Indeed as far back as Liberatore (1987) and Mandakovic and Souder (1990) the adoption of computer based software has been advocated to assist in the manipulation of the vast amounts of complex data. Cooper et al (1999) report on the use of specific software products, such as Monte Carlo simulation, which can assist in reducing the complexity. Similarly Linton et al (2002) and Verma and Sinha (2002) report that data envelopment analysis (DEA) can be used to automate "obvious" decisions and thereby free up the practising managers to make the critical decisions. Despite the abundance of portfolio methods, tools and software, the portfolio management process remains highly complex.

This is reflected in the complexity and diversity of themes found in the systematic review. As discussed in section **2.12**, 10 major themes were considered to be apparent in this systematic review. An additional theme of *Investment/Resource allocation* was added based on Agilent.

These were:-

Risk	Size of company
Technology	People Management structure
Re-use (Platform)	Level of innovation
Market	Strategy
Finance	Competition
	Investment/Resource allocation

4.2 Risk

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.17 Risk	3	2	8	12	2	*yes	2	11

*** possible gap.**

The treatment and discussion of risk within the systematic review is extensive. Ghasemzadeh and Archer (2000) discuss how accommodating the varying levels of risk introduces considerable complexity into portfolio management. Cardozo and Wind (1985) discuss the importance of uncertainty when prioritising or allocating limited resources to a portfolio of (R&D) projects. Different types of risk are evident within the systematic review. Cooper et al (1999) discuss the risk of project failure, competition producing a superior product and the risk that the market will not accept the product. Cabral (1994) reports that the risk of competition from rival firms in some instances may be higher than the risk of not executing projects. Firth and Narayanan (1996) consider whether the risks involved in product development may favour large innovative firms.

As part of the stage gate process, in the event that any of the risks is calculated to be too high, Cooper et al (1997; 1998; 1999) strongly advocate that the project is "killed" and the resources re-deployed. Van Arnum (1998) reports "buy down" options and minimal plans in the pharmaceutical industry to essentially exit the product and or market place. Lint and Pennings (2001) discuss the use of real options at Philips Electronics, as a tool for management to make the decision to "abandon" the project.

Despite the reported importance and methods of exiting a product development when the risk is too high, the actions in practice appear not to always follow this theory. Cardozo and Wind (1985) report that portfolio methods often lack explicit treatment of risk. Cooper et al (1997; 1998; 1999) consistently report that senior management exhibit a tendency to avoid "killing" a project. Paradoxically Graves et al (2000) discuss the suggestion that decision-makers are often risk averse.

Whatever the differing opinions on how to manage risk, the risk of product development clearly exists. Cooper (2000) reports that 46% of the product development investments made by U.S. companies ultimately fail in the marketplace. Indeed many products do not ever make it to market.

Agilent comparison	**Check list** *Reference section 3.3*
Risk.	❑ How focused are our risks - markets, products, customers? ❑ Do we have at least one bold move? ❑ How is our product portfolio balanced in terms of attractiveness vs risk? ❑ Are we confident that we execute successfully?

Agilent appear to be focused on risks. (Markets, product *(execution) and* customers) Error also appears to be extended on trying to balance the portfolio in terms of Risk.

Attractiveness vs risk. They appear to be calculating and preparing to take significant risk. "at least one bold move."

Possible future research requirement	
4.2 Risk	Japan and Asia not covered in the systematic review
	Management reluctance to "kill" products despite overwhelming recommendations that this will *(often)* improve overall business (Cooper et al, 1999). *(Has Cooper considered re-use reference from 4.4?)*

4.3 Technology

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.18 Technology	1	2	4	5	2	2	2	5

Cooper et al (1999) report that consideration of technology is a key element of portfolio management. Jolly (2003) finds that technological competitiveness depends on the value of the product development teams' competencies, the relatedness of the technology to the company's core business and the time advantage vis-à-vis the competition. The impact of technology would also appear to possibly have different significance to different types of firms. Verma and Sinha (2002) consider that the intensity of competition of high technology firms especially challenges them with managing multiple-concurrent R&D projects with constrained resources. Firth and Narayanan (1996) consider the technology strategy as a fundamental portfolio decision and differentiates, for example, between firms who are "investors in technology" and "business as usual" firms. "Investors in technology" firms focus on expanding their technological base whilst "business as usual" firms rely on existing technologies and products to serve existing markets. In the event that "business as usual" wish to introduce new technologies or market applications, they *(often)* turn to acquisition to gain these capabilities from external sources.

Mikkola (2001) reports that increasing complexity of technologies in addition to shorter product life cycles is forcing firms to evaluate not just their products but also their technologies from a portfolio's perspective. Mandakovic and Souder (1990) concluded that integrative portfolio approaches are effective project selection processes. Purdue and McAllister (1999) (Westinghouse) describe how options-pricing techniques and decision-analysis tools can evaluate R and D projects in a way that can accommodate the technical and commercial project-selection decisions.

Agilent comparison	**Check list** ***Reference section 3.3***
	❑ What are the product priorities short and longer terms to win our customers and markets? Do we recognize/utilize disruptive technology?

Agilent appear to have an integrated technology and product portfolio management process. Senior management appears especially concerned with identifying disruptive technologies. *(which is not specifically reported elsewhere in the systematic review as a major sub theme.)*

Possible future research requirement	
4.3 Technology	Agilent's consideration of disruptive technologies. *(Not specifically reported elsewhere in the systematic review as a major sub theme.)*

4.4 Re-use (platforms)

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.19 Re-use	***yes***	2	3	4	2	***yes***	3	3

*** possible gap.**

One aspect of product development, which may introduce even further complexity to portfolio management decisions, is the area of design re-use. Design re-use occurs when some of the design effort invested in one product is essentially re-used in other products. Therefore the development cost is substantially lower for the subsequent products than for the first. A good example of re-use is in the automotive industry where manufacturers produce what they term "platforms" which are re-used by multiple new models. In its 2002 annual report MG Rover, the UK based Car Company, announced their intent to invest up to £550 million in new product development in the next three years. MG Rover state to shareholders that this is less than would be expected as they inherited the new 75 car platform from BMW. Fox et al (1984) discuss the present value (PV) interactions, which may exist between R& D projects even though traditionally interaction is assumed to be absent. Fox et al (1984) show that ignoring PV Interactions can result in both non-optimal project selections and resource allocations. Cooper, K et al (2002) stress the value of comprehending project commonality and rework cycles in product development. Hendriks et al (1999) discuss methods of allocating resources including using resource dedication profiles and scatter factor techniques.

Van Arnum (1998) points out that re-use need not be just considered as subsidy for a product development to be justified. Even if a project is to be stopped or reduced to a minimal plan this still may enable value from this project to be realised for current or future use. In contrast Cooper et al (1997; 1998; 1999) and Cooper (2000) criticise senior management for not making tough and abrupt "kill" decisions and proposes that this failure to decide will prevent more profitable product developments from being pursued. What is not apparent from Cooper et al (1997; 1998; 1999) and Cooper (2000) is whether they have adequately considered calculating the re-use potential of the project prior to making the "kill"decision. Perhaps more importantly as Van Arnum (1998) implies with her report of a "minimal" funding plans in the pharmaceutical industry; has Cooper fully considered deciding the best time to exit the project and thereby maximising the re-use potential?

Agilent comparison	**Check list** *Reference section 3.3*
Agilent comparison.	❑ Are we making the best use of our competencies?

Whilst not specifically discussing re-use Agilent do have a checklist to ensure they make the best use of their competencies. It is possible that this could (or not) include reuse.

Possible future research requirement	
4.4 Re-use	Absence of survey data Absence of Japan Asia
	Japan/Asia not covered in SR
	Have Cooper et al (1997; 1998; 1999) fully considered deciding the best time to exit projects before "killing" them to maximise the "re-use" potential ? (Reference back to 4.2)

4.5 Market

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.20 Market	4	1	3	8	***yes***	1	1	7

*** possible gap.**

This systematic review is specifically concerned with the business to business firms and as such the market is in reality a collection of other firms. Firth and Narayanan (1996) suggest that new products should be closely aligned with their core markets and technologies and products to serve existing markets. Firth and Narayanan (1996) consider that most firms, though not necessarily highly innovative firms, are significantly influenced to produce portfolios of products to serve existing markets.

Griffin (1997; 2002) considers that integrated product marketing and product development organisations are generally desirable to promote synergy and ensure the customer voice is present within the product development process. Cooper (2000) agrees the customer voice should be present within the product development process stating that high quality marketing produces double the product success rate and 70% higher market share than those products developed with poor marketing. Cote and Stanmeyer (2001) perhaps extend this customer relationship further proposing that additionally companies should also consider their alliance relationships and channels as an extension of their portfolio of products. Similarly, Firth and Narayanan (1996) report that "business as usual" firms often turn to acquisition from external sources when introducing new technologies or entering new markets.

Cooper et al (1999) clearly state the importance of considering the market in portfolio management. The calculation of returns, financial or otherwise, requires that assumptions be made as to the customer's interest in the product and future demand from the customer. Cooper (2000) though agreeing the customer voice should be present within the product development process, possibly doesn't specifically advocate substantial customer involvement when moving a new-product project between gates and certainly not in the major portfolio management decisions, such as, "should the project be "killed". Spital (1979) reports that users were involved in the majority of the innovation processes, except when the product was initiated as a direct response to a competitor's product introduction. However when the major decisions, such as the decision to manufacture an innovation, were taken, this was *unrelated* to the user involvement in the innovation process.

Bhoovaraghavan et al (1997) introduce a regional discussion by contrasting Japanese companies, who appear to have a disposition towards a market orientation, with American companies, which tend towards a supply (product) orientation.

Agilent comparison	**Check list** ***Reference section 3.3***
	❑ Do we have seed or emerging (A) business? ❑ Do we focus on the right strategic customers? ❑ How focused are our risks -> markets, products, customers? ❑ Do we achieve growth, profit and target market position in each segment? ❑ What are the product priorities short and longer term to win our customers and markets? Do we recognize/utilize disruptive technology? ❑ Do we manage our B-Business appropriately? ❑ How much do we spend in which market/segment wave?

Agilent appear to heavily consider the market within their portfolio process. They appear to also consider the market product wave and generally be influenced by Moore (1992) in his book "*Crossing the Chasm*". This influence is not evident in the other studies within the systematic review.

Possible future research requirement	
4.5 Markets	Absence of Europe regional study
	Cooper (2000) despite advocating voice of customer in product development possibly doesn't specifically advocate substantial customer involvement in the major portfolio management decisions. (such as should the project be "killed") Similarly Spital (1979) re manufacturing decision.
	Agilent adoption of Moore (1992) "*Crossing the Chasm*" yet influence is not evident in the systematic review.

4.6 Finance

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.21 Finance	1	2	5	8	*yes	2	4	6

*** possible gap.**

Cooper et al (1999) define portfolio management as the process by which senior management try to select and develop both the winning products and the correct balance of products that they believe will best succeed in the long term and then try to decide how to most effectively allocate the firm's resources optimising the return on investment (ROI). The ultimate objective of portfolio management is return on investment, which is invariably measured in harsh financial terms.

The stakes can be very high. Van Arnum (1998) estimates the cost of developing a major new drug for leading pharmaceutical companies at $250 million to $350 million, yet for every blockbuster drug like Viagra, there are thousands of unsuccessful drugs. Even this sum is low when compared to the high tech companies, such as Intel who, in their annual report, state that to develop their microprocessor products requires an annual investment of over two billion dollars. Perhaps it is therefore not surprising to discover that Cooper et al (1999) in their survey of major US companies found that financial methods dominated the portfolio management methods with 40% of respondents using them. (See Section 3.4). Despite financial methods being so prominent in the portfolio management literature, financial methods also attract significant criticism.

Rosenau (1999) observes that in most product development bottlenecks, which he terms critical choke points, are often unique human skills or specific pieces of technical equipment and not merely costs. Whilst each of these can be allocated a financial value, managers who think of resources purely financially may miss the importance of the uniqueness of the person or equipment. Though they may have allocated sufficient budget to the project, the project may slip, or even fail, because the critical capability is not available at the appropriate time. This is compounded, as Repenning (2001) reports, in multi-project environments. Many projects may compete for the same possible unique resources leading to fire fighting.

Ayal and Rothberg (1986) discuss the need to apply a distinction between the *effectiveness* and *efficiency* of R&D spending. They found that most companies over control financial allocations focusing on tactical detail or efficiency, rather than the strategic implications of their decisions. Ayal and Rothberg (1986) urge that management increase their focus on considering the linkage between R&D spending and their overall corporate goals. Cooper et al (1999) found that benchmark companies rely far less on financial portfolio methods and prefer strategic methods and scoring approaches. Increasing the use of strategic methods tended to yield the best portfolios; whereas over reliance on financial methods tended to yield poorer portfolio results. Whilst Cooper et al (1999) are critical of over reliance on financial methods, they clearly are not providing an invitation to firms to abandon financial methods, rather instead recommending that they

complement them with strategic and other methods as part of a balanced portfolio method.

Whilst historically, as reported in the findings (See section 3.4), traditional financial techniques such as hurdle rates and net present value calculations have been used in portfolio management, this systematic review has found evidence of some firms investigating the potential of real options. This is also suggested by survey data (Cooper et al, 1999).

Luehrman (1998), MacMillan and McGrath (2002), Purdue and McAllister (1999) and Linton et al (2002) report that different types of real options can be used in combination with traditional portfolio methods to produce portfolios of research and development projects. Luehrman (1998) comments that option pricing can potentially provide management with earlier financial insight. Purdue and McAllister (1999) notes that such was the success of trials of using real options in portfolio management that Westinghouse now use a combination of options-pricing techniques and decision-analysis tools to manage their complete portfolio of projects. This systematic review appears to have failed to find a counter view to the preceding author's favourable views of real options. It is not clear from the evidence provided by the systematic review whether this is because real options are indeed effective techniques for complementing portfolio management or merely that few firms have enough experience of them to discuss their limitations.

Agilent comparison	**Check list** ***Reference section 3.3***
Agilent comparison.	❑ Do we achieve growth, profit and target market position in each segment? ❑ How is our product portfolio balanced in terms of attractiveness vs risk? ❑ How is our product portfolio balanced in terms of time to market. ❑ How are we balanced in terms of competitive differentiation and market leadership-> play, improve, set the rules?

Whilst aggressively stating their classical financial objectives, such as growth and profitability, Agilent would appear to be at least trying to devise a balanced portfolio method similar to that proposed by Cooper et al (1999). There is no mention of real options being used.

Possible future research requirement	
4.6 Finance	Absence of Europe
	It is not clear from the evidence provided by the systematic review whether real options are actually effective techniques for complementing portfolio management or merely that few firms have enough experience of them to discuss their limitations.

4.7 The size of company

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.22 Size of firm	1	1	3	3	2	*yes	2	4

*** possible gap.**

Many of the firms studied in this systematic review are anonymous, either through the method of study, for example Cooper et al (1999) survey of 205 large multi-billion dollar US firms, or have been given anonymity. The firms who are specifically named are: -

Abbott	Dodge	Maytag	Seagate
Aiwa	English clay	Medrtronics	Scott
AMP	Ford	Merk	Sharpe
Bank of Canada	Gillette	Mobil	Sony
Bell Laboratories	Helen Curtis	Philips	Sun
Chrysler Ely Lilly	Hoechst	Reilly Industries	Texas Instruments
CISCO	Hughes	Rohr	Tonka
Clorox	IFF	Royal Oak	Varian
Deere	Joostents	Sanyo	Wang
			Westinghouse

Though Harmsen et al (2000) do study small (circa $7m) Danish firms, the Systematic review is dominated by large multinational firms.

Firth and Narayanan (1996) suggest that large companies typically maintain broader portfolios of products and have easier access to capital markets. The ability to spread the risk over many products and the safety net of ease of capital in theory provides a significant advantage over small firms. Firth and Narayanan (1996) suggest that continual innovation might therefore provide a large firm with the means for achieving higher returns without higher risk. Cote and Stanmeyer (2001) equally discuss the ability of larger firms to form alliances to complement their product portfolio and leverage the brand. Hendriks et al (1999) describe the potential that large R&D firms have when being able to use resource deployment tools, such as scatter factor, to multiplex and leverage their diverse resources.

Despite the evidence that larger firms, with larger product portfolios, may generally benefit more than smaller firms from portfolio management, there are also some disadvantages for large firms reported in the systematic review to consider. Platje et al (1994) observe that in large multi-project organisations balancing the often-conflicting interests of multiple participants can be difficult. The planning and control cycle of individual projects needs to be traded off against the interests of project leaders and department heads in a team effort. This increases the need of managers to effectively

communicate, delegate and foster teamwork. Platje et al (1994) do not present them as insurmountable and indeed propose a framework to facilitate improving these issues. Similarly Bond and Houston (2003) recognise that internal competition exists for limited resources, technology capabilities, and control of market charters. Bond and Houston (2003) observe that communication and cultural barriers may exist between functional units. Bond and Houston (2003) also note that the language barriers are more difficult within the High Technology sector due to the complexity of technical terms.

Agilent comparison	**Check list** ***Reference section 3.3***
	❑ Are we making the best use of our competencies? ❑ Do we develop or acquire new competencies? ❑ Do we have the right structure, size, flexibility?

Agilent appear to be considering their size, structure and flexibility and appear willing to add competence through acquisition to meet their portfolio objective. Whilst not definitive as to whether large or small is better or worse this would appear to indicate that size does have an impact on how they manage their portfolio.

Possible future research requirement	
4.7 Size of companies	Absence of Japan/Asia regional study (language barriers?)
	A. Do large firms have an advantage over smaller firms? *(Why are Agilent concerned with size)* B. Language barriers are more difficult within the high technology sector. (Bond and Houston, 2003; Platje et al 1994).

4.8 People management

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.23 People Man	3	2	3	3	4	*yes	1	6

*** possible gap.**

Cooper et al (1999) define portfolio management as "The process by which senior management try to select and develop both the winning products and the correct balance of products that they believe will best succeed in the long term". Meadows (1999) summarising the 1999 PDMA Advanced Workshop, suggests that portfolio management is a new practice not (well) understood by senior management. Cooper et al (1999) though recognising the existence of benchmark firms, similarly identify significant numbers of firms which appear not to be satisfied with their portfolio methods and indeed some firms that do not even have a portfolio process. Specifically Cooper et al (1997; 1999) report a strong reluctance of senior management to *make decisions* to "kill" projects.

Elonen and Artto (2003) commenting on reasons for project failure, criticise management for lacking commitment, not providing clear roles and responsibilities and inadequate management of project-oriented organisations.

It would seem reasonable to assume that as product development is generally a highly complex task and undertaken by large numbers of people, who require clear direction from senior management, there might exist a potential for communication problems to exist in some firms. Platje et al (1994), though ultimately proposing techniques to minimise these issues, confirm that delegation and communication problems exist. Notably these include resolving the often-conflicting interests of individual project needs having to be traded off against the interests of project leaders and department heads. Team effort is therefore required from multiple participants. De Maio et al (1994) find that one of the main causes of project failure is as a result of the difficulty of managing project and resource interdependencies and assuring their compatibility. Bond and Houston (2003) also describe internal competition, which exists for limited resources, and technology capabilities, but also competition for control of market charters. Bond and Houston (2003) propose that significant communication and cultural barriers exist between functional units and notes that these barriers are complicated further when dealing with technology.

Senior management appears to react to and accommodate this "people" pressure. Cooper et al (1997) find that, despite senior management having great difficulty making "kill" decisions, in contrast most resource commitments are quite firm. Cooper et al (1997) report that the human side, i.e. team morale, commitments to customers etc and not "jerking around" the project team or leader is considered more important.

Agilent comparison	**Check list** ***Reference section 3.3***
	❑ Do we have the right structure, size, flexibility?

Agilent. Whilst commenting on the size and flexibility of the organisation there is no specific discussion relating to people motivation.

Possible future research requirement	
4.8 People issues	Japan Asia data absent

A. Portfolio management is a new practice not understood by senior management Meadows (1999). Some firms believe they have a weak portfolio management process (Cooper et al, 1999).

B. Despite evidence to re-deploy resources to improve business performance reluctance exists to kill projects. "Resource commitments are quite firm" & "the human side" team morale, commitments and not "jerking around" the team or leader is more important (Cooper et al, 1997).

C. Are language barriers more difficult within the high technology sector? (Bond and Houston, 2003).

4.9 Level of innovation

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.24 Innovation	3	1	3	7	*yes	1	*yes	7

*** Possible gap.**

Griffin (1997; 2002) differentiates between the types of products that firms develop and proposes four different types of innovation:-

- *New-to-the-world*
- *New-to-the-firm*
- *Next generation*
- *Incremental improvements*

Products which are new to the world, as their name suggests, are entirely new products, a consumer example of which might be the Sony Walkman. When a competitor such as perhaps JVC emulates the innovation, though this would be the first time they have built one, many of the issues, but probably not all those that Sony faced, may be easier. The risk of market acceptance perhaps might be less unknown as Sony had, to a large extent, essentially verified consumer demand. Next generation products and incremental improvements, as their names imply, are perhaps progressively "easier" to develop. Firth and Narayanan (1996) argue that large innovative firms enjoy higher returns than less innovative firms, but without an accompanying increase in risk and that continual innovation might provide a large firm with the means for achieving higher returns without higher risk. This doesn't appear to be a view strongly expressed or disagreed with by other authors in the systematic review.

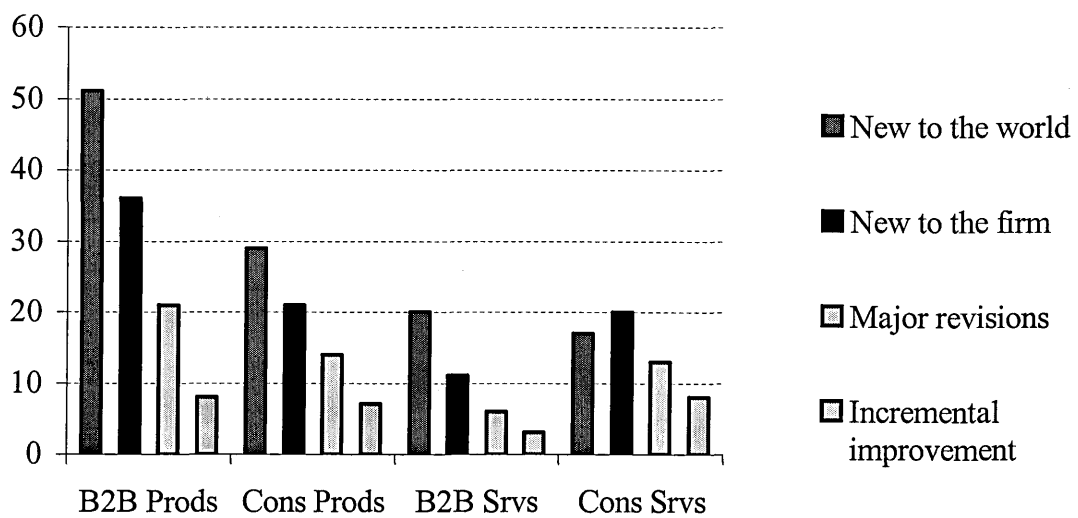

Fig 4.1 Product development cycle time (in months) compared to level of innovation by business sector (Griffin, 2002).

Griffin (2002) observes that the product development cycle time between the different types of level of innovations is significantly higher for the more innovative products as shown in fig 4.1. Cooper et al (1999) advocate that ideally there should be a balance between high risk and low risk and between genuine new products versus product extensions. Due to the length of the business to business cycle times, shown in fig 4.1, this equates not only to market and product risk but also to the long and short-term strategy. Perhaps most importantly the cash flow profile of the company is therefore determined by this strategy. From fig 4.1, it is apparent that the Business to Business product development cycle times are generally longer than for the other sectors, perhaps suggesting that this might be a major consideration for B2B firms. For example Griffin (2002) showed similar product development cycle times for B2B and Consumer companies for incremental product, but for new to the world products the cycle time difference almost doubles. It is not apparent from the systematic review whether or not the risks are also higher or not for B2B companies who try to pursue highly innovative strategies.

Alternate views or options appear to exist. Cote and Stanmeyer (2001) urge CEOs and managers to consider other strategies, such as co-ordinating alliances and new channels, to complement their product portfolios. Perhaps this not only complements the product line but also spreads the risks involved in product development.

Spital (1979) however noted that in his study only a few new products actually represented a major advance in functional performance. In fact most new products offered only incremental performance improvement, and many 'new' products were actually direct copies of competitors' offerings. This perhaps suggests that reacting to competition products could be a source driving some of the decisions regarding the level of innovation in some firms rather than necessarily the strategy being determined by a carefully calculated product portfolio. Boovaraghavan et al (1997) imply that Japanese firms tend to develop incremental products thereby reducing the uncertainty of the market adopting the product.

Agilent comparison	**Check list** *Reference section 3.3*
	Market, Wave, Customer Portfolio ❑ Do we have seed or emerging (A) business? ❑ Do we have the right balance between short term and long term? ❑ Do we have at least one bold move?

Agilent do appear to be considering whether their portfolio has the right balance between short term and long term. Possibly the consideration of "at least one bold move" could be related to innovation or new market entry.

Possible future research requirement	
4.9 Level of innovation	Absence of Europe Data

A. It is not apparent from the systematic review whether or not, with increased levels of innovation, the risks are higher for B2B companies who try to pursue highly innovative strategies.

B. Cote and Stanmeyer (2001) urge CEOs and managers to consider other strategies, such as alliances and new channels.

C. Spital (1979) reports that perhaps innovation is driven by competition rather than portfolio management in some cases.

4.10 Strategy

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.25 Strategy	1	1	6	5	1	3	2	4

Mikkola (2001) considers that globalisation of markets, shorter product life cycles and increasing complexity of technologies are increasingly forcing firms to rely on R&D as a source of strategy. Cooper et al (1999) reveal that senior management consider portfolio management important as it assists in strengthening the firm's strategic position. Ayal and Rothberg (1986) propose that to effectively allocate investment, senior management need to assess the linkage between R&D spending and the attainment of their overall corporate goals. Indeed Cooper et al (1997) suggest that strategy only begins when senior management spend money. Meadows (1999), reporting on the annual PDMA conference, notes that opportunity frequently exceeds the resources available for the firm to allocate to product development. Cote and Stanmeyer (2001) propose that CEOs and managers can complement this shortage of product development resources by developing alliances and new channels and developing integrated strategies to complement their existing products. Though few doubt the importance of effectively coupling their R&D product portfolios with their company's strategy, significant difficulty and some debate surrounds how to effectively do this.

As discussed in section 4.6 and 3.4 financial methods are used by 40% of US firms, though Cooper et al (1997; 1999) show that generally these financial methods provide poorer results than when integrated with strategic models, such as bubble diagrams and other visual models. Luerhman (1998) and Macmillan (2002) propose that improved product portfolio performance can be obtained by considering strategies as portfolios of related real options. Boovaraghavan et al (1997) observe that Japanese firms have taken a significantly different strategic approach to their product portfolios than US firms as reported in section 4.5 and 4.9, though no supporting research has been surfaced by this systematic review to confirm or explain this.

Agilent comparison	**Check list** ***Reference section 3.3***
	❑ Do we have seed or emerging (A) business? ❑ Do we focus on the right strategic customers? ❑ Do we develop or acquire new competencies? What are the product priorities short and longer term to win our customers and markets? Do we recognize/utilize disruptive technology? ❑ What are our investment priorities? How much do we spend in which market segment, Wave?

Agilent appear to be making great effort to integrate their portfolio management process into their business strategy.

Possible future research requirement	
4.10 strategy	Though Japanese firms are reported as having taken a significantly different strategic approach to their product portfolios than US firms no supporting research has been surfaced by this systematic review to confirm or explain this.

4.11 Investment/resource allocation

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.26 Resource	1	1	11	7	5	*yes	6	9

*** possible gap**

Portfolio management is important to provide efficient resource allocation

Cooper et al (1999) specifically list one of the top four reasons portfolio management is considered important by senior managers to provide efficient resource allocation. Van Arnum (1998) suggests that resource allocation is crucial in the pharmaceutical industry. This appears to be consistent with Meadows (1999) who, from the 1999 PDMA conference, observes that the business opportunities frequently exceed the resource available to the firm. In support of this sentiment Rosenau (1999) describes portfolio management as being about resource allocation and deciding which NPD projects to support based on their relative priority. Firth and Narayanan (1996) further confirm the belief that lack of resources constrains product strategy. This is highly consistent with Cooper et al (1999) encouraging senior management to "kill" products which fail to pass a stage gate and to focus the resource instead on "the winning products".

The difficulties in managing the resource inter dependencies in multi project environments are reported by De Maio et al (1994) and Elonen and Artto (2003). Hendriks et al (1999) report some success with project scatter factor and resource dedication profiles. However Ghasemzadeh and Archer (2000) and Tritle et al (2000) are by no means alone in discussing the importance of dealing with uncertainty and risk (see section 4.2 risk) when prioritising and/or allocating limited resource. Various software tools, dating back to the work by Liberatore (1987) on cost-benefit analysis and integer programming, are available to assist in the resource allocation decision. In practice, allocating resources is widely reported as *sometimes* problematic.

A principal difficulty, especially in multi- project organisations, reported by Repenning (2001) is the unplanned allocation of resources to fix problems which are discovered late in a product's development. (Firefighting). Similarly Rosenau (1999) points out that in reality resources have "choke points", which are analogous to operational bottlenecks. "Choke points" are critical individuals or pieces of equipment that may be assigned elsewhere when the product development teams need them. This in turn causes the product development to slip.

To compound the above, Bond and Houston (2003) suggest that significant communication and cultural barriers exist between functional units and notes that these barriers are complicated further when dealing with technology. Platje et al (1994) perhaps add yet an additional dimension to the issue by observing that internal competition exists for limited resources, technology capabilities, and control of market charters. No significant discussion of this aspect of resource allocation was evident elsewhere in the systematic review.

Agilent comparison	**Check list** ***Reference section 3.3***
Agilent.	❑ What is the right balance between HW, SW, solution divisions? ❑ What are our investment priorities? How much do we spend in which market segment, wave?

Possible future research requirement	
4.11 Investment resource	Absence of Japan and Asia
	Platje et al (1994) perhaps add an additional dimension to the issue by observing that internal competition exists for limited resources, technology capabilities, and control of market charters.

4.12 Competition

Summary of studies	Type of study			Region			Practitioner /Academic	
Reference	Survey	Case	Other	US	Euro	Other	P	A
3.27 Competition	1	1	3	3	3	1	1	5

Cooper et al (1999) showed that senior management believed that portfolio management was important to ensure a competitive position. Mikkola (2001) regards increasing globalisation of markets and new business practices as prompting high-tech firms to reconsider their competitive strategy. Increasing complexity of technologies in addition to shorter product life cycles are also forcing firms to rely on R&D as a source of strategy.

Verma and Sinha (2002) view that the intensity of competition especially challenges high technology firms. Jolly (2003) discusses the measurement of technology capabilities as being best determined by the advantage over competition. Spital (1979) observed that most new products offered only incremental performance improvement and many 'new' products were direct copies of competitors, suggesting in his study that product strategy was somewhat dictated by reaction to competition. Cabral (1994) warns that the risk of product failure may be higher due to the risk of competitive threat, rather than the failure in product development. Sympathising with the Cabral (1994) viewpoint, Mikkola (2001) stresses the need, that when ranking portfolios of products, to link the competitive advantages a product provides to a firm and the benefits these projects may provide to customers. Though not providing specific research, Mikkola (2001) comments that the Japanese firms tend to accept a lower competitive advantage in exchange for a higher level of certainty of market acceptance. Whilst not implying that Japanese firms seek a low competitive position, Boovaraghavan et al (1997) (as discussed in section 4.5) substantiate the view that Japanese firms tend to develop incremental products thereby reducing the uncertainty of the market adopting the product. The portfolio strategies of Japanese companies, with respect to their competitive positions, appear to be inconclusive in this systematic review.

Agilent comparison	**Check list** ***Reference section 3.3***
Agilent	❑ Are we playing offensive making the rules? ❑ What is the biggest threat to our portfolio? ❑ How are we balanced in terms of competitive differentiation and market leadership- play, improve, set the rules?

Agilent appear to take the importance of competition very seriously when making their portfolio decisions. Considerable effort appears to be extended on both "offensive" and "defensive" considerations.

Possible future research requirement	
4.12 Competition	Is there a lack of influence of competitive position on the choice of portfolio strategies of Japanese companies?

Fig 5.0 Executive Summary of what we know

A Risk
A 1 The importance of risk assessment in the portfolio management process.
A2 Risk substantially complicates the portfolio management process.
A3 Types of risks; competition, project execution, market and technology.
A4 (some) Firms under estimate risk.
A5 Risk portfolios may be more appropriate for large innovative firms.
A6 The need to stop product development if risks are too high.

B Strategy
B1 Product development portfolio is/should be (generally) linked to overall corporate goals.
B2 Product portfolio could include products from alliances and new channels.
B3 Portfolio techniques align with strategy.
B4 Possible regional differences (Japanese firms).

C Technology
C1 Importance of comprehending technology in portfolio management.
C2 Different types of portfolio /strategy decisions re investment in technology.
C3 Integrating technology selection into R&D portfolio decisions.
C4 Technological competitiveness is built on competencies.
C5 Technology competition.

D Re-use
D1 The importance of the project interdependencies.
D2 Methods of assessing project interdependencies.
D3 Re-use and exit plans.

E Market
E1 Market involvement in product development & portfolio management.
E2 Importance of alliances as an extension of a firm's portfolio.
E3 User (customer involvement).
E4 Demand orientation and regional differences (Japan/US).

F Finance
F1 Portfolio management is about optimising return on investment.
F2 Product development can require substantial financial investment.
F3 Financial portfolio methods are the most popular.
F4 Dangers of over controlling R&D through financial methods.
F5 Different results between traditional financial methods and real options.
F6 Portfolios management using real options.

G Size of company
G1Large firms are the principal subjects of this systematic review.
G2 Large firms may have advantages over smaller firms.
G3 Large firms may also encounter difficulties.

H People management
H1 Portfolio management emanates from senior management.
H2 (some) Senior managers may not be comfortable "managing" portfolios.
H3 Internal competition may exist for limited resources.

I Level of innovation
I1 Different levels of innovation.
I2 Innovation and risk.
I3 Competition influence.
I4 Other options & alliances.
I5 Possible regional differences Japanese firms compared to US firms.

J Investment/Resource allocation
J1 Portfolio management is important to provide efficient resource allocation.
J2 Investment/Resource allocation complicated by uncertainty and risk.
J3 Tools .
J4 Fire fighting.
J5 Resources have "choke points."
J6 Internal competition exists for limited resources.

5.0 Summary

Fig 5.0 contains a consolidated executive summary of the themes and sub themes emerging from the systematic review.

5.1 Discussion of gap analysis

Theme	Type of study			Region			P/A	
	Survey	Case	Other	US	Euro	Other	P	A
3.17 Risk						*yes*		
3.18 Technology								
3.19 Re-use	*yes*					*yes*		
3.20 Market					*yes*			
3.21 Finance					*yes*			
3.22 Size of firm						*yes*		
3.23 People man						*yes*		
3.24 Innovation					*yes*		*yes*	
3.25 Strategy								
3.26 Resource						*yes*		
3.27 Competition								

Fig 5.1: Consolidated "possible gap" analysis.

Figure 5.1 summarises the consolidated "possible" gaps from the analysis shown in section 3.28. Whilst recognising that this systematic review has been a relatively broad review of the extensive product development portfolio management literature, rather than an in depth focus on a specific tightly defined issue, there would appear to be a possibility of several gaps existing in the systematic review. These are perhaps worthy of additional investigation.

5.2 Possible regional gaps

Fig 5.1 appears to highlight a significant number of possible gaps in "other" regions, which in this analysis was defined as studies outside of North America and Europe. From the general findings reported in section 3 .1 and reproduced below in fig 5.2, the studies

captured by the systematic review are substantially focused on the firms resident within the United States. In fact, as also discussed in section 3.1, more than half the studies are based on firms resident in the United States and Canada.

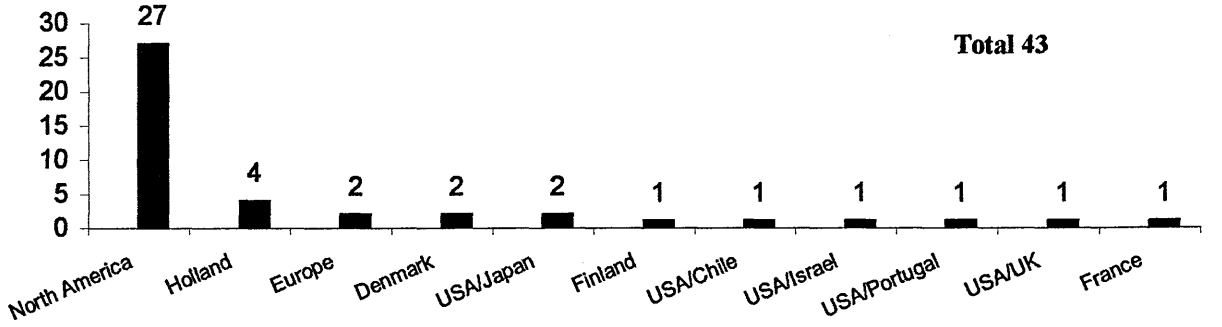

Fig. 5.2 Country of Study.

Whilst as shown in fig 5.2 there are several European resident firms studied in the systematic review, and Mandakovic and Souder (1990) perhaps arguably wrote from a Chilean perspective, it is apparent there are only two Asian studies. There is only one true Asia focused paper, the US/Japanese comparative study (Bhoovaraghavan et al, 1997).

The absence of Asian studies is particularly surprising when the omission is considered in the context of the types of industry the other studies in the systematic review report upon as widely using, and often benefiting from, portfolio management. The high technology industry is widely reported as a primary beneficiary of portfolio management. Indeed the analysis of the studies discussed in section 3.1 shows that 29% of the studies included in this systematic review are focused on high technology Industries. Cooper et al (1999) in their US survey of 205 large ($5b net revenue) US companies discussed in section 3.4 showed that 18% of those participating in his (US and Canada) survey were from the high technology sector. Japan has a major high technology industry. WSTS (world trade semiconductor sales) report that Japan consumes twenty percent of the total global microprocessor market, the fundamental building block of high technology electronic products. WSTS report that Japan is in fact also second only to the United States in microchip production. Further the Asia Pacific region has now surpassed Europe in microchip consumption and in production.

Fig 4.1 does show that some of the possible Japanese gaps were commented upon. For example Mikkola (2001), whilst not instigating her own specific Japanese studies, cites Winberg (1996) that Japanese high technology multinationals Aiwa, Sony and Sharp "successfully" operate with product portfolios which provide high benefits to customers and low competitive advantages. Mikkola (2001) considers this portfolio strategy contrary to Western practices. Bhoovaraghavan et al (1997), as evident in both the descriptive analysis (see section 3.2) and thematic analysis (see section 3.14) do compare global American and Japanese firms, and report differences in the respective innovation processes. These include differences in strategy, notably a market orientation rather than the supply oriented approach of American firms. Similarly Bhoovaraghavan et al (1997) propose that due to their supply orientation, US firms have been more focused on product

innovations and have tended to accept a higher risk associated with product adoption within their product portfolio. Conversely Bhoovaraghavan et al (1997) point out that Japanese firms, having taken a customer/demand orientation, tend to develop products incrementally, minimising the risk of new adoption. With these exceptions there appears otherwise to be little evidence of substantial Japan or Asia study contained within this systematic review.

As evident in fig 5.1, several possible gaps also emerged in Europe, though unlike Japan and Asia discussed previously, this lacked the substantiation of the study analysis shown in fig 5.2, which clearly shows that a substantial number of studies were conducted in Europe.

What is perhaps surprising about the European studies is that considering, as discussed extensively in section 3.1 and 3.11, that large companies and especially high technology and pharmaceutical companies, are principal beneficiaries of portfolio management, there are few studies from the large European Union countries with high gross domestic products. For example Germany is absent from fig 5.2 though a US subsidiary of Hoechst did participate. Whilst recognising that a certain UK bias may in part influence the assumption, it does seem rather strange that none of the large UK or German high technology or pharmaceutical multinationals, such as Siemens or Glaxo, appear to have been named in the systematic review.

Whilst not having specific evidence to discount the possibility that UK or German companies do not in fact use portfolio management, this would seem somewhat improbable. The UK based ARM and a German subsidiary of Agilent both willingly agreed to discuss their portfolio methods during the systematic review. There are possibly other more likely explanations. These firms may have participated and were granted anonymity, or perhaps were, as reported in section 2.12 in the case of ARM, not enthusiastic to disclose their methods to a public forum.

5.3 Synthesis of research possibilities

Section 4 (subsections 4.1-4.12 inclusive) summarises possible areas of future research emanating from the discussion. These are summarised in appendix 2 and referenced back to section 4. As previously discussed in section 4 each of these is recommended for further investigation. Additionally each of these recommendations might hold the possibility of synergy with another recommendation within the consolidated summary. Equally in the event that synergies exist, it might be useful to determine which if any of these might be investigated first. Each pair of possible research ideas were compared against the other and rated with (1 = low, 2 = med, 3 = high) to indicate the likelihood of possible synergy existing between the two pairs. The detailed analysis is shown in fig 5.3.

Ref.				4.5A,B			4.7A,B		4.8A,B,C			4.9A,B,C					
	4.2	4.3	4.4	*A*	*B*	4.6	*A*	*B*	*A*	*B*	*C*	*A*	*B*	*C*	4.10	4.11	4.12
4.2	**0**	3	3	3	2	2	**2**	**2**	**3**	**3**	**2**	**2**	**3**	**3**	3	3	3
4.3	3	**0**	2	2	3	1	**2**	**2**	**2**	**1**	**2**	**2**	**3**	**2**	2	2	2
4.4	3	2	**0**	1	1	1	**2**	**1**	**2**	**3**	**2**	**2**	**1**	**1**	1	3	1
4.5A	3	2	1	**0**	**3**	1	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	2	2	2
4.5B	2	3	1	3	**0**	1	**2**	**2**	**2**	**1**	**2**	**3**	**2**	**1**	2	2	2
4.6	2	1	1	**1**	**1**	**0**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	1	1	1
4.7A	2	2	2	**2**	**2**	1	**0**	**2**	**3**	**3**	**2**	**2**	**3**	**2**	1	3	1
4.7B	2	2	1	**2**	**2**	1	**2**	**0**	**2**	**3**	**0**	**2**	**3**	**1**	3	3	3
4.8A	3	2	2	**2**	**2**	2	**3**	**2**	**0**	**3**	**2**	**2**	**2**	**1**	1	3	1
4.8B	3	1	3	**2**	**1**	1	3	3	**3**	**0**	**3**	2	2	1	3	3	2
4.8C	2	2	2	**2**	**2**	1	2	0	**2**	**3**	**0**	2	3	2	3	3	3
4.9A	2	2	2	**2**	**3**	1	2	2	2	2	2	**0**	**2**	**2**	3	2	2
4.9B	3	3	1	**2**	**2**	1	3	3	2	2	3	**2**	**0**	**2**	2	3	2
4.9C	3	2	1	**2**	**1**	1	2	1	1	1	2	**2**	**2**	**0**	2	1	2
4.10	3	2	1	**2**	**2**	1	1	3	1	3	3	3	2	2	**0**	2	1
4.11	3	2	3	**2**	**2**	1	3	3	3	3	3	2	3	1	2	**0**	2
4.12	3	2	1	**2**	**2**	1	1	3	1	2	3	2	2	2	1	2	**0**
Total	42	33	27	32	31	18	33	32	33	36	34	33	36	26	32	38	30

Key (1 = low, 2 = med, 3 = high) likelihood of possible synergy existing.

Fig 5.3: Possible synergy existing between the potential research areas.

Reference				4.5			4.7		4.8			4.9					
Ref.	**4.2**	**4.3**	**4.4**	***A***	***B***	**4.6**	***A***	***B***	***A***	***B***	***C***	***A***	***B***	***C***	**4.10**	**4.11**	**4.12**
4.2	**0**	3	3	3					3	3			3	3	3	3	3
4.3	3	**0**			3								3				
4.4	3		**0**							3						3	
4.5A	3			**0**	3												
B		3		3	**0**							3					
4.6						**0**											
4.7A							**0**		3	3			3			3	
B								**0**		3			3		3	3	3
4.8A	3						3		**0**	3						3	
B	3		3				3	3	3	**0**	3				3	3	
4.8C										3	**0**		3		3	3	3
4.9A					3							**0**			3		
B	3	3					3	3			3		**0**			3	
C	3													**0**			
4.10	3							3		3	3	3			**0**		
4.11	3		3				3	3	3	3	3		3			**0**	
4.12	3							3			3						**0**
Total	42	33	27	32	31	18	33	32	33	36	34	33	36	26	32	38	30

Key (1 = low, 2 = med, 3 = high) likelihood of possible synergy existing.

Fig 5.4: Possible "high synergy" existing between the potential research areas.

Fig 5.4 shows the pairs of research ideas, which were believed to potentially hold most synergy with the others. (see section 2.15 methodology). The total score from each research idea shown in the total column of fig 5.3 and 5.4.was ranked as shown in fig5.5. The research ideas were split into quartiles as shown in fig 5.5. The top quartile of these research ideas are then summarised in section 5.4 for further discussion.

Top quartile	Second quartile	Third quartile	Last quartile
42 Ref. 4.2	**34** Ref. 4.8C	**32** Ref. 4.9A	**31** Ref. 4.5 B
38 Ref. 4.11	**33** Ref. 4.8A	**32** Ref. 4.7	**30** Ref. 4.12
36 Ref. 4.9B	**33** Ref. 4.7A	**32** Ref. 4.5A	**27** Ref. 4.4
36 Ref. 4.8B	**33** Ref. 4.3	**32** Ref. 4.10	**26** Ref. 4.9C
			18 Ref. 4.6

Fig 5.5: Research ideas split into quartiles.

Reference	4.2	4.8B	4.9 B	4.11
4.2		3	3	3
4.8 B	3			3
4.9B	3			3
4.11	3	3	3	

Fig 5.6: Top quartile.

The pairs of references (4.2 and 4.8 B), (4.2 and 4.9B), (4.2 and 4.11), (4.8B and 4.11), (4.9B and 4.11) emerged from the analysis as shown in fig 5.6.

5.4 Discussion of synthesis

Cooper et al (1997; 1998, 1999; 2001) continually report that many senior managers are not making tough decisions to kill products and focus on "winning products." Platje et al (1994) observe that internal competition exists for limited resources, technology and control of market charters. Though focusing more on the team motivation aspects of the dilemma, Cooper et al (1997) also recognise that in many instances the "human side" is more important than making the correct decision to "kill" products and appears to be stopping projects being "killed". Does this dilemma extend beyond the product development process?

It would appear reasonable for Cote and Stanmeyer (2001) to urge CEOs to seek alliances as part of a balanced product portfolio strategy and essentially export at least a proportion of the product development outside of the company. Platje et al (1994) observe that internal competition exists for control of market charters, within companies. If a charter were to be exported outside the company it would seem reasonable to assume that this would be at least as difficult, and possibly more so, than for a senior manager to kill a product. Similarly if design re-use provides for the work done by one team to be re-used by another team within the company, then this type of strategy might possibly also encounter the type of "human difficulties" reported (Cooper et al, 1997). The impact of alliances and design re-use on portfolio management, particularly in respect to the "human aspects", could quite possibly benefit from additional research.

5.5 Summary and conclusions

Theme	Type of study			Region			Practitioner /Academic	
	Survey	Case	Other	US	Euro	Other	P	A
3.17 Risk	3	2	8	12	2	yes	2	11
3.18 Technology	1	2	4	5	2	2	2	5
3.19 Re-use	yes	2	3	4	2	yes	3	3
3.20 Market	4	1	3	8	yes	1	1	7
3.21 Finance	1	2	5	8	yes	2	4	6
3.22 Size of firm	1	1	3	3	2	yes	2	4
3.23 People man	3	2	3	3	4	yes	1	6
3.24 Innovation	3	1	3	7	yes	1	yes	7
3.25 Strategy	1	1	6	7	2	3	2	6
3.26 Resource	1	1	11	7	5	yes	6	9
3.27 Competition	1	1	3	3	3	1	1	5

Fig 5.7: Consolidation of possible gaps. ***(Reference section 3.28)***

This systematic review has been a broad review of the portfolio management literature. It would appear that, as discussed in section 4 and summarised in appendix 2, a significant number of "possible" research gaps are apparent. The analysis of these possible research gaps, discussed in section 5.3, *(with the limitations previously discussed in section 2.15)* suggests that many of these can be synthesised into yet more interesting "possible gaps".

Though accepting the limitations of this systematic review and the overall systematic review process discussed in section 6, it would appear that there may be significant gaps in the regional research on portfolio management, notably Japan and Asia (as discussed in section 5.1). Whilst many research methods are detailed within the systematic review, when allocated against the major themes as shown in fig 5.7, these may appear to be insufficient to cover the multitude of possible gaps listed in Appendix 2.

Portfolio management would appear to be an area worthy of significant additional management research.

6.0 Limitations of the systematic review and sensitivity analysis

6.1 Sources of possible bias assessment

One of the principal theoretical advantages that a systematic review offers is the potential to recognise and attempt to reduce the impact of bias.

In section 2.2 I declared a positivist background and a pragmatic and positivist managerial perspective acquired during my 20 year product development career. Also the possibility of financial sponsorship for future research from my employer may have introduced bias.

Several steps were taken to reduce these and other possible biases.

Meetings with ARM, Agilent and Professor Goffin reported in section 1.5 were .a deliberate attempt to compare the portfolio management literature with sources external to Cranfield and solicit a practitioner feed back. The protocol used in this review was submitted to a panel of "neutral" academics consisting of two innovation academics and two process experts. The panel made significant recommendations:

- The key word protocol and search engine was to be submitted for approval, (see section 2.5). These changes are comprehended in this report.
- The 70 journals from which the papers were sourced were verified as described in section 2.93/2.94.
- The inclusion list of 43 papers was academically verified as described in section 2.94. The top 20 papers were also verified as having no notable omissions. Similarly the themes used in thematic analysis. These were then verified, using the Agilent checklist.

Even so, did all these measures eliminate bias? Whilst I believe that significant effort was extended to endeavour to eliminate bias, with hindsight I believe that some subconscious bias may still remain in the process.

6.2 Cooper, R influence

Cooper, R. (not K) had clearly enjoyed considerable citation success. Most papers cited Cooper. Cooper had 5 papers in the review. Even the Agilent which was used for a practitioner perspective had credited Cooper substantially for their internal flow. My supervisor, who of course acted as the verification step in the inclusion/exclusion process, continually referred to Cooper as "the man". Whilst it is quite probable that Cooper, to an extent, has earned the reputation he clearly enjoys, it is also a possibility that his reputation had in turn influenced the systematic review. Whilst it may appear that some 38 other sources exist to balance his 5 papers, perusal of their references reveal that most substantially build their foundations for study on his core assumptions, such as the Stage Gate Process. In the event that Cooper is the genius in the field, this systematic review is balanced. Clearly academics and practitioners alike think he is. The process undertaken dictates I accept this.

6.3 Employer bias

Whilst hopefully the systematic review has provided an audit trail for others to follow, ultimately the purpose for the systematic review was to discover gaps for my future research interests. If my employers do not approve of the gap, there will be no funding and consequently no research. Whilst one of the major gaps reported relates to Japan and Asia, which would most certainly not get funded by my employer, or possibly even solicit interest from Cranfield, there are clearly areas which might. Whether these have truly arisen without any subconscious bias remains difficult to prove beyond reasonable doubt. Certainly it would have been preferable for ARM to have assisted with the analysis reported in section 2.15.

6.4 Sensitivity analysis (what if)

6.41 Impact of inclusion and exclusion criteria

The inclusion and exclusion requirements described in section 2.61 and 2.62 form a significant factor in the sensitivity analysis.

Exclusion (1) all non-English papers. One of the primary findings of this systematic review was that there were significant portfolio management gaps in Asia studies. The exclusion of non-English papers in the systematic review is clearly a limitation of the review. Consideration of this point must be addressed prior to commencing further research on this finding. Exclusion (2) all papers not relevant to the field of study. As discussed in section 2.62 the method of separating the innovation literature from the substantial stock market literature meant that several hundred papers were excluded from the total search on this basis. This was probably a relatively unique situation, which ordinarily would not be as significant for other subject choices. Section 2.95 lists the exclusions due to relevancy from 124 papers selected.

6.42 Geography

The original protocol for the systematic review constrained the study to just UK and US companies. It was the review panel's recommendation to expand the systematic review to source global companies. This was clearly extremely significant and has undoubtedly considerably shaped the systematic review. From section 3 and 4, it is also apparent that there were few UK studies. Without this recommendation, the study would be almost entirely composed of US papers and studies. The European, Chile and Israel studies may have been lost. This would have revealed a possible gap within the UK for further research, as the findings of the review would be almost entirely American. Perhaps most importantly the possible gap in Asia and Japan would not have been provisionally identified without this change to the protocol.

6.43 Exclusion criteria

The exclusions due to exclusion criteria are summarised in fig 6.1. Clearly without the criteria many of these papers would have been included in the review.

Exclusion Reason	Author Date
Services sector	
3	Buxton and Hanney (2000)
3	Duysters and de Man (2003)
3	Heidenhain (2001)
3	Morris (2002)
Overtly technical	
4	Archer and Ghasemzadeh (1999)
4	Hemmerick (1997)
4	Heung and Yu (1998)
4	Hung et al (1996)
4	Islei et al (1990)
4	Kirchhoff et al (2001)
4	MacMillan (2001)
4	Regan and Holtzman (1995)
4	Webber et al (2002)
4&3	Jiang and Klein (1999)
Consumer sector	
5	Anderson et al (1987)
5	Bernstein and Macias (2002)
5	Blattberg and Deighton (1974)
5	Boddington (2002)
5	Chapman (1985)
5	Heartland (2002)
Before 1980	
6	Blackman (1973)
6	Jones (1971-1972)

Fig 6.1: Excluded papers by exclusion criteria.

6.44 Inclusion criteria

Whilst there are 6 consumer papers listed in section 6.43 excluded due to the exclusion criteria, in reality, the decision to remove consumer and services from the analysis took place within the scope of the original study inclusion criteria. The impact this decision had on the design of the protocol eliminated dozens of papers studied. Had time allowed, perhaps if another three months were available, inclusion of the consumer sectors could have enhanced the study and provided additional insights. This would most definitely be a recommendation for consideration by future researchers.

The papers listed by the inclusion criteria are shown in Fig 6.2. It is apparent that most are "multiply qualified" by the 8 criteria for inclusion.

	Inclusion criteria (See section 2.61)							
Author Date	**1**	**2**	**3**	**4**	**5**	**6**	**7 ***	**8**
Ausura (2003)	x	x	x	x		x	x	x
Ayal and Rothberg (1986)	x		x	x		x	x	x
Bhoovaraghavan et al (1997)	x		x	x	x		x	x
Bond and Houston (2003)	x		x	x	x		x	x
Cabral (1994)	x		x	x	x		x	x
Cardozo and Wind (1985)	x		x	x		x	x	x
Cooper, K. et al (2002)		x	x	x		x	x	x
Cooper et al (1997)	x		x	x	x		x	x
Cooper et al (1998)	x		x	x	x		x	x
Cooper et al (1999)	x		x	x	x		x	x
Cooper (2000)	x		x	x	x		x	x
Cooper et al (2001)	x		x	x	x		x	x
Cote and Stanmeyer (2001)		x	x	x		x	x	x
De Maio et al (1994)	x		x	x		x	x	x
Elonen and Artto (2003)	x		x	x	x		x	x
Firth and Narayanan (1996)	x		x	x	x		x	x
Fox et al (1984)	x		x	x	x		x	x
Ghasemzadeh and Archer (2000)	x		x	x	x		x	x
Graves and Ringuest (1992)	x		x	x	x		x	x
Graves et al (2000)	x		x	x	x		x	x
Griffin (1997)	x		x	x	x		x	x
Griffin (2002)	x		x	x	x		x	x
Harmsen et al (2000)	x		x	x	x		x	x
Hendriks et al (1999)	x	x	x	x		x	x	x
Jolly (2003)	x		x	x	x		x	x
Liberatore (1987)	x		x	x		x	x	x
Lint and Pennings (1998)	x		x	x	x		x	x
Lint and Pennings (2001)	x		x	x	x		x	x
Linton et al (2002)	x	x	x	x		x	x	x
Luehrman (1998)	x		x	x	x		x	x
MacMillan and McGrath (2002)	x		x	x	x		x	x
Mandakovic and Souder (1990)	x		x	x	x		x	x
Meadows (1999)		x	x	x		x	x	x
Mikkola (2001)	x		x	x		x	x	x
Platje et al (1994)		x	x	x		x	x	x
Purdue and McAllister (1999)		x	x	x	x		x	x
Repenning (2001)	x		x	x	x		x	x
Rosenau (1999)	x	x	x	x		x	x	x
Spital (1979)	x		x	x	x		x	x
Spradlin and Kutoloski (1999)		x	x	x	x		x	x
Tritle et al (2000)		x	x	x	x		x	x
Van Arnum (1998)		x	x	x		x	x	x
Verma and Sinha (2002)	x	x	x	x		x	x	x

Key. x denotes inclusion.

Fig 6.2: Papers listed by inclusion criteria.

6.45 Impact of choice search engines

Author year	Science Direct	ESBCO	PDMA	Practitioner or Academic
Ausura (2003)			1	p
Ayal and Rothberg (1986)	1			
Bhoovaraghavan et al (1997)	1			
Bond and Houston (2003)		1		
Cabral (1994)	1			
Cardozo and Wind (1985)	1			
Cooper, K. et al (2002)	1			
Cooper et al (1997)		1		
Cooper et al (1998)	1	1		
Cooper et al (1999)	1	1		
Cooper (2000)		1		
Cooper et al (2001)	1	1		
Cote and Stanmeyer (2001)			1	p
De Maio et al (1994)		1		
Elonen and Artto (2003)	1	1		
Firth and Narayanan (1996)	1	1		
Fox et al (1984)		1		
Ghasemzadeh and Archer (2000)	1	1		
Graves and Ringuest (1992)	1			
Graves et al (2000)		1		
Griffin (1997)	1			
Griffin (2002)	1			
Harmsen et al (2000)	1			
Hendriks et al (1999)	1			
Jolly (2003)	1	1		
Liberatore (1987)		1		
Lint and Pennings (1998)	1			
Lint and Pennings (2001)		1		
Linton et al (2002)		1		
Luehrman (1998)		1		
MacMillan and McGrath (2002)		1		
Mandakovic and Souder (1990)	1			
Meadows (1999)			1	p
Mikkola (2001)	1	1		
Platje et al (1994)	1	1		
Purdue and McAllister (1999)		1		
Repenning (2001)	1	1		
Rosenau (1999)			1	p
Spital (1979)		1		
Spradlin and Kutoloski (1999)		1		
Tritle et al (2000)		1		
Van Arnum (1998)		1		
Verma and Sinha (2002)	1	1		
Total	**23**	**27**	**4**	

Fig 6.3: Summary of author and source publication.

One of the most striking observations in the sensitivity analysis is the impact of the choice of search engine. Fig 6.3 lists the papers included in the systematic review by source. Whilst it is apparent that 11 papers are common to Science Direct and ESBCO, no less than 32 papers are solely source. In the event that only one search engine had been selected for example Science Direct, 20 papers would have been lost or, in the event of just using ESBCO, 16 papers lost. This point is further discussed during the assessment of the systematic review process.

6.5 Limitations of systematic review and recommendations to future researchers

6.51 Relatively narrow base of academic focus

There are many strengths of the systematic review process and within these strengths perhaps might also reside some of the weaknesses. One of the primary strengths of systematic review is that the rigorous search protocol and disciplined inclusion/exclusion criteria provide an extremely tight focus on a relatively narrow area of literature throughout the review. The methodology is perhaps less helpful to compare other areas of literature. Fig 6.4 attempts conceptually to capture this issue. This systematic review has been focused on portfolio management and, in surfacing this literature, it has arguably also included a substantial amount of very closely related literature. The product development literature would be an excellent example of this. However there may be literature which is not traditionally associated with portfolio management which might well be extremely helpful for future research which the search protocol would exclude.

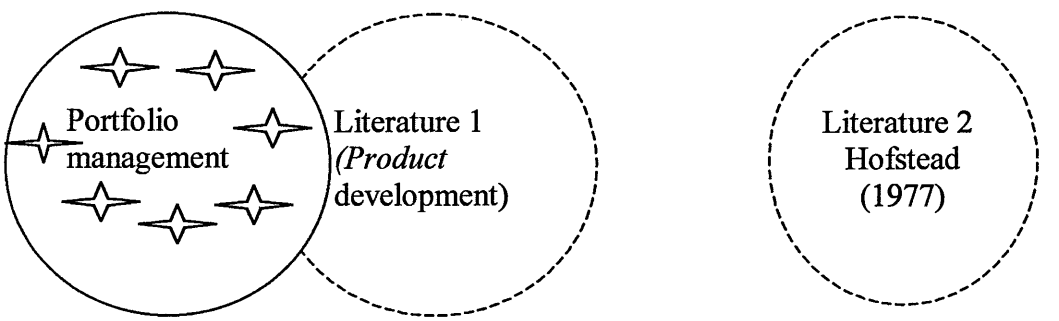

Fig 6.4: Conceptual map of systematic review.

A good example of this scenario in the context of this systematic review would be Hofstead (1977) who extensively studied national differences, but was not sourced through the systematic review. Hofstead (1997) specifically addresses the issue of differences in risk profile between the Japanese and the rest of the world and finds that risk aversion in Japan is substantially higher than for the UK and USA. However a possible solution to this limitation might be that, having identified a provisional gap through the systematic review, a revised protocol and a second systematic review targeted more at differences between Japan and the USA possibly would have revealed Hofstead (1977) and similar literature. This might especially be the case if a review panel consisting of members from a broad base of academic disciplines were to offer input on

the key words and protocol. I would urge future researchers to consider this type of approach.

6.52 The search engines and their publication lists

Another limitation of the systematic review is the high level of dependency on the power of the search engines. In section 6.45, the sensitivity analysis (fig 6.3) shows what the impact to this systematic review would have been if just one search engine had been used. Almost half the papers would have been lost from the final systematic review. This perhaps raises the question of how many more papers would be found with additional engines.

The analysis in fig 6.3 is reported in terms of the authors' papers which would have been absent from the review. An alternative analysis is to consider the publications which were missing from each search engine. The results are rather interesting. Whilst, as reported in section 2.94, *70 publications* were evident in the initial search results, the analysis shown in fig 6.5 reveals that as few as 9 publications provided the majority of the 43 final papers.

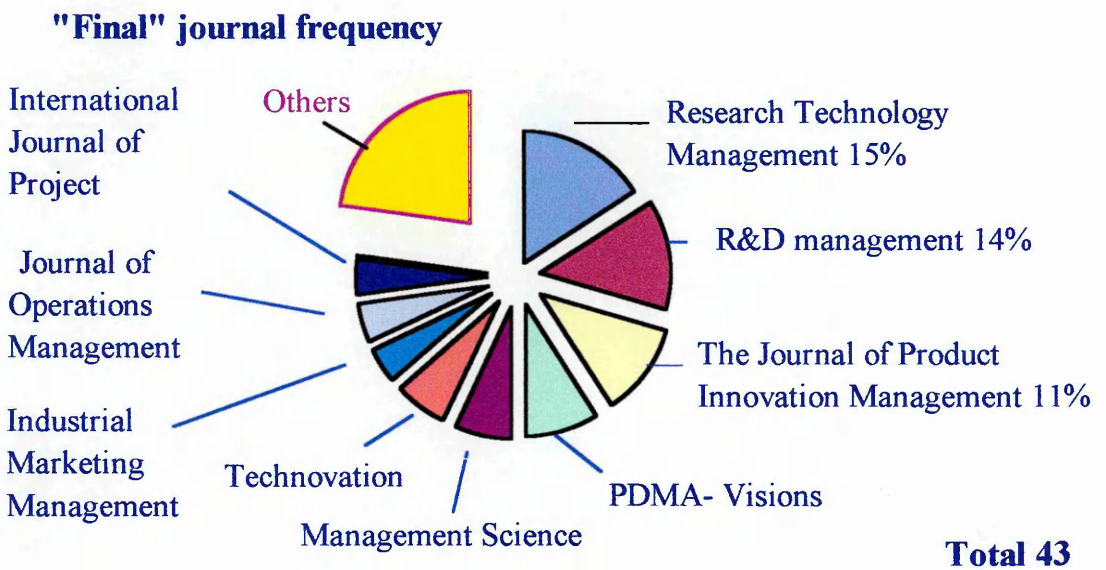

Fig 6.5: The journals included in the final selection of papers used in the systematic review.

The "what if" analysis shown in fig 6.3 was re-compiled to provide the source publication by search engine. The results are shown in fig 6.6.

"What if" Science Direct missing	
Chemical Market Reporter	Van Arnum (1998)
Harvard Business Review	Luehrman (1998)
IEEE Transactions on Engineering Management	Liberatore (1987)
Interfaces	Purdue and McAllester (1999)
Ivey Business Journal	Cooper (2000)
Journal Of Operational Research	De Maio et al (1994).
Journal of Product Innovation Management	Bond and Houston (2003).
PDMA -Visions	Ausura (2003) Cote and Stanmeyer (2001) Rosenau (1999) Meadows (1999)
Research Technology Management	Cooper et al (1997) Fox et al (1984) Graves et al (2000) MacMillan and McGrath (2002) Spradlin and Kutoloski (1999) Tritle et al (2000)
Research Policy	Spital (1979)
R&D Management	Lint and Pennings (2001) Linton et al (2002)

"What if" ESBCO missing	
Industrial Marketing Management	Griffin (2002)
International Journal of Industrial Organization	Cabral (1994)
International Journal of Project Management	Cooper, K. et al (2002) Hendriks et al (1999)
Journal of Engineering and Technology Management	Mandakovic and Souder (1990)
Journal of Product Innovation Management	Bhoovaraghavan et al (1997) Griffin (1997) Ayal and Rothberg (1986) Harmsen et al (2000)
PDMA -Visions	Ausura. (2003) Cote and Stanmeyer (2001) Meadows (1999) Rosenau (1999)
Research Policy	Spital (1979)
The Journal of High Technology Management Research	Graves and Ringuest (1992)

Fig 6.6: Publications "what if" analysis.

The results shown in fig 6.6 initially appear to suggest a theory that each search engine has excluded specific publications. Science Direct appears to have provided papers from Bhoovaraghavan et al (1997); Griffin (1997); Ayal and Rothberg (1986) and Harmsen et al (2000) published in the *Journal of Product Innovation Management* which ESBCO seems to have not been able to provide.

To investigate this further the search engines publication lists were then checked. The theory that each search engine has excluded specific publications was confirmed to be plausible, with the exception of one contradiction. ESBCO and not Science Direct provided Bond and Houston (2003) who were also published in the Journal of Product Innovation Management. Deeper investigation revealed that, effective Jan 2003, Science Direct had cancelled the *Journal of Product Innovation Management* and ESBCO had initiated coverage of the Journal. In summary a critical factor in the selection of the search engines is the importance of investigating how complementary the publication lists of search engines are, as well as the total number of papers they can source, whilst conducting a pilot study.

Three recommendations are made for future researchers to consider when conducting their search engine pilot strategy: -

1) Increase the number of search engines used in the systematic review.

2) Include a publication verification step in the process as described in section 2.94 and section 2.5. Additionally include a process step which compares the source publication lists. When adding additional engines consider, not just the total number of papers, but also whether the publication lists are complementary.

3) Do not be concerned about duplications in the pilot results. Whilst this may appear to be redundancy in the process, consider that Procite can very rapidly separate the duplications and can be quickly programmed to publish and sort the list by publication to perform this analysis as discussed in section 2.93.

6.54 Vision of the future for systematic review

Examining portfolio methods through the lens of this systematic review has enabled considerable time to reflect upon the systematic review process. As previously discussed in section 6.51, there are some fundamental trade-off decisions to be made.
Typically these arise at the following major gates:-

1. When defining the search strategy (key word/strings and search engines).
2. Inclusion/exclusion criteria.
3. Quality assessment.
4. Synthesis.

5. Audit capability.

These factors need to be considered very carefully prior to undertaking a systematic review. Such is the power of the search technology that literally thousands of papers can easily be generated, many of which may not necessarily always be what the user intended. This might appear to introduce a classical trade off between the resources and the time and the quality of the review which can be generated. To some the ability of the technology to generate huge quantities of data, coupled with the administrational overhead which is associated with the later stages of the process, might be considered to be eating into the quality of reporting. An alternative vision could be that the relentless progress of Moore's law, and the power it provides to the computing industry, would appear to be more than capable of providing innovative solutions to these problems. During the learning process of the systematic review the power of Procite whilst frustrating in some areas was equally impressive in others. Once programmed, hundreds of databases could be downloaded in real time. Equally the electronic publication industry appears to be engaged in a highly competitive struggle to solve many of these issues and appears to be rapidly adopting ever-increasing capabilities.

It would appear not inconceivable that, with the rate of technical progress evident even in just the past 2 years, perhaps most of the front end of the systematic review will become automated. An altogether different vision emerges. Search results downloading automatically into electronic databases, automated inclusion/exclusion criteria, possibly even automated quality assessment could become the norm. Authors and publications could provide the essential descriptive and thematic data in a format that enables both rapid and automated capture. One area, which might provide a bottleneck, will be the need to develop synthesis tools and strategies, which can cope with the vast through put from the front end of the search process. Nvivo, which though not ultimately used in this systematic review, initially was thought to hold promise and synthesis potential. Having experimented for several weeks with the software it appeared that there might be some significant reasons why Bill Gates had become the richest man in the world rather than the inventor of Nvivo. Surely methods will emerge from more sophisticated disciplines to fill this void of synthesis.

If this quite plausible technical vision is additionally complemented by increasing numbers of academics and practitioners generating systematic reviews, thereby establishing a twenty-first century replacement to the traditional literature reviews, the progress will be all the more rapid. Future researchers might then be able to take the existing systematic reviews and focus entirely on expanding known frontiers of subjects and adding alternate dimensions. Specifically the limitations discussed in section 6.51 and conceptualised in fig 6.4 might be provided with "plug and play" solutions. Rather than merely advising upon additional areas for the researcher to explore, a broad based academic might in future merely hand over a CD. or website address of a full and diverse toolkit of relevant systematic reviews to be integrated into and synthesised with the researcher's specific field of study. Certainly synthesis needs to change, but the future for systematic reviews looks highly encouraging.

Contents

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Appendix 1

Consolidated Science Direct, ESBCO and Visions (PDMA) selected for abstract

1. Agarwal (1994)
2. Agarwal (1992)
3. Altman (1977)
4. Andersen and Jessen (1994)
5. Anderson (2001)
6. Anderson & Settle (1996)
7. Anderson (1987)
8. Anderson & Prezas (1999)
9. Anil (2002)
10. Archer & Ghasemzadeh (1999)
11. Armstrong and Brodie (1994)
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13. Ausura (2003)
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15. Bailey (1994)
16. Bardsley (2001)
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206.Stackpole and Beth (1998)

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217. Van Arnum 1998

218. Van der Haar (2001)

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222. Walker (1984)

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Appendix 2

Possible future research requirements

Risk ***(Ref. discussion 4.2)***

❑ Management reluctance to "kill" products despite overwhelming recommendations that this will *(often)* improve overall business (Cooper et al, 1999). *(Has Cooper considered re-use reference from 4.4?)* **Technology** ***(Ref. discussion 4.3)***

❑ Agilent consideration of disruptive technologies. *(Not specifically reported in the systematic review as a major sub theme.)*

Re-use ***(Ref. discussion 4.4)***

❑ Has Cooper fully considered deciding the best time to exit projects before killing them to maximise the "re-use" potential?

Markets ***(Ref. discussion 4.5)***

A. Cooper (2000) despite advocating voice of customer in product development possibly doesn't specifically advocate substantial customer involvement in the major portfolio management decisions. (such as should the project be "killed") Similar Spital (1979) re manufacturing decision.
B. Agilent adoption of waves, Moore (1992) *Crossing the Chasm.* Influence is not evident in the systematic review.

Finance ***(Ref. discussion 4.6)***

❑ It is not clear from the evidence provided by the systematic review whether real options are actually effective techniques for complementing portfolio management or merely that few firms have enough experience of them to discuss their limitations.

Size of companies ***(Ref. discussion 4.7)***

A. Do large firms have an advantage over smaller (Why are Agilent concerned with size?)
B. Bond (2003) language barriers are more difficult within the high technology sector.

People issues ***(Ref. discussion 4.8)***

A. Portfolio management is a new practice not understood by senior management (Meadows, 1999). Some firms believe they have a weak portfolio management process (Cooper et al, 1999).

B. Despite evidence to re-deploy resources to improve business performance reluctance exists to kill projects. "Resource commitments are quite firm" & "The human side" team morale, commitments and not "jerking around" the team or leader is more important (Cooper et al, 1997).

C Bond (2003) language barriers are more difficult within the high technology sector.

Level of innovation ***(Ref. discussion 4.9)***

A. It is not apparent from the systematic review whether or not, with increased levels of innovation, the risks are higher for B2B companies who try to pursue highly innovative strategies.
B. Cote (2001) urges CEOs and managers to consider other strategies, such as alliances and new channels.
C Spital (1979) reports that perhaps innovation is driven by competition rather than portfolio management in some cases.

Strategy ***(Ref. discussion 4.10)***

❑ Though Japanese firms are reported as having taken a significantly different strategic approach to their product portfolios than US firms no supporting research has been surfaced by this systematic review to confirm or explain this.

Investment resource ***(Ref. discussion 4.11)***

❑ Platje (1994) perhaps adds an additional dimension to the issue by observing that internal competition exists for limited resources, technology capabilities, and control of market charters.

Competition ***(Ref. discussion 4.12)***

Is there a lack of influence of competitive position on the choice of portfolio strategies of Japanese companies?