

An Antiviral Disinfectant Research and Development Process Model for  
Small to Medium Enterprises Based within the United Kingdom

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## **Abstract**

Viral infections have produced commercial drivers to develop products to treat and reduce viral outbreaks and infections. Antiviral disinfectants have found particular favour in limiting new infections. The nature of viruses has however necessitated a continued stream of products successfully moving through the research and development (R&D) stage into commercial usage. With high product failure rates in R&D, and difficulties for executive and R&D managers to communicate effectively in the R&D stage, there was a perceived need from within the sector to further elucidate antiviral disinfectant R&D. Prior research had shown that the R&D stage is technically sophisticated with a requirement for management to engage in the technical, scientific and business aspects. This can be challenging for management decision-making, as many aspects of R&D, have different levels of knowledge required as well as language used. The use of models has received much attention in simplifying the R&D stage, but with little attention paid to creating shared meaning between different managers. In this study, executive and R&D managers from antiviral disinfectant UK based R&D SMEs were examined, using semi-structured case study interviews within a phenomenological paradigm. Explication was used to draw out meaning from respondent interviews, which showed that executive and R&D managers were from business and scientific backgrounds respectively. This resulted in difficulties in communication about R&D between manager types, which added to the opacity of R&D. It was noted that executive managers had greater knowledge of wider organisational aims for R&D, but little knowledge about what was carried out in the R&D stage. Conversely, R&D managers had greater knowledge about the scientific testing carried out in R&D, but little understanding of the business drivers of R&D. Using interview information, an alpha and beta model were constructed that showed a linear path through R&D, based predominantly on technical stages. An expanded view of the model was utilised to aid in R&D and executive management sense made of the R&D. This model contributed to the knowledge base through shared and warranted knowledge between R&D and executive managers as well as expanded model views of each of the R&D process stages. Both of these factors are novel and have created new academic knowledge as well as this model currently being used by three respondent companies.

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# ACADEMIC REGISTRY



## Research Thesis Submission

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## Table of Contents

Declaration.....	ii
Abstract.....	iii
Acknowledgements.....	iv
Research Thesis Submission.....	v
Table of Contents.....	vi
Abbreviations.....	x
Glossary.....	xi
List of Figures.....	xiv
List of Tables.....	xiv
Chapter 1. Introduction.....	1
1.1. Motivation and Aim.....	1
1.2. Research Question, Research Aim and Research Objectives.....	4
1.3. Research Methodology.....	5
1.4. Significance and Contribution of the Research.....	6
1.5. Thesis Outline.....	8
Chapter 2. Literature Review.....	10
2.1. Introduction.....	10
2.2. The Antiviral Market.....	11
2.3. Research and Development.....	12
2.3.1. Technology Companies and High Technology Products.....	16
2.3.2. New Product Development.....	18
2.3.3. Viruses and Antiviral R&D.....	20
2.3.4. The R&D Environment.....	25
2.3.5. The Antiviral R&D Environment.....	29
2.3.6. R&D Risk and Uncertainty.....	32
2.3.7. Management of R&D.....	35
2.3.8. Making Sense of R&D.....	38
2.3.9. Management Decision Making.....	40
2.4. Modelling R&D.....	44

2.4.1. Modelling ‘Reality’ – What is a Model?.....	45
2.4.2. Modelling ‘Reality’ – What is a Business Model?.....	46
2.4.3. Process Models in R&D.....	47
2.4.4. A Critique of R&D Models.....	51
2.4.5. Management Interaction with R&D Models.....	57
2.4.6. Intersubjectivity and Development of R&D Models.....	61
2.4.7. Language, ‘Reality’ and Modelling.....	64
2.5. Summary.....	65
 Chapter 3. Literature Synthesis.....	 67
3.1. Introduction.....	67
3.2. Research Gap in Antiviral Disinfectant R&D Management.....	67
3.3. Research Question.....	73
3.4. Research Aim.....	73
3.5. Research Objectives.....	73
 Chapter 4. Research Methodology.....	 74
4.1. Introduction.....	74
4.2. The Phenomenological Paradigm.....	75
4.3. Research Strategy: Case Studies.....	77
4.4. Sampling Frame.....	82
4.4.1. Sample Size.....	84
4.5. Interview Stage.....	85
4.5.1. Pilot Study.....	86
4.5.2. Main Study.....	87
4.6. The Process of Explicitation.....	88
4.6.1. Bracketing and Phenomenological Reduction.....	90
4.6.2. Delineating Units of Meaning.....	91
4.6.3. Clustering Units to Form Themes.....	92
4.6.4. Summarising each Interview and Warranting.....	92
4.6.5. Extracting Themes and Summarising.....	93
4.7. Reliability and Validity of Data Collected.....	94
4.7.1. Rigour.....	94
4.7.2. Validity.....	96

4.7.3. Warrantability.....	97
4.7.4. Generalisability.....	98
4.7.5. Researcher Sensitisation.....	99
4.7.6. Ethical Considerations, Data Storage and Protection.....	100
4.8. Summary.....	101
Chapter 5. Pilot Study.....	103
5.1. Introduction.....	103
5.2. Findings from the Pilot Study.....	103
5.2.1. Viruses and Antiviral Disinfectants.....	105
5.2.2. R&D Management.....	106
5.2.3. Process R&D.....	107
5.2.4. Other Areas of Interest.....	108
5.3. Summary.....	109
Chapter 6. The Main Study and Construction of the Alpha/Beta Models....	111
6.1. Introduction.....	111
6.2. Data Collection and Handling.....	112
6.2.1. Data Collection: Semi-Structured Interviews.....	112
6.2.2. Findings: Semi-Structured Interviews.....	115
6.3. Data Explication.....	130
6.3.1. Bracketing and Phenomenological Reduction.....	130
6.3.2. Delineating Units of General Meaning.....	131
6.3.2.1. Units Relevant to the Research Question.....	133
6.3.2.2. Eliminating Redundant Units of Meaning.....	135
6.3.3. Clustering Units to Form Themes.....	135
6.3.4. Summarising each Interview and Warranting.....	138
6.3.5. Extracting Themes and Summarising.....	138
6.4. Construction of the Alpha Model.....	141
6.5. Construction of the Beta Model.....	142
6.6. Summary of the Results.....	146
6.7. Discussion of the Results.....	147



Chapter 7. Conclusions and Recommendations.....	152
7.1. Introduction.....	152
7.2. Conclusion of the Study and Recommendations.....	152
7.3. The Contribution to the Knowledge Base.....	162
7.4. The Limitations of the Study.....	166
7.5. The Implications of the Study.....	167
7.6. The Recommendation for Future Research.....	169
References.....	171
Bibliography.....	229
Appendix A – Letter Sent To Prospective Interviewees.....	233
Appendix B – Excerpt from a Transcript with an R&D Manager.....	234

## Abbreviations

ADP	Antiviral Disinfectant Process
FDA	Federal Drug Administration
WHO	World Health Organization
CDC	Centre for Disease Control
HIV	Human Immunodeficiency Virus
CMV	Cytomegalovirus
HSV	Herpes Simplex Virus
SARS	Severe Acute Respiratory Syndrome
OED	Oxford English Dictionary
R&D	Research and development
SME	Small to Medium Enterprise
CRO	Contract Research Organisation
FIPNet	Fully Integrated Pharmaceutical R&D Network
UK	United Kingdom
COSHH	Control of Substances Hazardous to Health
CDA	Critical Discourse Analysis
WHO	World Health Organisation
NPD	New Product Development
EM	Executive Manager
R&DM	Research & Development Manager

## Glossary

### Business

- Case Study: A method often carried out under direct observation, without controlled variables, relying on multiple sources of evidence and requiring ‘triangulation’ (Yin, 2009) and/or warranting (Wood and Kroger, 2000).
- Decision Making: A range of processes from conscious thought through to random picking, leading to a selection being made from numerous choices (Kahneman and Tversky, 2000).
- Development The stage of R&D that is primarily concerned with exploiting knowledge for commercial gain (Di Masi *et al*, 2003).
- Emic An approach into how people sensitised to a particular environment think (Kottak, 2006).
- Etic An approach to shift the thinking of a sensitised individual to the role of the ‘researcher’ (Kottak, 2006).
- Explicitation: The process of making respondent meaning clear from transcribed verbal discourse (Hycner, 1999).
- Bracketing: An attempt made by a researcher to limit their preconceptions of the phenomenon throughout the explicitation stage and become more open to it’s meaning (Hycner, 1999).
- Generalisability: The process (also known as ‘external validity’), where the extent to which research claims can be extended to wider populations are considered (Wood and Kroger, 2000).
- High Technology: A categorisation of products constructed as ‘advanced’ that fill some level of societal need (Haverila, 2013).

Intersubjectivity:	The agreement between individuals about a particular meaning (Scheff, 2006).
Main Study:	The in depth respondent interview stage, which is the secondary stage to the pilot study (Wood and Kroger, 2000).
Model:	A symbolic representation of subjective or objective reality (Box, 1979).
Phenomenology:	A constructionism ontological stance, where a researcher attempts to see things from a respondent's point of view (Bogdan and Taylor, 1975).
Reduction:	A phenomenological research finding in its own right, with its own attached meaning, and in this study achieved by the method of explicitation (Fouche, 1993; Hycner, 1999).
Research	The initial stage of R&D that is primarily concerned with 'discovering' new knowledge that can be fed into development and commercialisation (Di Masi <i>et al</i> , 2003).
Pilot Study:	The exploratory stage of respondent interviews, used as a basis to construct the main study (Wood and Kroger, 2000).
Reliability:	A collection of research processes to determine the 'quality' of data and results (Wood and Kroger, 2000).
Rigour:	Often constructed as statistical validity, but in this study can be taken to mean replicability (Wood and Kroger, 2000).
R&D:	A collection of business activities composed of both 'research' and 'development' stages, to construct new products for commercialisation (Di Masi <i>et al</i> , 2003).
Sensitisation:	The extent to which the researcher perceives they are influenced by prior experiences, while undertaking research (Kottak, 2006).
Validation:	A process in rationalist research where research findings mirror the 'real' world, but as this study is

utilising discourse as data; the term warranting is preferred (Wood and Kroger, 2000).

**Verification:** A process embedded within rationalist research where justification and grounds for claims made is provided (Wood and Kroger, 2000).

**Warranting:** A process embedded within qualitative research where justification and grounds for claims made is provided (Wood and Kroger, 2000).

### **Scientific**

**Antiviral Disinfectant:** A product (also known as an antiviral sanitiser) that ‘targets’ pathogenic viruses to ‘kill’ them (OED, 2012).

**Drug:** A chemical treatment against a pathogenic disease-causing agent (OED, 2012) which in this study refers to viruses.

**Efficacy:** The percentage of viruses ‘killed’ by a drug or sanitiser (Xiao *et al*, 2007).

***In vitro*:** Testing that is carried out in an environment outside of a body such as a test tube (Alberts, 2008).

***In vivo*:** Testing that is carried out on a whole body or inside a body (Perkel, 2007).

**Stability:** The shelf life of a product before it degrades and becomes unsuitable for sale (BS EN1276: 2009).

**Virus:** A small biological cellular parasite capable of causing disease (Carter and Saunders, 2007).

## List of Figures

Figure 2.1. Human Papilloma Virus.....	21
Figure 2.2. Diagrammatic Representation of Antiviral Treatments.....	22
Figure 2.3. Stage Gate Model.....	53
Figure 2.4. Gates for the Stage Gate Model.....	53
Figure 2.5. Design Thinking Model.....	54
Figure 2.6. Technological R&D Framework Model Overview.....	55
Figure 2.7. Technological R&D Model with Increased View.....	56
Figure 4.1. The Research Process.....	102
Figure 6.1. Explicitation Process.....	112
Figure 6.2. R&D Manager Initial Process Model.....	141
Figure 6.3. Executive Manager Initial Process Model.....	141
Figure 6.4. Beta Model of Process R&D.....	143

## List of Tables

Table 2.1. The five generations of R&D.....	14
Table 4.1. The relationship between research methods.....	77
Table 4.2. Factors for Research Rigour.....	94
Table 5.1. The Areas and Questions Explored in the Pilot Study.....	104
Table 5.2. Summary.....	110
Table 6.1. The Questions Explored in the Main Study.....	113
Table 6.2. Delineating units of general meaning.....	131
Table 6.3. Addressing Units of General Meaning to the Research Question	136
Table 6.4. Clustering Units to Form Themes.....	137
Table 6.5. Extracting Themes and Summarising.....	140
Table 6.6. An Examination of this R&D Model against Others.....	145

# Chapter 1. Introduction

## 1.1. Motivation and Aim

In an increasingly competitive and globalised marketplace, product innovation is an important part of the strategy for technology companies to sustain their market position and achieve growth (Teece, 1986; Freeman and Soete, 1997; Wang, Lin and Huang, 2010). Research and development (R&D) has been shown as pivotal for company strategies reliant upon the exploration and exploitation of knowledge, resulting in the production of novel products (Wang, Lin, and Huang, 2010). R&D is challenging for management, as it can be uncertain and risk-laden (Zhang, Mei and Zhong, 2013). Developing R&D process models has received attention in numerous sectors (Cooper, 1983; Adler *et al*, 1995; Browning, 2010; Bednyagin and Gnansounou, 2012; Popp *et al*, 2013) as they can provide greater management insight and understanding into R&D and be used to minimise risk and uncertainty. R&D models have also been perceived as a vehicle to reduce R&D resources used, which can potentially increase profitability. Even though R&D process models can be beneficial for management and the wider organisation, they can create challenges. These challenges are based on the difficulty of producing a ‘useful’ model that does not create confusion or misunderstanding during the R&D stage, and that adequately mirrors the phenomenon of R&D, and is generally ‘better’ than not having it (Dolk and Kottemann, 1993; Crowston, 2003; Browning *et al*, 2006). There are thus many conflicting drivers for developing and using a process model, but arguably, as the complexity of R&D increases (particularly technological complexity), so does the importance of using an R&D model to mirror a fit-for-purpose view of the R&D stage to allow shared meaning and understanding to be constructed and linked to R&D (Shane and Ulrich, 2004).

Technological complexity throughout R&D can be particularly acute in the technology sectors including, biotechnology, pharmaceuticals and speciality chemicals. These sectors can have multiple unique considerations, which are crucial during and beyond the R&D process stage, and can include, product safety, toxicity, legislative compliance, efficacy (how well the product works), shelf life and risk,

amongst others (Dewar and Dutton, 1986; Henderson and Clark, 1990). Where the R&D environment and processes are not ‘adequately’ controlled, R&D may fail (Doctor *et al*, 2001; Raz *et al*, 2002; Lee *et al*, 2010) and is perhaps most clearly demonstrated by the pharmaceutical sector having an R&D to market success rate of less than 10 percent (CMR, 2006). This is however somewhat of a simplistic view for pharmaceutical R&D but is perhaps demonstrative of the difficulty of biologically based R&D. Process models can be used to facilitate how management make sense and decisions in and about R&D, particularly for increasing shared meaning between managers, reducing risk and uncertainty, as well as increasing company knowledge about R&D processes leading to an increased potential for successful product commercialisation (Smith and Merritt, 2002; Keizer *et al*, 2002; Bush *et al*, 2005; Pisano, 2006).

The type of product of interest in this study, is antiviral disinfectants, which has had little academic attention paid to it or the relevant R&D processes. Simplistically, antiviral products are generally liquids that target viruses to stop them infecting new hosts or limiting the damage viruses can do to an already infected host (by ‘killing’ the virus or inactivating it). Developing commercial products to target viruses can be challenging for R&D companies, as viruses are small biological particles (approximately 0.0000002 metres in diameter) that can cause disease states in a wide variety of hosts. Their small size means that they cannot be seen by the ‘naked’ eye and are not easily detected by routine scientific analysis such as light microscopy. Although small, the health and mortality cost from viral infection is high, with examples of pathogenic human viruses including, human immunodeficiency virus (HIV), cytomegalovirus (CMV), herpes simplex virus (HSV) and influenza to name a few. Pathogenic viruses are not limited to infecting humans as they can also infect animals and crops, which can result in micro- and macroscale negative financial and economic impacts. As an example of the damage a human viral outbreak can cause, viral respiratory infections can cost the USA \$25 billion per annum (Fendrick *et al*, 2001). This is coupled with a loss to the USA economy of 148 million days of restricted activity, nearly 20 million days of missed work, 22 million days of missed school, and 45 million bedridden days (Adams, Hendershot and Marano, 1999). The wider claims of this data are backed up by



Zohrabian *et al* (2004: 1736) who linked viral pathogenicity to socio-economic impacts, ‘(1) medical costs (inpatient and outpatient); (2) non-medical costs, such as productivity losses caused by illness and premature death, costs of transportation for a patient to visit a healthcare provider, and childcare expenses; and (3) costs incurred by public health and other government agencies for epidemic control’.

In many cases antiviral product R&D appear to have been driven by global disease outbreaks attributed to viral infections and market demand for novel products (Gilbert, Bestman-Smith and Boivin, 2002). There are three product types commonly used to stop the spread of viruses, including; (1) vaccines, which are administered to create immunity in a non-infected host; (2) *in vivo* antivirals, which inactivate (destroy) viruses present within the host; and (3) non-*in vivo* antiviral disinfectants, which inactivate viruses in the environment to stop their spread. All three products are different in the way they act, whether they can treat infected hosts, or are limited to stopping infection, as well as the side effects of treatments, costs and R&D processes. In this study, it is only non-*in vivo* antiviral disinfectants (herein referred to as antiviral disinfectants) that are of interest. In comparison to the two other product types of vaccines and *in vivo* based technologies, antiviral disinfectants have received little attention for understanding the R&D stage or the production of R&D process models.

Although antiviral disinfectants are limited to being used outside of host bodies (*i.e.* external surfaces) Bray (2008) has suggested that their targeted use could be an invaluable tool in reducing the pathogenic spread of rapid viral outbreaks where there is limited time to develop vaccines and/or *in vivo* products. The development of antiviral disinfectants potentially offers much quicker routes to market as well as lower R&D costs, in comparison to the other antiviral product types (Dellanno, Vega, Boesenberg, 2009).

This study is of importance to the author as he is the CEO of the sponsoring company that is actively involved in antiviral disinfectant R&D. Moreover, this research is perceived as having importance to management in other companies engaged in antiviral disinfectant R&D, for understanding and optimising their R&D

processes. While allied technologies within the antiviral sectors of vaccines and *in vivo* therapeutics have received much academic attention (Lakdawalla and Sood, 2012), the ability to generalise this knowledge into the antiviral disinfectant sector for R&D was simply unknown. Coupled with much academic literature arguing the importance of models for R&D (Browning, 2010), a nuanced methodological approach was undertaken using phenomenology to ‘see’ the antiviral disinfectant process R&D stage through the eyes of managers engaged in this R&D. Thus enabling the production of antiviral disinfectant models that could be considered and contextualised in light of prior models in allied antiviral sectors but also as models in their own right. This approach was expected to develop a higher-level of business performance and bring new insights to this area.

In this study, the examination of business and scientific processes relevant to the R&D stage was carried out by a multiple case study method, interviewing R&D managers in antiviral disinfectant small to medium enterprises (SMEs) and produced a model of antiviral disinfectant R&D processes. Model development took place by the production of an alpha model, which was subsequently modified through R&D manager verification/warranting, to produce a beta model. The ‘Research Question, Research Aim and Research Objectives’ driving this study are detailed in the following section.

## **1.2. Research Question, Research Aim and Research Objectives**

To address the shortfall in research identified in the previous section, the research question guiding this study is:

*How do UK based SMEs carry out process R&D for antiviral disinfectants?*

From this a research aim was derived:

*To examine current theory and practice in order to produce a model for process R&D used by UK SMEs producing antiviral disinfectants.* From this a number of research objectives were constructed:

- a) Through a literature review and current practice, to determine the current scientific and business processes for UK SMEs engaged in antiviral disinfectant process R&D;*
- b) Informed by a) above to produce an initial alpha model for UK SMEs engaged in antiviral disinfectant process R&D;*
- c) Informed by a) and b) above, to verify/warrant the initial alpha model and so produce a beta R&D model.*

N.B. The words ‘verify’ and ‘warrant’ used in objective c) are more fully described in section 4.7.2 and 4.7.3 for how they relate to each other and are used in the social science method of ‘explicitation’.

After developing the initial alpha model by examination of current theory and data derived from in depth interviews and analysed by explicitation, the researcher presented the alpha model to the case interviewees to receive further comment/feedback/verification/warranting. This process was to determine the extent to which the alpha model represented their view of antiviral disinfectant R&D processes within their company. It also allowed their responses to the alpha model to be used to further refine the alpha model into a beta model, encompassing their feedback.

### **1.3. Research Methodology**

This study is based within the phenomenological interpretivist research paradigm (described in greater detail in section 4.2) and investigated how UK based SMEs carry out antiviral disinfectant process R&D, which resulted in the researcher of this study constructing an R&D process model.

Interviews with fourteen key managers (seven executive and seven R&D) was carried out as they were considered ‘experts’ who work in SMEs actively involved in antiviral disinfectant process R&D. The number of managers in this industry is relatively low, and was coupled with limited access to these individuals. Seven executive and seven R&D managers were chosen based upon the ability to access these individuals, their willingness to divulge information anonymously and that this number sits within the suggestion of Creswell (1998) and Mason (2010) for the number of interviewees required in phenomenological case study research. A further factor in reaching this decision was that there are a low number of SMEs actively involved in antiviral disinfectant R&D in the UK. Despite these limitations, the number examined in this study, represents 70 percent of the UK industry.

The sample was limited to the UK geographically as the UK represents the vanguard of this type of research and is in line with the findings of Lager, Blanco and Frishammar (2013) who stated that this type of activity in this industry is strongly integrated in a few locations. A fuller justification of the number of manager interviewees is given in section 4.4.1.

The next section examines the ‘Significance and Contribution of the Research’ carried out within this study.

#### **1.4. Significance and Contribution of the Research**

The research carried out in this study has provided an in-depth examination of antiviral disinfectant process R&D for SMEs in the UK. Prior to this study, academic examination had been paid towards vaccines and *in vivo* antivirals, but not antiviral disinfectants. As the commercial, legislative and scientific barriers for R&D are arguably lower for antiviral disinfectant technologies in comparison to other antiviral products, this study is of great potential interest and value to SMEs, who often do not have the resources to carry out vaccine and *in vivo* antiviral research. The timescale required for antiviral disinfectant R&D is also substantially shorter than for other

antiviral technologies, and with potentially fewer R&D managers and departments involved.

Within the UK-based antiviral disinfectant R&D sector there are a low number of companies (ten), who employ a low-number of managers overseeing R&D, which supported the use of a phenomenologically based case study method to construct a warranted R&D model, reflective of management views. This approach facilitated a greater level of involvement from executive and R&D managers engaged in antiviral disinfectant R&D, which has resulted in the model produced in this study currently being trialled in three respondent companies. Importantly, and although extending beyond this study, the model will also be trialled by a further two companies, which will result in further research and a move to not only warrant the model but also validate it in light of prior R&D practices within these companies.

This is a novel study as it has produced a model from a phenomenological case study method, which heavily considered management discourse regarding the complexity of R&D, and how a model could be used to aid in sense- and decision-making. Multiple warranting stages, and a further validation stage of this model will rigorously assess this model for its academic and practical management claims. Critically, this is the first model that has been constructed for the antiviral disinfectant sector, and it is expected that research findings will find international relevance to numerous other companies based outside of the UK.

The main outcome from this study was the production of a DBA thesis. The thesis brought increased knowledge to the academic and business community in an area of research that has a high-value but has received limited research activity. Beyond the practical applications, research findings will be disseminated in appropriate management journals, focussing on the discursive elements of using a phenomenological approach for R&D model construction as well as the validation of the model, which will come from future work.

## **1.5 Thesis Outline**

### **Chapter 1. Introduction**

This chapter introduces the study, research question, aim and objectives as well as briefly detailing the methodology. The significance of the research carried out in this study is also examined in light of contributions to academia and practitioners.

### **Chapter 2. Literature Review**

This chapter focuses on the theoretical background supporting this study. In particular there are two main areas that are examined including (1) antiviral R&D, and (2) modelling R&D. In part (1), the R&D environment is examined, including how antiviral R&D seeks to address market demands for antiviral products, but also the academic and business challenges of antiviral R&D. In part (2), modelling R&D is considered, including philosophical aspects of what a model is, including previous and current models used in R&D. Finally, antiviral R&D model production is examined in light of this being a phenomenological study utilising semi-structured in-depth interviews with R&D managers in UK based SMEs.

### **Chapter 3. Literature Synthesis**

This chapter draws together the research gap in antiviral disinfectant management, with an examination of 'executive' and R&D management, to consider the production of an R&D process model for this area. The various strands of the literature are thus synthesised and the research question, aim and objectives are defined.

### **Chapter 4. Research Methodology**

This chapter details the research methodology and phenomenological paradigm utilised throughout this study as well as a rationale for using phenomenology to develop meaning within social structures (the management of antiviral disinfectant

R&D) leading to the production of an R&D process model. This is alongside assessing the premise for the use of multiple case studies for interviewing. The theory behind content analysis, which in this study is explicitation, is explained and the reasoning behind this method detailed.

### **Chapter 5. Pilot Study**

This chapter examines the rationale for carrying out an exploratory pilot study, as well as the findings produced in this stage. Finally, adjustments to the main study are considered and presented.

### **Chapter 6. The Main Study and Construction of the Alpha/Beta Models**

This chapter introduces the results from the main study and covers the data collected and the analysis procedures utilised to achieve the aim of this study. How data was collected and explicitation used to produce an R&D process alpha and beta model is described. Further aspects of validity, reliability, warrantability, trustworthiness and generalisability were considered in light of data collection and analysis.

### **Chapter 7. Conclusions and Recommendations**

This chapter examines the production of an R&D process model, and in particular, focuses on the production of an alpha model and the sequential beta model. Further to this, this chapter draws together the initial alpha and final beta model with theoretical work and considers the research findings in this light of what this study has brought to the research knowledge base. Finally, the limitations within this study are also recognised, with future work being suggested to address shortcomings with this work, and to allow greater impact for academic and practical aspects of this work.

In the following chapter, the ‘Literature Review’, antiviral R&D is considered in both an academic and business context, particularly focussing on the production of a model.

## **Chapter 2. Literature Review**

### **2.1. Introduction**

In this chapter, the ‘Literature Review’ is presented in order to (a) provide the theoretical underpinning to the research and (b) to inform the research. In the first section of this chapter there is a particular focus on antiviral R&D, including the sub-components of the physical, and business and management aspects of R&D. Attention is paid towards how management make sense of complex R&D environments, and subsequent decisions based on this information. Not surprisingly there have been a variety of vehicles found in previous management studies to make sense of R&D including the use of models and linguistic devices to produce shared meaning. This suggested an in-depth examination of the R&D environment, which could impact the sense- and decision-making of management, which is undertaken in this chapter. The most pivotal findings for complex R&D environments highlighted the difficulty in the construction of shared meaning between managers when the environment was highly complex, technical and with risk and uncertainty. The use of models, which is explored in the second part of this chapter, ‘Modelling R&D’, demonstrates how shared meaning between managers can be increased through model-based simplification, facilitating sense- and decision-making. Research into this area has indicated the benefit of simple models, to aid in sensemaking but has had a propensity not to warrant model construction between different manager types in and between companies in the same sector or carry out testing after warranting. This study sought to overcome this perceived limitation through the use of the phenomenological paradigm to ‘see’ R&D through the eyes of executive and R&D managers and construct a model based on findings. The macro-themes discussed in this section are drawn together to inform the research direction and questions required for this research to produce an R&D model, which are more thoroughly considered in ‘Chapter 3. Literature Synthesis’.

As a starting point to set up this chapter and to contextualise the rest of the literature review, the process of examining the background literature begins with a consideration of ‘The Antiviral Market’ in the following section.



## 2.2. The Antiviral Market

The antiviral disinfectant market is composed of companies carrying out R&D to produce antiviral products that can be sold in business-to-business (B2B) or business-to-consumer (B2C) markets, to sanitise surfaces contaminated with pathogenic viruses. While there is a wealth of literature on the business and scientific aspects of antiviral products produced by the pharmaceutical sector (Lakdawalla and Sood, 2012) the information for antiviral disinfectants is relatively sparse, and has received relatively little academic attention. The distinction between pharmaceutical antivirals and antiviral disinfectants will be explored more thoroughly in the following sections, but at this stage, it is sufficient to regard pharmaceutical antiviral products as being ‘drugs’ for consumption and antiviral disinfectants as cleaning products, not for consumption. While it is not the point of this section to necessarily distinguish between pharmaceutical antivirals (of which there are numerous classes) and antiviral disinfectants, the lack of research into antiviral disinfectants suggests that it is an area not well known in either a common or academic sense and needs some explanation. There is also the potential sensitisation of individuals to pharmaceutical antivirals to create prior concepts of knowledge of the ‘antiviral market’ or ‘antivirals’ as ‘one-size fits all’. This may skew the perception of the phenomenon of antiviral disinfectants as being more like pharmaceutical antivirals, which has been addressed by examining aspects of both types of antiviral to draw out a deeper understanding of product differences. Importantly, some understanding of other antiviral products has been considered to inform the phenomenon of interest *i.e. how UK based SMEs carry out process R&D for antiviral disinfectants*. Prior to the interview stage no assumption was made about how managers in antiviral disinfectant companies constructed aspects of the antiviral market and how they made sense or decisions for the environment they work in.

Irrespective of how managers construct antiviral R&D, in the UK, both disinfectant and pharmaceutical antivirals are produced through R&D, with antiviral disinfectant companies in the UK predominantly being SMEs, and with pharmaceutical companies typically being larger and having a greater resource to carry out R&D (Reich, 1995; McKelvey, Aim and Riccaboni, 2003; Kotwani, 2010). While antiviral

disinfectant SMEs typically export globally, they do so through networks with their B2B-based customers usually selling their products in different locations. Data from the pilot studies carried out within this study (page 103-110) suggested that antiviral disinfectant customers ('buyers') who go on to sell these products, heavily influence (1) what products are sent into the R&D stage, (2) what the aim of the product (or market need) is, and (3) what is an 'acceptable' cost per product unit etc. This is quite a different scenario to pharmaceutical antivirals, where products have a much higher cost, and are more likely to be monopolistic through patent protection (Acemoglu and Linn, 2004; Dubouis *et al*, 2011; Lakdawalla and Sood, 2012). Importantly, antiviral disinfectant companies sell their products produced from R&D to selling agents or larger companies, and do not sell directly into B2C markets. This aspect has been explored further in the main interview stage.

After this overview of the antiviral market the following section introduces 'Research and Development' to explore deeper the literature focussing on contextual and conceptual aspects important to this study.

### **2.3. Research and Development**

R&D refers to a set of business activities that is composed of both 'research' and 'development' stages. It is a totality of processes that allows new knowledge to be discovered, and once applied, can be used to create new, or improve existing products or services. Briefly and simplistically, R&D process can be regarded as successful if the product goes to market (Di Masi *et al*, 2003). R&D can often be company, product or sector specific, which can create difficulties for generalisability and warrantability of models produced to manage the R&D stage. This is no more apparent than in process industries like antiviral disinfectants, where, as Lager, Blanco and Frishammar (2013) stated, the R&D process is very asset intensive, can be sector specific and strongly integrated in one or a few physical locations.

To aid in the understanding of R&D, this study examines how and why companies carry out R&D, alongside how they perceive it. Verma, Mishra and Sinha (2011: 462) state that: '*high tech firms compete in a dynamically changing market place*

*where, to survive and thrive, firms need to introduce a continuous stream of successful new products*'. This suggests that R&D is part of a strategy for taking new products to market to secure company survival, which may be more difficult in high technology markets due to increased product and R&D complexity. While in many sectors, the conventional approach to improving R&D has been to focus company resources on reducing the time taken for R&D (Adler *et al*, 1995), which is arguably a myopic view. Interestingly, both Stalk and Webber (1993) and Gerwin and Barrowman (2002) have argued that focussing company resources purely on reducing the time taken for an R&D project, considers only aspects such as efficiency and ignores wider strategic considerations. At worst, this has the potential to result in products without customers. It also simplifies the phenomena of R&D, which can be complex, uncertain and risk-laden, which the author of this study suggests is more pronounced in biologically based products, such as antiviral disinfectants. Nobelius (2004) argued that understanding R&D is pivotal for companies undertaking it, as with a greater understanding of R&D processes comes an ability to manipulate the R&D stage, thus allowing a greater opportunity to reap financial benefit. A popular vehicle for understanding R&D is the use of models to mirror the R&D process stage, which can simplify complex technological aspects of R&D (Cooper, 1983; Adler *et al*, 1995; Bednyagin and Gnansounou, 2012; Popp *et al*, 2013). While it is accepted that R&D is complex, understanding the way that managers perceive, make sense of and construct this phenomenon can be pivotal. This study therefore sought to expand on prior work and more fully engage with these aspects via the phenomenological paradigm to construct R&D models, which could be 'true to themselves'.

The development of R&D models is influenced by multiple social factors that exist at the time of R&D model construction. Nobelius (2004) segmented many of these social factors into those of 'context' and 'process', which are used to show the five generations of R&D in Table 2.1, and that have occurred since the 1950s. Since the 1950's the two social factors of 'context' and 'process' have varied, based on numerous factors, but including the perceived 'best' practice at different points in time. Table 2.1 suggests that R&D models are continually changing through management driven evolution and adaption of 'context' and 'process'.

**Table 2.1. The Five Generations of R&D**

R&D Generation	Context	Process
First Generation.	Black hole demand (1950s to mid-1960s).	R&D as ivory tower, technology-push oriented, seen as an overhead cost, with little/no interaction with company strategy. Focus on scientific discovery.
Second Generation.	Market shares battle (mid-1960s to early 1970s).	R&D as business, market-pull oriented, and strategy-driven from the business side, all under the umbrella of project management and the internal customer concept.
Third Generation.	Rationalisation efforts (mid-1970s to mid-1980s).	R&D as portfolio, moving away from individual projects view, and with linkages to both business and corporate strategies. Risk-reward and similar methods guide the overall investments.
Fourth Generation.	Time-based struggle (early 1980s to mid-1990s).	R&D as integrative activity, learning from and with customers, moving away from a product focus to a total concept focus, where activities are conducted in parallel by cross-functional teams.
Fifth Generation.	Systems integration (mid-1990s onward).	R&D as network, focusing on collaboration within a wider system, involving competitors, suppliers, distributors, etc. The ability to control product development speed is imperative, separating R from D.

Source: Nobelius (2004: 370).

As might perhaps be expected, and as Nobelius (2004: 374) and Chaudri (2013: 228) have respectively argued, the fifth generation of R&D is now being superseded by the sixth generation, where: *‘management is predicted to return to the roots, i.e. back to the purpose of the first generation’s corporate research labs, one pursuing more radical innovations. One could see this as a re-focus towards the research part of research and development’*. And further, *‘[t]he bases for the shift or new set of approaches are a broader multi-technology base for high-tech products and a more distributed technology-sourcing structure. There will be a palette of technology-sourcing strategies available, e.g. corporate research labs, internal corporate venturing, technology company acquisitions, intellectual property acquisitions, corporate venture capital, joint ventures, independent research groups or networks, and internally driven R&D’*.

This prediction has for many sectors been realised, for example, in that the technology aspect of R&D is now within the hands of joint ventures, intellectual capital acquisitions and internal corporate venturing. The company for whom the author of this study works for is an example of internal corporate venturing and,

more significantly, this research mirrors Nobelius's contention that the focus will be on the '*research part of Research and Development*' whilst not ignoring by any means, the other important aspects of the process. Before the interview stage in this study it was not known which generation of R&D antiviral disinfectant companies would be based within, with this aspect being sought.

Within the generations of R&D activities, are two main models of R&D, which are separated by the influence of commercial drivers and management decision-making (and are explored more fully throughout this study). The first model exists where the primary function of R&D is to develop new products and services and is commonly known as the 'consumer' or 'marketing' model (Kotler and Armstrong, 2010). In the 'marketing' or 'consumer' model, the emphasis has been on (1) integrating the R&D technological function more with the marketing function (Leenders and Wierenga, 2001) and (2) the 'time to market' response (Chaudri, 2013). Attempts have been used with this model to reduce the physical distance via ICT to help in integrate the 'technological' process with the 'marketing' process. The second model exists where the primary function of R&D is to discover and create new knowledge about scientific and technological topics for the purpose of uncovering and enabling development of valuable new products, processes, and services and is known as the 'technological' model (Kahn, 2004). The use of this model is more prevalent within technology R&D, such as process R&D, where antiviral disinfectants are situated.

The two previously mentioned models are not the only models used to depict R&D however, as there have been numerous specific models developed for process R&D, which will also be discussed throughout this study. In developing an R&D process model for antiviral disinfectants, and understanding the reliability through generalisability and verification/warranting of any such model, is the requirement to examine the phenomena of antiviral disinfectant R&D. The author of this study believes that by considering the phenomena of antiviral disinfectant R&D through a phenomenological paradigm, the development of R&D models can more closely mirror the subjective reality of R&D managers interviewed in this study. With the antiviral disinfectant sector currently being under-researched, the direct application of either the 'consumer', 'technological' or other models is problematic, as none of

these models appear to sufficiently cover the antiviral disinfectant processes under review, from either a business or technological perspective.

Before a more in depth examination of these aspects is carried out, the following sections explore ‘Technology Companies and High Technology Products’ to engage directly with the way that companies produce new products (the focus of antiviral disinfectant R&D).

### ***2.3.1. Technology Companies and High Technology Products***

High-technology companies in B2B markets often have a more ‘intense’ product focus in comparison to other company types (Marcus and Segal, 1989; Dugal and Schroeder, 1995; Jobs, 1998; Rosen, Schroeder and Purinton, 1998). This can be problematic for product development and commercialisation, as R&D processes can be ‘*long and tedious*’ (Haverila, 2013: 4), with high technology companies putting a large emphasis on new products and their successful commercialisation. This can increase the pressure for successful product R&D and for management understanding of R&D. After products enter the commercialisation stage, failed or low product adoption can have damaging effects on these companies, necessitating ‘fit-for-purpose’ marketing strategies (Kotler, 1994). Although this study is interested in the pre-commercialisation aspects of R&D, the interaction of marketing management is not mutually exclusive with the R&D process stages and both can influence each other.

There are two types of market strategies that are broadly recognised for new technology products (Nemet, 2009), and include market pull (Schmookler, 1966) and technology push (Schumpeter, 1947). Briefly, technology push strategies are based on the idea that innovations are pushed through R&D, into sales and onto the market, without a proper consideration of whether it satisfies a user need (Martin, 1994). Market pull strategies are focused towards market and customer needs where there is ‘opportunity recognition’ (Schmookler, 1966), and is based on the concept that companies find and exploit perceived market opportunities (Kirzner, 1979).

Wonglimpiyarat and Yuberk (2005) have argued that these two market strategies are the driving force in the process of innovation and commercialisation. Technology push has been argued as being greater during the initial stage of technology adoption; with market pull increasing as technology push decreases (Mowery and Rosenberg, 1979). High technology companies are often based with the area of technology push, which can create challenges during the marketing stage.

Unfortunately there can be somewhat of an absolutist view of technology push commercialisation from technology-orientated managers, and as stated by Rogers (2003: 7), '*[m]any technologists believe that advantageous innovations will sell themselves, that the obvious benefits of a new idea will be widely realized by potential adopters, and that the innovation will diffuse rapidly. Seldom is this the case. Most innovations in fact, diffuse at a disappointingly slow rate, at least in the eyes of the inventors and technologists who create the innovations and promote them to others*'.

This can influence the decision-making of management throughout the R&D stage, where fulfilling customers 'needs' is given a second place to the production and eventual promotion of technical innovation (Kotler, 1994; Craig and Douglas, 2000; Kustin, 2010), such as uniqueness, superiority, compatibility, performance, cost to user and a customer support-base (Cooper, 1980, 1981, 1983; Cooper and Kleinschmidt, 1987a, 1987b; Zirger and Maidique, 1990; Yap and Souder, 1994). Although the communication of technical innovation is potentially more complex for the selling company, B2B markets are often more niche in comparison to B2C markets, with lower numbers of potential buyers, reducing the resource potentially required for a higher frequency of selling (von Hippel, 1986). More than this though is the potential for different respondent managers to use or frame their R&D process stage based on their personal preferences. For example R&D managers may promote technology push, whereas executive managers may promote market pull based on their backgrounds. For larger companies engaged in R&D (albeit not antiviral disinfectant), biological R&D stages have been shown to be more separate from executive management, and thus more likely to be technology push orientated. As SMEs are smaller and with greater interactions between managers who often have

more than one organisational role and identity, it was unknown what influence this would have on the R&D stage.

As the crux of R&D in antiviral disinfectant companies is based on R&D and commercialisation of new products, the following section examines the environment and activities carried out in ‘New Product Development’.

### ***2.3.2. New Product Development***

New product development (NPD) and innovation have been stated as being vital to the success of high technology companies (Yalcinkaya, Calantone and Griffity, 2007), with both aspects being of greater importance in high-technology companies in comparison to other company types (Kobrin, Madhok and Osegowitsch, 2000). The importance of these aspects is coupled with high technology companies often having complex and opaque internal environments with multiple competing drivers for where resource should be allocated particularly throughout R&D (Jolly, 2012). This can create difficulties for management decision-making from the inception of a product to its commercialisation (Burgelman *et al*, 2008; Tidd and Bessant, 2009; Badawy, 2010). For companies carrying out NPD R&D, management can face many decisions, including, which products to send into the R&D stage, how much attention should be paid to market pull forces, and how and where to allocate resource throughout the R&D process stage (Shehabuddeen *et al*, 2006). All of these decision-making challenges are against a backdrop of internal and external competition for limited resource (Badawy, 2007), with various interest groups exerting pressure and pushing agendas within and external to the organisation (Jolly, 2012). The paucity of data in the antiviral disinfectant sector meant it was not known to what extent these factors or others would be relevant and thus the interview stage was left open enough to capture ‘unexpected’ information. What was known however was that R&D and executive managers would have to make sense and decisions made on a host of such factors, potentially based on their background knowledge and information available to them.



Cooper (1999: 118) argued that *'today's complex projects require a multitude of technical and people skills to be an effective, well-rounded team leader or player'* for developing new high technology products. Unfortunately though, *'one recurring problem is the lack of experience and/or education of people expected to undertake new projects'*, which was cited for new product development in both B2B and B2C based markets (Cooper, 1999: 119). The lack of education and knowledge within high technology companies can result in various problems for NPD and R&D, particularly for communication between managers. This study therefore addressed this aspect in the interview stage.

More generically, and drawing on resource-based theory (RBT), background resources have been argued as being vital for NPD, with one of the most important aspects of this being the experience of the individuals and teams in carrying out management of NPD (Cooper, 1999; Adams-Bigelow, 2006). Nevis, DiBella and Gould (1995) suggested that higher levels of experience could result in more successful R&D; product launches, and creates a competitive advantage through marketing. Ordanini, Rubera and Sala (2008) have argued that management often overlooks these aspects, thus reducing the potential return to companies engaged in R&D activities.

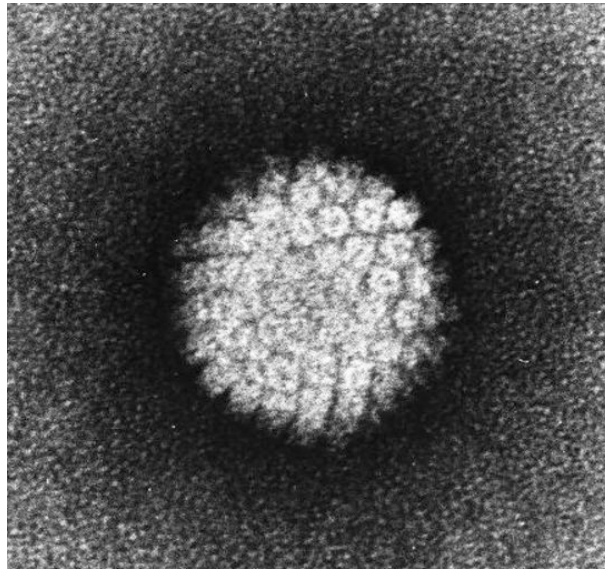
Prior research has examined the link of educational and professional backgrounds of key personnel in high technology companies engaged in NPD R&D through to marketing (Cooper and Kleinschmidt, 1990; Zirger and Maidique, 1990; Yap and Souder, 1994). This research found that 'high' skill levels including engineering, manufacturing, sales and marketing, and project management were significantly positively correlated with NPD performance in opaque and uncertain environments. For lower levels of uncertainty (Haverila, 2011), a much weaker correlation was found between skills and new NPD. This potentially suggests that higher levels of individual knowledge enable a greater view for looking at organisational life and fits with the suggestions of Weick (1995). This study expanded on prior research to examine manager backgrounds (education and professional) and expanded this consideration by also looking at the discourse used by different managers to make sense of R&D.

Central to the products being developed by antiviral disinfectant based SMEs are the biological entities being targeted by the products and the nature of the R&D being carried out. The following section therefore examines ‘Viruses and Antiviral R&D’.

### ***2.3.3. Viruses and Antiviral R&D***

Antiviral disinfectants (also known as antiviral sanitisers) ‘target’ pathogenic viruses and can be described as ‘*a drug or treatment active or effective against viruses*’ (OED, 2012). Viruses exist in a wide variety of environments, including living hosts, such as humans, animals, crops etc. or non-living environments such as tabletops, door handles, clothes etc. A virus is a disease-causing pathogen, with the word virus being derived from the Latin and referring to a poisonous or noxious substance. Importantly however, the Latin meaning of virus is no longer suitable today, as describing viruses as ‘poisonous’ or ‘noxious substances’ is suggestive of many disease-causing agents. In a common sense meaning, viruses can perhaps be regarded as ‘poisonous’ or ‘noxious substances’ but these definitions are not helpful for companies carrying out antiviral R&D. Looking beyond the older definitions it is interesting to examine the medical meaning of a virus, which can be taken from Harper (2012) who described it is a small entity that causes an infectious disease. Again, for companies carrying out antiviral R&D, this is still not a particularly helpful description, especially where there is a requirement for R&D using selected product ‘ingredients’ to target and inactivate viruses. Carter and Saunders (2007: 11) provided a scientific definition, and they stated that: ‘*a virus is a very small, non-cellular parasite of cells*’. Although a scientific definition provides a foundation for understanding the biological pathogens that antiviral disinfectant R&D companies target, it was not assumed by the author of this study that all managers in such companies use scientific definitions of viruses and may perhaps use quite different socio-linguistic constructions. A different way of defining or engaging with the concept of a virus is through visual representation, as shown in Figure 2.1.

## Figure 2.1. Human Papilloma Virus



Source: [http://news.softpedia.com/news/How-to-Reduce-Pap-Testing-Frequency-in-HIV-Positive-Women-282594.shtml#sgal\\_0](http://news.softpedia.com/news/How-to-Reduce-Pap-Testing-Frequency-in-HIV-Positive-Women-282594.shtml#sgal_0)). Last accessed 01/11/2014. Other viruses may vary.

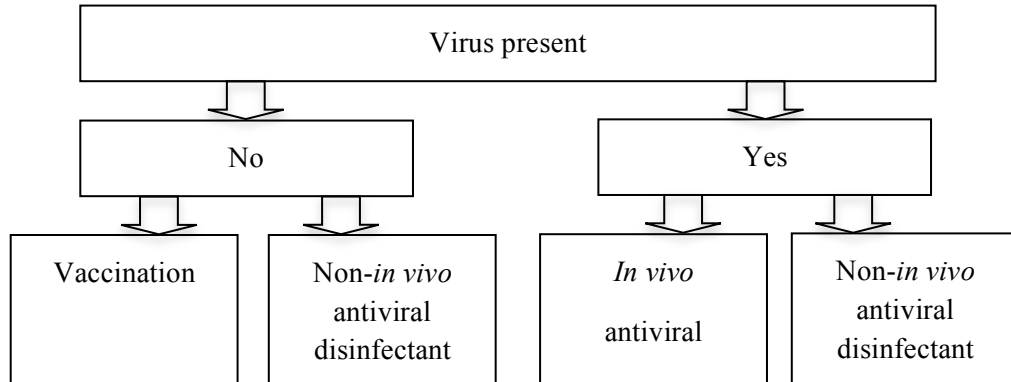
Physically, viruses are small pathogenic cellular parasites that through their infection and interaction with host cells (often in a larger host organism) create diseased states for the host. Due to their small size of between 2.5 million and 50 million times smaller than a metre (Koonin, Senkevich and Dolja, 2006) and coupled with their biochemical traits, viruses are able to penetrate larger cellular entities such as bacteria, yeast and mammalian cells (with the latter composing organisms such as humans). Edwards and Rohwer (2005) have expressed a belief that viruses are the most abundant biological entities on the planet. This ‘fact’ often receives little attention as it not possible to see viruses with the ‘naked’ eye. Unlike many other biological infectious agents (such as bacteria and fungi), viruses require living cells to survive and replicate, but when they do replicate, they do so at incredible rates, and for example, a person infected with HIV can potentially produce  $10^{11}$  viruses a day (Carter and Saunders, 2007).

In the replication and transmission of viral particles from one host to another (*i.e.* human to human), numerous routes may aid in viral transmission, such as sexual contact, sneezing, coughing, touch etc. (Bielanski *et al*, 2013; Gorgos, 2013; Wen *et*

al, 2013). The method of transmission can be briefly described as (1) the virus exists inside the host, (2) the virus leaves the host (existing on an external surface), and (3) if transmission and infection is successful, the virus will enter a new host.

The physiology of viruses and their replication requirements predicates the types of product treatments used to reduce pathogenic infection due to the viral requirement to exist inside a host cell (which is not to say that they cannot temporarily exist outside of a cell). As described previously, there are three treatment methods, which act in quite different ways to stop the transmission of a virus and are as follows. (1) The use of a vaccine, which stops an uninfected host becoming infected, (2) the use of an *in vivo* antiviral, which treats an already infected host, and (3) a non-*in vivo* antiviral disinfectant which ‘kills’ viruses that have left one host, before they enter a new host. A diagrammatic decision-making diagram for the three antiviral treatments is shown in Figure 2.2.

**Figure 2.2. Diagrammatic representation of antiviral treatments**



*This flowchart shows when it is pertinent to use the different types of viral treatments, including vaccination, in vivo antiviral and non-in vivo antiviral.*

In this study, it is the use of (non-*in vivo*) antiviral disinfectants that is of primary interest and it is important that the difference between the three products is noted, as it greatly influences the R&D strategy. Simplistically, both vaccinations and *in vivo* treatments are to be administered directly into a host, whereas antiviral disinfectants (which are always non-*in vivo*) are used outside of a host, such as on the hands, tabletops and door handle etc. The difference for where a product works (in or

outside of a body) creates different R&D processes. An example of this is that there is generally no requirement for animal or human testing via clinical trials for antiviral disinfectant testing of toxicity, whereas this is always a requirement for vaccines and *in vivo* antivirals (Griffith, 2008). This greatly reduces the requirements for antiviral disinfectant R&D resources and time to complete a project. Antiviral disinfectants are often much less specific in their mechanisms of ‘killing’ viruses, as they can be used outside of a host, so generic antimicrobial constituents such as bleach (Fraise, 1999) can be used instead of complex molecules. This means that in rapid outbreaks of viral infection, existing antiviral disinfectants can be trialled against new pathogens or an existing formulation modified, thus potentially allowing a quick route to market. However, as viral outbreaks can often mean that infecting viral particles can infect a wide variety of surfaces outside of a body, this necessitates different product testing challenges, to make sure that the product doesn’t negatively impact of numerous surfaces that an antiviral disinfectant product may contact, when used.

Viral outbreaks and particularly pandemics are becoming major drivers for antiviral disinfectant R&D (Hom and Chous, 2007). Examining literature from over the past 100 years shows that viral pandemics have resulted in large losses of human life, as shown by Lim and Mahmood (2010):

- a) Spanish flu A(H1N1) occurred in 1918-1919 and resulted in 20-40 million deaths;
- b) Asian flu A(H2N2) occurred between 1957-1958, with over 2 million deaths;
- c) Hong Kong Flu A(H3N3) occurred between 1968-1969, with between 1-4 million infections and over 30,000 deaths in England and Wales alone.

More recently however, and linked with increased ease of human global travel, there have been numerous viral outbreaks, with pandemics including:

- a) Severe acute respiratory syndrome (SARS) which infected over 8,000 people and killed 74 people in 2003 (Lingappa *et al*, 2004);

- b) Avian influenza H5N1, which infected a minimum of 108 people and killed 54 people in 2005 (CDC, 2005; WHO, 2005);
- c) Swineflu H1N1, which infected over 18,000 people and killed 1799 people in 2009 (Sinha, 2009).

All of these outbreaks have resulted in increased consumer demands for ‘new’ products that can easily be incorporated into existing products such as hand washes (Cargill *et al*, 2011), used to clean easily contaminated areas such as medical devices (Teich, Cheung and Friendman, 1992) and transport systems such as airliners (Hom and Chous, 207). Looking briefly at the example of airliners, it has not been possible to eradicate person-to-person spread, but it has been possible to heavily reduce viral transmission, by the use of antiviral disinfectants in conjunction with other strategies, and is a cheap and relatively easy to use method.

Finally, in biologically orientated product development in general, there have been many products developed for an end use other than what they were initially designed for (Jurovcik and Holy, 1976). In part, this is often due to the uncertainty surrounding biologically orientated product development, where unexpected side effects can prohibit commercialisation or may make the product more attractive for a different application. This is coupled with the general difficulties of predicting the return-on-investment (ROI) and longevity of biologically orientated products, including antiviral disinfectants. This was certainly the case for HIV *in vivo* antivirals, where it took many years for development companies to understand their life-cycle value (Asante-Appiah and Skalka, 1999). Factors such as these can complicate management decision-making for the R&D stage. Thus the interview stage sought to draw out management understanding of viruses and antiviral disinfectants and contextualise this knowledge with the sense made of these aspects and how decisions are made for R&D.

Importantly R&D does not exist in isolation from external forces within and outside of the organisation undertaking R&D, and while it has been pivotal to understand viruses and antiviral R&D, an examination must also be undertaken to understand ‘The R&D Environment’.

#### ***2.3.4. The R&D Environment***

The R&D environment can be defined as a totality of all factors that surround and interact with R&D. It can include factors such as, employees, management, the micro- and macro economy and customers etc. Within this description is a potential segmentation of internal and external R&D environments, which both interact and influence R&D. The internal environment is process based and in this study is focussed on which processes occur, as well as how and why they occur. As these processes are management driven, R&D management decision-making is important for how companies attempt to internally regulate the R&D environment, while still focussing on external factors.

R&D environments are not static, and can change multiple times during the R&D stage, which in turn can alter goals and requirements during this stage. As Verma, Mishra and Sinha (2010: 463) stated: '*R&D projects in high tech firms are also characterized by changing goals and requirements during a project's lifetime, which can span several years*'. These environments can be regarded as dynamic, uncertain and risk-laden, which create challenges for managing these projects (Brown, 1995). These elements inherent within the R&D environment lead to management drivers to understand the R&D stage, which in many cases can be through modelling the R&D stage, to aid in management decision-making to create shared meaning for complex phenomena.

Beyond the aspects discussed so far is the question of how do companies approach R&D projects? As argued by March (1991) and Mudambi and Swift (2011), there are two main paths available for companies, including exploration and exploitation, both of which can be used to create or appropriate company value through R&D. It has been argued that exploitation occurs where companies leverage their existing knowledge base (Rosenkopf and Nerkar, 2001; Benner and Tushman, 2003), while exploration involves the search for new utilisable knowledge in areas that are relatively distant from the company's core knowledge base (Baum *et al*, 2000; Rosenkopf and Nerkar, 2001; Benner and Tushman, 2003; He and Wong, 2004). Exploration can involve aspects such as experimentation, varying processes (Baum

*et al*, 2000) or changing the technological trajectory (Benner and Tushman, 2003; He and Wong, 2004). Exploitation however, can involve re-using existing knowledge (Rosenkopf and Nerkar, 2001; Benner and Tushman, 2003) or changing company competencies (He and Wong, 2004). Gupta *et al* (2006) have suggested that successful exploration and exploitation skills can require fundamentally different skills.

Exploration and exploitation are not mutually exclusive however and can be carried out, individually, simultaneously, or with fluctuation between the two paths. Where there is movement between exploration and exploitation, the R&D environment has been described as under conditions of ‘punctuated equilibrium’ (Mudambi and Swift, 2011) due to the change between management drivers between these paths. The process of moving from exploitation to exploration has been argued as a form of extreme organisational change (McGrath, 2001; Burgelman, 2002; Katila and Ahuja, 2002; Lee *et al*, 2003; Benner and Tushman, 2003; Holmqvist, 2004; Gupta *et al*, 2006). This can be challenging for managers (particularly between non-R&D and R&D managers) due to a lack of symmetry of information and knowledge between these two types of manager (Stein, 2003).

R&D projects can suffer due to their opacity in the eyes of executive R&D managers. Opacity can occur as a consequence of difficulties in predicting R&D outputs, particularly what the output will be, and when it will occur (Anderson and Tushman, 1990). This can be coupled with the types of information disclosed to executive management from R&D management not always being clear and vice versa. Where information from R&D management is not clear, it can be difficult for executive management to accept or refute R&D claims (Stein, 2003), complicating decision-making.

With such challenging information environments, it has been argued that the ‘best’ companies are capable of operating between such conflicting goals as described so far (March, 1991, 1996, 2006; Dougherty, 1992; Eisenhardt and Martin, 2000; Ancona *et al*, 2001; Benner and Tushman, 2003; Feinberg and Gupta, 2004; Levinthal and March, 1993). The argument has been made that the ‘best’ performing



companies engage in exploration and exploitation activities simultaneously (Tushman and O'Reilly, 1996), although, this has been disputed by other theorists (March, 1991; March, 1996; March, 2006; He and Wong, 2004).

R&D can act as a vehicle for companies to leverage their existing knowledge base, and for antiviral disinfectant SMEs, this can be in the form of new products being brought into existing or new markets entered. As Mudambi and Swift (2011: 429) stated: '*Proactive management of the firm's R&D function requires not only exploiting current knowledge-based competencies, but also exploring new opportunities once those competencies lose their competitive edge.*' Exploring new competencies can be through infrequent discontinuities that enable new knowledge to be leveraged. Management of discontinuous events by companies is not a simple task, as the timing of such events can be difficult to predict (Kuhn, 1962). Even though discontinuities can create benefits for R&D companies (as well as difficulties), there can be long periods of stability, where companies can exploit their existing competencies (Mudambi and Swift, 2011).

For companies undertaking R&D (exploration/exploitation based), company size can impact on the level of resource, knowledge (management and scientific), as well as the level of commitment that can be given to an R&D project. Smaller companies are more likely to be entrepreneurial consisting of single business units (Reinganum, 1983), and as Lubatkin *et al* (2006: 647) argued, they are more likely to lack 'facilitating resources' and 'slack resources', which enable larger companies to have a greater flexibility in R&D. Perhaps not surprisingly, R&D capability has been shown to increase with company size (Kogut, 1991; Hernan *et al*, 2003) and can increase the likelihood that a company can carry out the exploration and exploitation of new technology at the same time (Zahra and George, 2002). Mansfield (1981) demonstrated this point, by showing that while R&D expenditure dedicated to refining existing products increased with company size, R&D portfolios, including new products were also likely to increase.

With resource being a challenge for smaller companies carrying out R&D, it has been shown that smaller companies specialise as a method of dealing with this lack

(Beckman, 2006). Specialisation can occur on many fronts, including whether a company engages in exploitation or exploration, with Benner and Tushman (2003) arguing that smaller companies typically focus on one of these aspects. Due to the limited resource that SMEs face for carrying out R&D, it is acknowledged that inefficiency, lack of resource and management ability to understand the R&D process can ‘hurt’ the company, and particularly R&D outcomes.

Beyond the challenges facing R&D companies, it is interesting to look at what ‘facilitates’ a company to be successful. Fines (1998) have stated a belief that ‘successful’ companies exist in ‘clockspeed’ industries; where rates of product development, process, capital equipment and design have relatively rapid management decision-making, which allows them to keep pace with the speed of opportunities confronting them (Davis *et al*, 2009). Companies existing in lower ‘clockspeed’ industries can often place a greater emphasis on operational efficiency and less on strategic flexibility (Pisano, 1994; Rivkin and Siggelkow, 2003). For SMEs, these problems can be compounded by a general lack of resource to exploit opportunity (Beckman, 2006). Simplistically, as Mudambi and Swift (2011: 430) stated: *‘firms must have the domain expertise and knowledge management processes that enable them to move in the right direction, at the right time.’*

Verma and Sinha (2002: 451) argued that high-technology companies rarely produce one product at a time, and instead: *‘introduce a continuous stream of successful new products to survive in today’s intensely competitive and dynamically changing market place’*. This is not to argue that all R&D companies carry out simultaneous R&D on multiple-products but that it can be a popular method and bring requirements for managing multiple R&D projects, as well as using shared resources between multiple companies working together (Adler *et al*, 1995; Gupta and Wilemon, 1996). The use of networks in R&D is long recognised (Huston and Sakkab, 2006) and in this study, this aspect was investigated during the interview stages. R&D carried out via network structures can result in pooled interdependencies between companies (Thompson, 1967). Verna and Sinha (2002) segmented R&D interdependencies into three distinct categories including, (1) resource interdependencies, (2) technology interdependencies, and (3) market

interdependencies. As Verna and Sinha (2002: 451) stated: '*market interdependencies stem from (i) a new product's diffusion into an already existing market and (ii) utilizing a current product's market knowledge (e.g. how to manager a dealer network) for a new product for an entirely different market*'. Companies working together on R&D have created greater output with less resource (Gupta and Wilemon, 1996; Cooper *et al*, 1997), but the notion of best practice for an individual company or one engaging in a network is still not well understood (Gupta and Wilemon, 1996; Krishnan and Ulrich, 2001).

To continue exploring the relevant literature underpinning this study, the following section moves on to consider 'The Antiviral R&D Environment'.

### ***2.3.5. The Antiviral R&D Environment***

The antiviral disinfectant sector can be considered highly specialised, with valuable physical and knowledge-based resources. Penrose (1959) believed that these conditions create an incentive for companies operating within such sectors to expand via R&D, to more profitably exploit their capabilities (Teece, 1982; Teece, 1986; Wernerfelt, 1984; Montgomery, 1994). Within this incentive is a drive for R&D management, capable of creating a clear pathway through the physical and business processes of R&D, while reducing waste and optimising resource, with attempts to achieve this often being through the creation of a model (Kerssen-van Drongelen and Bilderbeek, 1999). To develop a model for management that adequately reflects the reality of R&D is a requirement to understand the phenomena of R&D, particularly the environment that R&D operates within. This section is therefore focused on understanding the environment surrounding the phenomena of R&D.

From limited academic literature and the author's prior sensitisation to the sector, antiviral disinfectant R&D can in many ways be regarded as sector and product specific, but with some similarity to other product and process based R&D. Fundamental to the R&D stage is the antiviral product being developed, with much product R&D potentially being complex, with many uncertain and risk-laden

decisions to be made by management. These decisions can include, when and how to carry out a process, and in which order, as well as how much resource to commit to any process stage. R&D is not necessarily linear and if one process stage ‘fails’, a product may be recycled through previous stages until it achieves internal criteria set by management for ‘success’. Coupled with this are changing management preferences throughout R&D and a paucity of information about the product. An example of this was early stage HIV drug R&D, where management perceived drugs as having limited usage with any patient *i.e.* they would ‘cure’ the disease. At the latter stages of R&D, it was found that the product was required to be used throughout a patient’s lifetime as opposed to a simple cure, which greatly increased product sales (Wainberg, 2009). Situations like this make it difficult for management to estimate the resource that should be committed during R&D as the product could arguably have a greater or lesser value than anticipated. These issues can also complicate the business case for R&D, which for antiviral disinfectants is inherently complex, with understanding required of the following process stages for product: (1) formulation, (2) toxicity, (3) stability, (4) legislation and (5) economics. Within each of these stages are aspects including cost, risk, uncertainty and ROI etc.

Arguably the first stage associated with R&D is design. Bolken and Hruby (2008: 2) stated that *‘the first challenge that drug developers face is the paucity of available information.’* The paucity of information can be with regard to business and scientific knowledge held within a company, as well as the ability of a company to access information outside of itself *i.e.* through specialists and access to journals etc. Beyond knowledge, is whether a company has access to physical facilities to carry out adequate antiviral disinfectant R&D? While, all companies have the choice of whether to carry out their own R&D, or subcontract it, antiviral work can bring its own unique challenges for R&D companies. This is based on companies either having their own facilities or requiring access to facilities for testing products against highly pathogenic viruses, which are heavily regulated and not easy to set up or maintain. In cases where companies do not have access to these facilities, it limits R&D, and can mean that companies use substitute viruses or less pathogenic viruses, which can limit the marketing claims of subsequent product releases. Not

surprisingly, Baker and Peacock (2008) have stated their belief that for antiviral product development, access to literature and facilities is paramount for R&D.

The formulation of an antiviral disinfectant product is pivotal to the pre-commercialisation stage of R&D, as well as the post R&D stage, including the marketing claims that can be made. As mentioned previously, antiviral disinfectants target viruses outside of a host, when and where an infected host has spread the virus through sneezing, coughing or the release of other biological fluids (blood, semen etc.). Once on an external surface (and depending on environmental surface conditions and the type of virus) the virus can remain active for up to a month (Terpstra *et al*, 2007). As antiviral disinfectants are predominantly liquid-based, they are suitable for incorporation into a wide variety of dispersal systems, including sprays, wipes, fogging machines etc. (Spencer, Cohen and McAllister, 2007). A further advantage is that they can also be added into existing products, for example directly into an antibacterial formulation, to give it further functionality (Mecitoğlu *et al*, 2006). This can allow numerous market entry points into already existing product ranges such as hand washes (Cargill *et al*, 2011), medical device cleaners (Teich, Cheung and Friedman, 1992) and airliner cleaners (Hom and Chous, 2007).

One of the advantages of antiviral disinfectants is that there is no requirement for animal or human testing, as the products function entirely outside of the body, unlike vaccines and *in vivo* antivirals, which do operate inside a host body, and complicate the R&D stage. Briefly, antiviral disinfectant products operating outside of a host means, greatly simplifies the scientific testing for product toxicity throughout the R&D stage. A potential disadvantage of antiviral disinfectants is that each product target market, may have its own toxicity requirements (even if not human or animal), and may therefore add additional stages to R&D. Beyond toxicity, is the challenge of identifying surfaces that products may come into contact with, as each surface could potentially interact differently with each product, requiring further R&D testing. Bleach based antiviral disinfectants are an example of this, as they can be suitable for cleaning tabletops, but not carpets or medical instruments, as in the latter case, they may burn patients. Generically, using 'simpler' product constituents like bleach can reduce the time to market as well as lowering R&D costs (Federsel, 2000; Lin

and Saggi, 2002; Federsel, 2010) but do have disadvantages. There is of course the requirement for the antiviral disinfectant to have a limited detrimental effect on the surface, to which it is applied. A further challenge is that the environment where the product will be used could inactivate the product, as in the case of heavy organic ‘dirt’ contamination on kitchen floors (Favero and Bond, 1991; Rutala and Weber, 1997). Arguably, all of the interactions that the product may have with environments when used as a product need to be considered during the formulation stage, even if not physically tested. These and other factors can reduce ‘R&D Risk and Uncertainty’, which is explored more fully in the following section.

### **2.3.6. R&D Risk and Uncertainty**

The issues of risk and uncertainty have received much attention in R&D and management literature (Bacon *et al*, 1994; Smith, 1988; Kim and Wilemon, 1999; Doll and Zhang, 2001) and with perceptions varying for how they should be addressed and perceived. Nobelius (2004: 369) has argued that: ‘*many companies perceive research and development (R&D) as somewhat fuzzy, involving high uncertainty, with unclear rate of return, and troublesome to manage.*’ However, as Verma, Mishra and Sinha (2010: 463) stated, these aspects can be considered in the wider context of R&D, particularly from the viewpoints of exploration and exploitation: ‘*Generally speaking, R&D projects can be classified into two broad categories: (i) projects that operate within the realm of current technical capabilities or require a stretch of current technologies, and (ii) projects that require a radical innovation to deliver functions. The first category requires exploitation of old certainties and involves mutual learning between members of an organization and an organizational code. The code is buried in many features of organizational forms and customs, e.g., in organizational policies of reducing risk. The second category requires exploration of new possibilities leading to learning and competitive advantage.*’

R&D projects based on the exploration of new possibilities are arguably less certain than exploitation based projects, as they require more time and are organisationally

more complex in comparison to exploiting an existing knowledge base. Although exploitation is often preferable for short-term gains, it has the potential to hinder company growth in the longer-term (Tushman and O'Reilly, 1996). It has therefore been argued as important for companies looking to achieve long-term growth, to engage in some risk-laded R&D projects via exploration of knowledge, but once the knowledge is attained, to exploit it (March, 1991). It is not an easy task for managers to select between different R&D projects, which can vary in their potential for short and long term profits (Benner and Tushman, 2003). This can be coupled with general difficulties faced by managers making decisions about R&D, as poor decision-making and regulation of the R&D stage can result in R&D being halted or terminated (Gurgur and Morley, 2008). In such circumstances increased development times and costs can be incurred, as well as an increase in the likelihood of R&D failure (Wang, Lin and Huang, 2010). This can be particularly problematic where multiple R&D projects occur simultaneously, which can create further challenges for management sense- and decision-making (Kavadias and Chao, 2006).

As might be imagined, different R&D projects have varying levels of uncertainty and risk associated with them (Doctor *et al*, 2001; Raz *et al*, 2002; Lee *et al*, 2010). Biologically based R&D is regarded as being inherently difficult, uncertain, and risk-laden, with high levels of R&D product failure not being uncommon (CMR, 2006). Within the biological R&D sectors and as Bush *et al* (2005) argued, much risk management has focussed on identifying and understanding the physical issues of product R&D such as toxicity. Once identified, subsequent development often focuses on risk mitigation strategies) to increase R&D success and business opportunity (Blau *et al*, 2000; 2004; Rajapakse *et al*, 2005), which has resulted in an overall lack of research examining risk management for R&D processes beyond toxicity (Wang, Lin and Huang, 2010). Although important, linking risk almost entirely to potential product toxicity is limiting and ignores many other risk aspects associated with R&D.

To understand the importance of risk to an R&D project, it is important to be able to understand what risk is. Simplistically, risk can be considered an event that has an unknown but often negatively perceived outcome (Browning *et al*, 2002; Raz *et al*,

2002; Smith and Merritt, 2002; Keizer *et al*, 2002, 2005; Perminova *et al*, 2008; Wang, Lin and Huang, 2010). Not surprisingly, risk is defined differently in different academic disciplines. In economics, risk refers to situations where a decision maker can assign probabilities to different outcomes (Knight, 1921). In decision theory, risk is the construct that a decision is made under the condition of known probability over the state of nature (Luce and Raiffa, 1957). In project management, there is a lack of a consistent definition for risk (Ward and Chapman, 2003; Perminova *et al*, 2008) but was defined by the Project Management Institute (PMI, 2004) as being ‘*an uncertain event or condition that, if it occurs has a positive (opportunity) or negative (threat) impact on project objectives*’. There is however a predominant focus from academics and practitioners to viewing risks in a negative light (Williams, 1995; Boehm and DeMarco, 1997; Smith and Merritt, 2002; Ward and Chapman, 2003). As Wang, Lin and Huang (2010: 602) stated: ‘*from this perspective, project risk management seems to be about identifying and managing threats to the project*’. It has been argued that management of risk and uncertainty throughout the R&D processes is important to improve the success rate of products making it through R&D (Smith and Merritt, 2002; Keizer *et al*, 2002; Bush *et al*, 2005; Pisano, 2006).

As Wang, Lin and Huang (2010: 601) stated: ‘*risk management is a structured approach for the identification, assessment, and prioritization of risks followed by planning of resources to minimize, monitor, and control the probability and impact of undesirable events*’. While from a common sense perspective, it could be argued that minimising ‘undesirable events’ is desirable; it doesn’t take into account the impact of serendipitous discovery, which may arise out of ‘undesirable events’. Risk management has been utilised in a wide variety of sectors and processes, but in R&D management, the focus is towards increasing the potential success of the R&D project (Wang, Lin and Huang, 2010).

Related to R&D risk, is uncertainty, which in R&D management literature is defined as an inability to predict the R&D environment, R&D environmental change, and the consequences of decision-making (Milliken, 1987; Doctor *et al*, 2001; Sicotte and Bourgault, 2008). It has also been argued as the absence of relevant information (Galbraith, 1977) and can be considered a measure of an organisation’s lack of



awareness of the value of defining constructs in the planning process (Doll and Zhang, 2001). Importantly, risk has been defined as the exposure to uncertainty (Smith, 1999; Browning *et al*, 2002; Raz *et al*, 2002; Smith and Merritt, 2002; Keizer *et al*, 2002, 2005). Interestingly, considering that risk and uncertainty are both often linked to negative R&D outputs, it is not surprising that managing R&D uncertainty (Doctor *et al*, 2001; Loch *et al*, 2006) and risk (Williams, 1995; Smith, 1999; Keizer *et al*, 2002; Raz *et al*, 2002; Cooper, 2003; Smith and Merritt, 2002) has received much academic attention. Academic studies have thus focussed on managing risk management to improve project success rates (Raz *et al*, 2002; Salomo *et al*, 2007; O’Conner *et al*, 2008), with modelling R&D also being favoured (Kerssen-van Drongelen and Bilderbeek, 1999). Thus modelling R&D can be seen as not only a management practice to reduce the loss of R&D resource, but to effectively ensure a desirable R&D outcome. Considering that these are potentially desirable aspects of R&D, the social and cognitive aspects of the organisation can also be considered for how individuals, groups and the organisation makes sense of technical and management orientated. This is particularly the case for how representation through the use of language and images can enable sense to be made of complex and uncertain environments. Importantly and although sensemaking has been applied to numerous areas of organisational life, thus study sought to add knowledge to the production of an R&D process model to understand and potentially mitigate risk in the R&D stage. Mitigation of risk and other organisational R&D aspects comes under the umbrella of ‘Management of R&D’ and is considered in the following section.

### **2.3.7. Management of R&D**

Nobelius (2004: 369) stated that: ‘*the perspective on R&D processes has been different throughout the years, since the structure and prerequisites of the economy have changed and so has the presumption of best practice*’. R&D and management practices can thus be considered as existing in a perpetually changing landscape, where perceptions of requirements and best practice continually change over time, which at some level can be linked to ‘*der Geist seiner Zeit*’. This can be translated to

mean *'the spirit of his time'*, and in this context means that *'no man can surpass his own time, for the spirit of his time is also his own spirit'* (Magee, 2011: 262). This has created a shift of management R&D from a view of isolation, to existing in complex and connected internal and external influences.

Overseeing and managing R&D, are various managers, who have different roles and perceptions with regard to this activity. At the most senior level are executive managers who oversee wider company objectives, of which R&D feeds into, but these managers are arguably less 'hands on' in day-to-day decision-making. There are also R&D managers, whose sole function is to manage the R&D stage, and who have less interaction with wider company management and agendas. Due to sensitisation to management literature and experience of working in the antiviral sector, the author of this study, perceived that executive managers and R&D managers, are pivotal in the management of the R&D stage, although potentially interact with R&D differently. Through the construction of a management model of R&D, both management views can be considered and represented, thus both types of manager were interviewed.

Badawy (1989) has argued that while many companies might successfully develop new technology, management of the R&D and commercialisations stage is pivotal for the commercial success of products. While a wider management view is important for the commercialisation of products, this study has a predominant focus on the pre-commercialisation aspects of R&D, but methodologically has allowed respondents to discuss post R&D elements if they perceived it as necessary. In this way, the researcher attempted to draw out the most important points of R&D and factors influencing R&D that would enable the translation of R&D products into commercial products, while understanding management aspects (Lansiti, 1977). It is important to note that the researcher was embedded within the antiviral disinfectant sector before and throughout this study, which challenged the notion of objectivity on behalf of the researcher. While the notion of complete objectivity of any researcher is a moot point and is rejected in this study, this researcher's objectivity was dealt with through the explicitation process, particularly phenomenological bracketing (as detailed in page 90).

Prior to the physical aspects of R&D being undertaken, is the first consideration made for R&D, which is to determine what level of front-end planning is carried out. This is where management first considers an idea for R&D, all the way through to a decision being made for whether a potential product should enter the R&D stage (Kim and Wilemon, 1999). It is at this point in time that management must decide what desired output of product R&D is, as well as the level of resource to commit (Moenaret *et al*, 1995). Various planning activities can be carried out to facilitate management understanding and decision-making for the R&D project, and can include, R&D strategy formulation, opportunity identification and assessment, technological feasibility studies, R&D project planning, and internal interviews (Cooper, 1997; Khurana and Rosenthal, 1988). Song *et al* (2007: 232) *confirming the work of Nobelius (2004:369), stated that: ‘Because of embedded uncertainties, ambiguities, or “fuzziness” with respect to market, technology, R&D process, funding, etc., this stage is characterized as knowledge seeking, learning, communication and study, experimenting and creating’*. Thus the sense made of this stage is pivotal to facilitate R&D decision-making.

Although, R&D has numerous challenges for companies undertaking it, successful R&D has the potential to create *‘greater market share, premium prices and dominant designs, leading to a much sharper competitive edge’* (Nobelius, 2004: 369) through management. The management of R&D processes and the R&D stage raises several management challenges for companies, including (1) strategic, (2) operational, and (3) methodological (Nobelius, 2004). Throughout these three aspects, are both physical and mental elements, in that physical processes are carried out, but are also socially and cognitively interpreted, communicated and with a requirement to manage these elements. The processes of how managers make sense of their world in company life and R&D is important, for understanding how management is carried out, and decisions made. In the next two sections, ‘Making Sense of R&D’ and ‘Management Decision-Making’ these aspects are considered. This study was predominantly focussed towards the operational but also encompassed an exploration of the strategic and methodological elements.

### **2.3.8. Making Sense of R&D**

Managers exist in a complex environment where competing organisational and individual drivers, compete for resource. Within this environment is a need for managers to be able to make sense of their world, communicate effectively about it, make decisions and facilitate shared meaning and understanding to aid in their role as manager. These aspects often lead to physical action and the communication of complex ideas, such as in R&D.

Making sense of complex phenomena is not necessarily an easy task for individuals, particularly where it is opaque, ambiguous, uncertain, or risk-laden, as is often the case within biological R&D. This can be further complicated, where individuals within a company communicate using different discourse styles based on their self-identities as scientists and managers etc. via different terminology, and non-verbal intonations to communicate about the same phenomena. This can make the production of shared meaning more difficult, resulting in challenges for making sense and ultimately decisions about R&D.

There is a set of cognitive (Starbuck and Milliken, 1998) and social (Weick, Sutcliffe and Obstfeld, 2005) processes known as sensemaking that can enable individuals to make and communicate sense about complex aspects of their world. Briefly, language and image based cues (amongst others) can be used in sensemaking to produce a simpler version of reality, or a version that is more preferred by the individual experiencing it (Brown, 2000; Maitlis, 2005; Weick, 1995; Sutcliffe, 2013). Sensemaking can be defined as creating '*rational accounts of the world that enable action*' (Maitlis, 2005: 21), and is '*a continuous effort to understand connections (which can be among people, places, and events) in order to anticipate their trajectories and act effectively*' (Klein *et al*, 2006: 71). Prior sensemaking research in a business environment focused on a variety of aspects including strategic change and decision-making (Gioia and Thomas, 1996; Sonenshein, 2010; Rerup and Feldman, 2011), innovation and creativity (Drazin, Glynn and Kanzanjian, 1999) and organisational learning (Weick, 1988, 1990, 1993; Gephart, 1993; Blatt *et al*, 2006; Catino and Patriotta, 2013).

In R&D environments, which can be complex and uncertain, there is often a requirement for technical and business concepts to be communicated between individuals, groups and to the wider organisation, to produce action. In other words, once an individual has information, there is a need for the information to be distributed throughout the organisation to promote sense and facilitate decision-making (Day, 2002). The term for disseminating sense is known as sensegiving (Weick, 1969, 1979, 1995) and is concerned with how communication is used to give sense to a recipient, upon which they will construct, meaning and reality, leading to action. Gioia and Chittipeddi (1991: 442) argued that sensegiving is concerned with '*the process of attempting to influence the sensemaking and meaning construction of others toward a preferred definition of organizational reality*'. The question can be raised though, how does this occur in R&D environments where there is a split between 'science speak' and business speak?' This study expanded the literature, which had previously given little attention to this aspect.

The method of communicating information and sense is critical for the success of management and what sense recipients make of a communication (Weick, 1995; Clark, Abela and Ambler, 2006; Pauwels *et al*, 2009). Language is often regarded as a vehicle to convey sense to promote individual and shared meaning (Weick, 1995; Taylor and Robichaud, 2004; Nicholson and Anderson, 2005; Sonenshein, 2006). Taylor and Van Every (2000: 40) supported this view by stating that: '*sensemaking involves turning circumstances into a situation that is comprehended explicitly in words and that serves as a springboard for action*'. There can be an even greater requirement for this in R&D environments, where there may not be shared understanding of terminology, processes and organisational drivers etc. between R&D management and executive management. Perhaps not surprisingly, the vehicles of narrative (Abolafia, 2010; Maitlis and Christianson, (2014: 31), metaphor (Cornelissen, 2005; Nicholson and Anderson 2005; Cornelissen *et al*, 2012), and models (Hill, 1995) have all found favour in constructing shared meaning between individuals and social groups within organisations, which ultimately result in management decision-making and action. Cornelissen (2010, 2012) has suggested that linguistic tools such as metaphors can simplify complex situations and aid in providing order and justification for certain actions in unfamiliar situations. While

this is not a sensemaking study, it does utilise concepts from the area of sensemaking, in that individuals often look to simplify communications regarding complex phenomena to increase the sense given, which can result in desired action. The author of this study believed that there may be synergy between some of the concepts from sensemaking and R&D models, whereby the model simplifies the communicated aspects of the R&D processes to facilitate decision-making by different organisational members, but particularly management. This could impact on the construction of R&D by different managers' discourse styles about R&D and many other factors feeding into R&D. The following section therefore examines 'Management Decision Making'.

### ***2.3.9. Management Decision Making***

R&D is constructed by management, insofar as what product to design, enter into the R&D stage, processes to carry out, and how these processes are moderated etc. It is however accepted that there are wider influences such as the market pull view of product development that may influence the R&D stage. Management decision-making is therefore crucial for the R&D stage. The management of R&D is carried out by individuals with a variety of skills sets and knowledge about the different aspects of R&D. Due to prior sensitisation of the author to the antiviral disinfectant R&D sector, it has been argued that there is a predominant splitting of management into executive and R&D, which may be attributable to factors including individual knowledge and experience. Importantly, Mudambi and Swift (2009) have shown that management utilise different knowledge sets to communicate about business and science/technology can subscribe to different belief systems, which influences the way they interact with R&D. For example, there can be differences in what R&D managers perceive as social and business incentives for successful R&D. Management from non-technical/scientific backgrounds are more likely to view 'excellence' in terms of market performance (Dasgupta and David, 1994; Gittelman and Kogut, 2003). This can be at odds with management from technical/scientific backgrounds, where the creation of knowledge is perceived as having an inherent value in itself irrespective of market performance (Duncan and James, 1974), and

where ‘excellence’ is measured in terms of primacy (Mudambi and Swift, 2011). Examples of this can include making ‘significant’ scientific discoveries, which can result in rewards such as research grants, professorships and increased esteem but which may have little value for R&D (Merton, 1957; Dasgupta and David, 1994; Sorenson and Fleming, 2004). These divergent views over what constitutes scientific ‘excellence’ in a business environment can compound management decision-making and efforts to evaluate R&D projects, which at worst can produce products with scientific merit but little to no commercial value. With this and other difficulties, it can be seen that clarity is needed in R&D management decision-making and a vehicle for shared meaning of these values. This can involve aspects such as how and when to carry out a process as well as how and when to allocate resource. Where there is uncertainty in management decision-making, for when and how to allocate resource, there is the potential for inefficiency, meaning that promising products may not receive adequate resource and failing products may continue to act as a drain on resources.

Although this study is primarily concerned with understanding R&D processes for antiviral disinfectant R&D, drawing out and understanding management decision-making for processes is also beneficial to understanding the how and why of R&D. In this study, respondents detailed how they made decisions, which could have varied from deliberation all the way through to *‘just random picking...or just using the likeability heuristic’* (O’Shaughnessy, 2005). Importantly, Kotler (2000: 88) suggested that managers make decisions via the following processes, *‘both marketing and environmental stimuli enter the buyer’s consciousness. In turn, the buyer’s characteristics and decision process lead to certain purchase decisions. The marketer’s task is to understand what happens in the buyer’s consciousness between the arrival of outside stimuli and the buyer’s purchase decisions’*. The marketing management view is useful but limited by its simplicity and while it is not possible to understand the buyer’s consciousness, his/her mental processes can arguably be examined via the examination of discourse (Ellis and Hokinson, 2010), such as the method of explication (Hycner, 1999) as used in this study.

Numerous perspectives have been used to examine decision-making (Kahneman and Tversky, 2000), whether it is rational and if it is an individual or group-activity. It occurs when a selection is made from alternatives, with every decision ultimately producing a final choice (Reason, 1990). Decision-making can be regarded as a problem solving activity via reasoning or emotional processes, which can be rational/irrational and reaches completion when a satisfactory solution is attained or an unsatisfactory selection is made, but the individual is not prepared to make more selections. Kenji and Shadlen (2012) argued it as an involuntary process, where individuals seek to maximise benefits and minimise costs via analysis of available data (Schacter, Gilbert and Wegner, 2011). This is referred to as ‘Rational Choice Theory’ (RCT), which assumes that individuals maximise benefits and minimise costs (Schacter, Gilbert and Wegner, 2011). According to Hollis (1987, 1996) standard economic theory constructs individuals as rational maximisers of ‘utility’ who select the most efficient means of achieving goals, based on self-interest. Although RCT has been extensively used in a variety of academic disciplines (Ryan, 2003) there are limitations of this theory, as detailed more extensively by Baron (1998). Perhaps the crux of the challenge of RCT is the assumption that self-interest is pursued at the exclusion of all other factors (Sen, 1987). As Kahneman, Knetsch and Thaler (1990) pointed out, classical microeconomics assigns no role for other factors such as generosity, social conscience, goodwill and fairness, but research suggests that people act out of these interests and against self-interest at times.

Irrational behaviour on the part of a manager may also be linked to factors such as availability bias or availability heuristic (Schacter, Gilbert and Wegner, 2011). This is a shortcut for judgment making about the probability of an event occurring, based on how easily information can be recalled. In such cases, the individual perceives recalled information as important, with a positive relationship having been demonstrated between recalled information and the consequences of something occurring based on recalled information (Tversky and Kahneman, 1973). For example, this could result in an R&D management decision being influenced by the manager having watched a film that depicts the technology in a particular way, which is a non-intentional communication. For managers with a lower knowledge of science/technology, there is a greater potential for ‘information overload’ which,



occurs, where there is a high volume of cost/benefit information resulting in processing problems which impact on decision-making (Kutty and Himanshu, 2007). The problem can at this point become how to make a decision, when all criteria are being considered simultaneously, and how to prioritise processes and resources.

The issues explored in this section suggest that R&D management decision-making is not only complex but potentially takes place within risk-laden and uncertain environments, and is not as simple as Kotler (2000) has suggested. Using R&D models to represent complex environments has been shown to aid management-decision making, and R&D outcomes (Bean and Guerard, 1989; Tian, Ma and Liu, 2002; Wang *et al*, 2013). Although a model may not represent ‘all’ of reality, it is not always necessary for high-levels of information to be presented for decision-making. For instance, Weick (1995) has suggested that often, managers seek information that is ‘good enough’ for them to operate in complex and opaque environments (Hastie and Pennington, 1995). Andreassen and Kraus (1989) believe that for some managers, the process of finding ‘enough order’ and clarity must be rapid, with managers needing little to clarify their decision-making when incoming data met with their expectations. The need to make sense and dig deeper only became important when expectations were violated. For decision-makers, the question can be asked though, to what extent can models be driven by plausibility or accuracy. Lundberg (2000) argued that ‘accuracy’ could be less important than prompting action and bringing order to the world. As Bruner (1973: 30) stated that, *‘[t]he cost of close looks is generally too high under the conditions of speed, risk, and limited capacity imposed upon organisms by their environment or their constitutions. The ability to use minimal cues quickly in categorizing the events of the environment is what gives the organism its lead-time in adjusting to events. Pause and close inspection inevitably cut down on the precious interval for adjustment’*.

This concludes the examination of the ‘Antiviral Market’, where aspects including the nature of viruses, how they are inactivated by antiviral disinfectants, as well as the business aspects of managing and making sense of antiviral disinfectant product development, risk and uncertainty and decision-making have been considered.

Importantly, the complexity and opacity of this area was highlighted for managers in both R&D and executive posts were drawn out, suggesting the need for a simpler view of R&D. Thus, the following section explores ‘Modelling R&D’, as a symbolic representation of the reality of antiviral disinfectant R&D, to aid in management understanding, and decision-making.

## **2.4. Modelling R&D**

The development of models is widely used throughout business and science, and has found both theoretical and practical use in various academic fields and industrial sectors. Not surprisingly, modelling has focussed on numerous areas of R&D, including business outputs such as producing patents (Popp *et al*, 2013) as well as the physical processes carried out and understanding how processes impact upon the business (Bednyagin and Gnansounou, 2012). One of the challenges for modelling R&D is what it means to ‘model R&D’ and what is expected from such a model. As much as there is a requirement to understand the term model and accept that it can mean many things to many people, but also be able to have managers construct shared meaning about models so they are of wider organisational benefit. Coupled with this is a need to define what is what R&D means to management, and whether it is predominantly ‘R’, ‘D’ or ‘R&D’ being modelled. These issues will be examined in the following sections.

According to Geertz (1973: 5) anthropology is ‘*not an experimental science in search of law, but an interpretive one in search of meaning*’. The researcher of this study believes this statement is relevant (although from a different academic area), as through the production of an R&D model, we have an interpretation in search of meaning and not a law. More than this though, an R&D model is an interpretation of R&D that is to aid in sense- and decision-making and is not necessarily ‘correct’.

The exploration of modelling R&D starts in the following section, by briefly exploring ‘Modelling ‘Reality’ *i.e.* ‘What is a Model?’

### ***2.4.1. Modelling ‘Reality’ – What is a Model?***

A model can be defined as an explicit representation of some portion of reality as perceived by an individual (Wegner and Goldin, 1999). It can be regarded as ‘active’ if it influences the reality it reflects, which in the scheme of this study, would be the ability of a model built on antiviral disinfectant R&D processes, to influence management engaged in this field. As both Hirschheim and Klein (1989) and Schuette (1999) have argued, the development of models can be based upon their ontological and epistemological stance. Briefly, ontological realism assumes that reality exists independently from an individual, whereas ontological idealism (or nominalism) refutes this claim (Schuette, 1999). Epistemology allows objectivism (the stance that objective knowledge is possible) and subjectivism (the stance that objective knowledge is not possible) to be distinguished (Schuette, 1999). Viewing reality as a being socially constructed (Burr, 2003) allows these perspectives to be connected in a way that is beneficial to model development. Due to the importance of social constructionism to this study and sensemaking, interview questions were framed through a phenomenological paradigm whereby respondents’ construction of the organisational and R&D realities were accepted on the basis of their discourse. This deviates from objectivism whereby respondents’ claims could be verified against external factors outside of themselves (this being a simple view however). It is important to recognise that although respondent discourse was taken as a proxy to respondent inner worlds, constructed realities of organisational life and R&D, the process of warranting (Wood and Kroger, 2003), was used to differentiate good and bad discourse.

Examining the work of Berger and Luckmann (1996), objectivity and subjectivity were integrated in an on going dialectical process of articulation, objectivation and socialisation. In this way, subjective reality affects objective reality through articulation, and is affected by objective reality through socialisation, although it is worth pointing out that *‘this conception of philosophy is, however a recent historical development’* (Rabinow, 1986: 235). Thus Jørgensen (2004) has claimed that interactive models can become an objective reality. There is however the requirement for models to reflect an individual’s subjective reality, for instance, and

as an example, to facilitate discourse through storytelling (Brown and Duguid, 1991; Orr, 1996) and negotiation of meaning (Wenger, 1998) throughout the business. One of the challenges of developing a business model is to embed it within the phenomenon being examined. The challenge of embedding the business model within the phenomenon is in understanding the phenomenon being examined at a deep enough level to be able to mirror it in the model. Arguably a danger for companies is not adequately modelling the phenomena of interest, which can result in a model ‘*without origin or reality*’ (Baudrillard, 1994: 1). In the next section the aspect of ‘Modelling ‘Reality’ – What is a Business Model?’ is explored.

#### ***2.4.2. Modelling ‘Reality’ – What is a Business Model?***

Models are developed and used by businesses for a variety of reasons, including, increasing management understanding of R&D, standardising procedures, quality control, aiding in commercialisation, unlocking latent value in a technology and facilitating theory development within a business environment (Chesbrough and Rosenbloom, 2002; Morris *et al*, 2005). There is however, a lack of consensus of what constitutes a business model, or how to define it. This can be coupled with the questions, which as Baden-Fuller and Morgan (2010: 156) asked ‘*are business models useful?*’ ‘*who uses them, for what, and how?*’ A simple answer is that ‘*business models have the characteristics and fulfil the roles of ideal types: they are based on both observation and theorizing*’ (Baden-Fuller and Morgan, 2010: 162).

Morris *et al* (2005) have suggested that there are three categories of business model, including (1) economic, (2) operational, and (3) strategic, with each having a unique set of parameters and variables. The economic model is based upon the logic of profit generation, and focuses on revenue sources, pricing, costs, margins and volumes. As Stewart and Zhao (2000: 287) stated, the economic model is ‘*a statement of how a firm will make money and sustain its profit stream over time.*’ The operational model is based on an architectural configuration, which focuses on internal processes and design of infrastructure, which enables the business to make money (Morris *et al*, 2005). Mayo and Brown (1999: 20) referred to this as: ‘*the*

*design of key interdependent systems that create and sustain a competitive business.’ The strategic model focuses on aspects such as the businesses’ marketing position, growth opportunities and interactions across organisational boundaries (Morris et al, 2005). A fundamental for this type of model is competitive advantage and sustainability. Slywotzky (1996: 15) refers to this as: ‘the totality of how a company selects its customers, defines and differentiates its offerings, defines the tasks it will perform itself and those it will outsource, configures its resources, goes to market, creates utility for customers and captures profits.’*

Trott (2012) suggested that there are eight models for new product development R&D, which are, (1) departmental-stage models, (2) activity-stage models and concurrent engineering, (3) cross-functional models (teams), (4) decision-stage models, (5) conversion-process models, (6) response models, (7) network models, and (8) outsourced. The two main types of models used are the activity-stage model and the decision-stage model, which have similarities with each other, based on their ‘over-the-wall’ approach to R&D. Looking at allied technologies to antiviral disinfectants, such as the pharmaceutical industry, biotechnology and specialty chemicals, there are numerous models used in product R&D. The stage-gate process (herein referred to as the ‘consumer’ model) is commonly used, as is the departmental-stage model (herein referred to as the ‘technological’ model). These commonly utilised models are further described in the following sections, with the next section focussing on ‘Process Models in R&D’.

### **2.4.3. Process Models in R&D**

One of the first process models of industrial product development was proposed by Cooper (1983), which was a seven-stage model to serve as a normative guide to management, to reduce critical steps being overlooked. Cooper’s model focussed on products being developed sequentially and not simultaneously, and was perceived as a flaw by Adler et al (1995), where interdependent R&D was taking place. While studies such as Cooper (1983) and Adler et al (1995) are vital for developing core theory, the practical aspects of defining and understanding a specific phenomenon in

company R&D environments is also important. From initial studies such as these, a variety of R&D process models have been proposed, with different philosophical and business constructions attached to them. It is important however to define process R&D models.

Within process R&D models, Hammer (2001: 5) stated that a process is '*an organized group of related activities that work together to create a result of value*'. A process or processes may span the entire R&D stage. In an attempt to produce a fuller understanding of R&D processes, academics and practitioners have used different models to represent R&D (Browning and Ramasesh, 2007). Simplistically, '*a model is an abstract representation of reality that is built, verified, analyzed, and manipulated to support a particular purpose, even if that purpose is merely to increase understanding of a situation*' (Browning, 2010: 317). As Box (1979: 201) however stated, '*all models are wrong, but some are useful*'. Not surprisingly, no model truly represents objective or subjective reality, as each model selectively communicates information. It can be argued that this is the same for process R&D models and although they do not communicate all information they can simplify shared meaning and a simple view of R&D. Importantly, the philosophical basis for constructing models and shared meaning must also be considered. In prior studies reductionist stances have been predominantly embedded within a positivist paradigm has been used for model production. While informative and insightful, a more 'holistic' approach was taken in this study, which is via phenomenology to allow the phenomenon of R&D to be 'true to itself'. There is arguably no right or wrong way for which philosophical stance to take, but more that for exploratory research with the aim of getting close to the phenomenon, phenomenology is more fitting than prior approaches based in positivism.

Shane and Ulrich (2004) have argued that as the complexity of R&D increases, so does the need for a model. The complexity of the R&D model, and ability of management to interpret the model is paramount for the success of the model (Browning, 2010). This often necessitates the need for a simplified model, or even 'mental models' (Senge, 1990) to describe and control projects (Flanagan *et al*, 2006). Little (1970) argued that managers tend to prefer models that are (1) simple

and easy to understand, (2) complete and including pertinent phenomena, (3) robust and limited to pertinent answers, (4) adaptive and easy to adjust for new information inputs, (5) easy to control, whereby the user knows what input roughly equals what output, and (6) easy for the manager to interact with. Not surprisingly, some of these criteria conflict with each other, such as robustness and simplicity, which creates further challenges for constructing models. Arguably though, whichever route is taken for modelling R&D, the model has to be capable of being interpreted by different managers and stakeholders who will carry out physical actions based on the model. Thus the language and symbolic representation is pivotal for model production. While symbolic aspects have received much attention for how to represent models, less attention has been paid for the language used to communicate sense. This study has therefore expanded the literature in this area to directly consider language used by different managers to convey sense and shared meaning. Coupled with a more encompassing approach created the potential for something to more adequately capture the ‘essence’ of R&D and would enhance the reflexivity of the model.

The factors discussed so far arguably necessitate the need of a model to be useful to the manager for whatever purpose in process R&D the model was developed for. As Browning (2010: 317) stated: ‘*a process model should include the attributes of a process which are deemed appropriate to describe it. However, this determination of appropriateness is always made (explicitly or not) in relation to a particular purpose*’. Fitness and appropriateness are arguably subjective constructions however, with Engwall *et al* (2005) describing project managers as perceiving ‘canonical’ process models as having a variety of different purposes. This can create challenges for process models, as a process model developed for one purpose may not necessarily be appropriate for another (Browning *et al*, 2006; Crowston, 2003; Dolk and Kottemann, 1993). A simple example of this is a general process model would likely be insufficient in detail for each process part. Whereas it might seem easy to rectify this lack of data in the general model, it might make it too complex for a general model, meaning that the elements of complexity may have to be dealt with elsewhere (for example through an expanded view). This suggests that managers may well use process models differently, which was argued by Browning (2010),

who argued that not only do different managers have different reasons for using process models, but that they can be used as a preliminary method to further their understanding of process situations. Perkins (1986) contended that understanding requires three things, including; (1) a purpose for analysis, (2) a model of the process to be understood, and (3) arguments about why the model is fit for purpose. Further to this, Steiger (1998) argued that evaluative arguments include, model accuracy, simplicity, conceptual validity and model component sufficiency. *‘In particular, the necessity and sufficiency of a model’s components help determine the alignment between a managerial purpose and a model used to support it’* (Browning, 2010: 317).

It is important for management to understand the desired results of developing an R&D model, and whether the type of model can adequately deliver the desired aims. Put more simply, whereas a model can demonstrate the processes in R&D, it can show much more beneath the surface of the processes, allowing more considered decision making, if required. In utilising process models in R&D is the requirement to understand that there is a temporal order and sequence in which discrete and continuous events occur throughout R&D processes occur. Prior research had predominantly considered process R&D as relatively static, and in line with realist thinking something that is ‘is’. Utilising a lens of attempting to more closely mirror R&D led this study to step away from singular constructions of R&D even within the same organisation, other than through shared meaning, based on social construction and discursive framing.

As Meredith and Mantel (2003) argued, initiating an R&D project does not guarantee that the R&D stage will be completed or that a new product will be commercialised. *‘As R&D organizations have limited resources, a project in an R&D organization has to continuously justify its existence in the presence of other projects’* (Verma, Mishra and Sinha, 2011: 464). Reasons given for a project not being completed include: changing market conditions, unanticipated technological challenges, competitor actions and a change in competitive strategy of the R&D or funding company (Balachandra *et al*, 1996: Guan *et al*, 2002). For the R&D stage to continue, it is important for the activities and output from R&D to be viewed



favourably by the wider business, particularly management (Verma, Mishra and Sinha, 2011). This need has become more pronounced among high technology companies due to an increasingly competitive global market place (Huston and Sakkab, 2006). This arguably necessitates the need for models with a wide context for different stakeholders, or different models for different business segmentations.

The model literature is ‘vast’, but much research has focused on theoretical models at the expense of understanding how these models impact on practice (Shane and Ulrich, 2004). This has also been the case for understanding different management stakeholder views on model development, implementation and use. Taking a more practical approach, as carried out in this study enabled a more thorough examination of model development from multiple stakeholders within and between companies engaged in a specific sector (antiviral disinfectant R&D), as well as feedback for the final construction and use of such a model.

Moving more to look at what R&D models have been constructed and given theoretical and practical examination in the past, the following section digs into ‘A Critique of R&D Models’ to create a foundation of prior academic knowledge to facilitate the production of process models in this study.

#### ***2.4.4. A Critique of R&D Models***

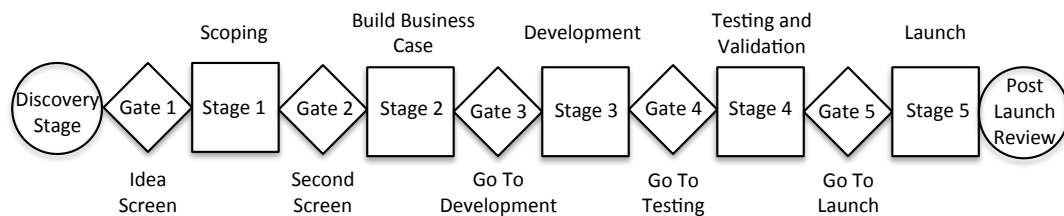
R&D models have ‘evolved’ over the last fifty years from the ‘Black Hole’ first generation model to the ‘Network/co-operation/acquisition/lab based’ sixth generation model (‘fuzzy’) (Nobelius 2004; Lager, Blanco and Frishammar, 2013). This evolution has taken mainly two pathways, the ‘market/consumer’ model, focusing on market needs *i.e.* ‘the outside in’ approach (Cooper and Edgett, 2013) and the ‘technological’ model, focusing on optimising resources and processes, *i.e.* ‘the inside out’ (Canongia, 2007). On studying the evolution of models, and according to Nobelius (2004), it would appear that although the technological model has advanced into the sixth generation, the consumer model seems still to be a mixture of the second and fourth generation, with its emphasis on cost, quality and

particularly, time to market (Chaudri, 2013) However, a deeper study of the consumer model, in theory and practice, (Liedtka, 2011; BRIDGE Collaboration (2013) indicates that in the desire to collapse the process time, the first stage at least, requires that all actors in the R&D process are identified and utilised. This has some resonance with the sixth generation with its emphasis on networking and collaboration. In the research under review, where entrepreneurship, asset intensity and ‘lab based’ development are key processes (Lager, Blanco and Frishammar, 2013), it was not clear at the beginning of the research how these factors would relate to an antiviral disinfectant R&D model and as such necessitated an exploratory approach for an under researched sector. In capturing the phenomenon of any R&D process, arguably no ‘one size’ will fit all but again raises the issue of what it is to model a process, and how closely that any model should fit the process. Given these diverse and numerous attempts at designing models and frameworks in the ‘technological’ and ‘consumer/market’ domains, and in their attempted integration, no wonder Pisano (2012) concluded that no one R&D model that is universally superior has emerged over the last few decades and *‘it’s not surprising that attempts to revolutionise the process has met with jaded skepticism’*. Given this comment, the researcher of this study, feels justified in modelling process R&D for the antiviral disinfectant industry, hitherto informed by, but not embraced, in past research. This approach may have produced a model similarly mirroring a prior model but this could not have been known prior to the research element of this study being undertaken.

When deciding how to interact with R&D models, companies have a choice of using existing and potentially ‘popular’ models such as the ‘consumer’/‘marketing’ model (Cooper and Edgett, 2013; Kotler and Armstrong, 2010) with numerous variants e.g. the ‘time to market’ model (Kahn, 2004) or the ‘technological’ model (Canongia, 2007). Briefly, the ‘consumer’ model concentrates on the R&D processes driven by marketing research, which can be regarded as an ‘outside-in’ approach, and prior to the research stage, it was expected that executive managers may utilise this model for constructing R&D. The ‘technological’ model is driven by scientists and technicians, which can be regarded as an ‘inside-out’ approach, and with it being perceived likely that R&D managers may well construct similarly. An example of

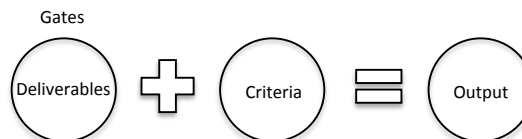
the ‘consumer’ model is the Stage Gate Model, redrawn and shown in Figures 2.3 and 2.4.

**Figure 2.3. Stage Gate Model**



Source: <http://www.prod-dev.com/stage-gate.php>. Last accessed 01/06/2013

**Figure 2.4. Gates for the Stage Gate Model**



**Deliverables:** Inputs into the gate from the preceding stage, and defined in advance.

**Criteria:** What the project is judged against in order to make the go/kill decisions.

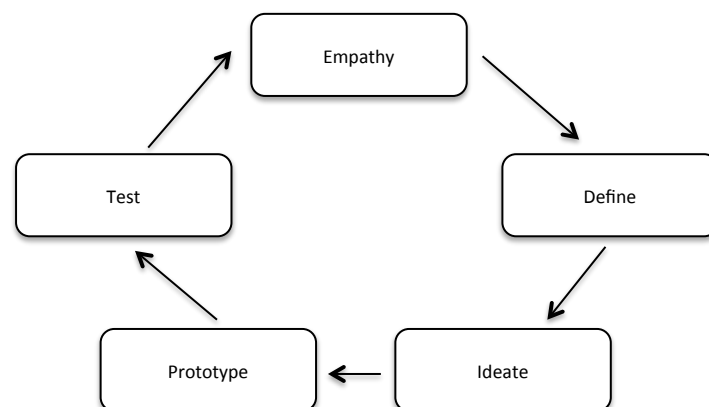
**Outputs:** Results of the gate review, where gates must have a decision and a path forward.

Source: <http://www.prod-dev.com/stage-gate.php>. Last accessed 01/06/2013.

Influential marketing authors like Kotler *et al* (2013) have used this model as the basis of their writings to describe the R&D process. Models like the Stage Gate Model are believed to enhance product innovation and technology strategies, improve business innovation cultures and allow investment in the right projects (Cooper and Mills, 2005; Jaruzelski, Dehoff and Bordia, 2005; Cooper and Edgett, 2013). They have also been used by organisations to inform their product development through to commercialisation (Koen, 2003; Adams and Hubilkar 2010; Grörlund, Rönneberg, and Frishammar 2010; Cooper, 2011). Arguably however, although simple to use, at best such models produce a ‘thick’ representation of the phenomenon. Although the researcher could envisage similarities between the Stage Gate Model and his emic experience of R&D in the antiviral disinfectant sector, it was not known at what level if any such a model might be used in different companies.

Attempts have been made through the use of models such as the Design Thinking Model (Martin *et al*, 2012) to simplify the R&D process further. Although the Design Thinking Model can be considered an attempt to ‘collapse’ the Stage Gate Process to accelerate the R&D stage, this is an over simplification of this model, as there are different elements in the Design Thinking Model. Figure 2.5, shows an example of the Design Thinking Model, which is composed of five stages, including, (1) empathy (getting to ‘know’ the actors), (2) defining (what the problem and parameters include), (3) Ideate (find an ideal solution), (4) prototype (produce a working model) and (5) test (the model or solution). Perhaps not surprisingly, the Design Thinking Model has a greater focus on ‘design’, including greater potential aspects of creativity to achieve the goals of R&D. This can be seen from the stage (1) where there is an attempt to get to know the actors, enabling a greater access to internal actor knowledge. Secondly, defining the problem and ideating can be construed as drawing out the problem and theoretically solving it (even though this may not occur in objective reality), before prototyping begins. Undoubtedly organisational culture may well influence the use of the Design Thinking Model, where for example R&D managers may perceive terms such as ‘empathy’ negatively, as something not fitting for the natural sciences. These aspects could only be drawn out during the interview stage, and as discussed previously, this study sought to embed itself within a greater examination of language used which was addressed by questions asked in the interview stage.

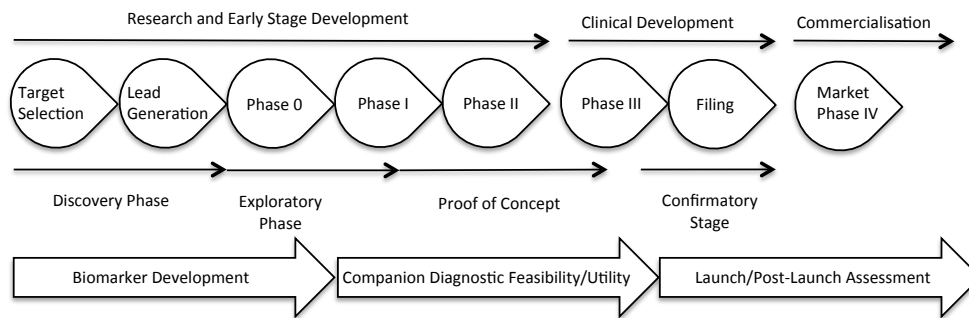
**Figure 2.5. Design Thinking Model**



*Source: Martin (2012:12).*

As well as the ‘consumer’ model is the other type of ‘popular’ model, known as the ‘technological’ model. This model is focussed towards the technological aspects of R&D and often segments R&D into different ‘thick’ stages such as formulation and toxicity etc. An example of this redrawn model is shown in Figure 2.6.

**Figure 2.6. Technological R&D Framework Model Overview**

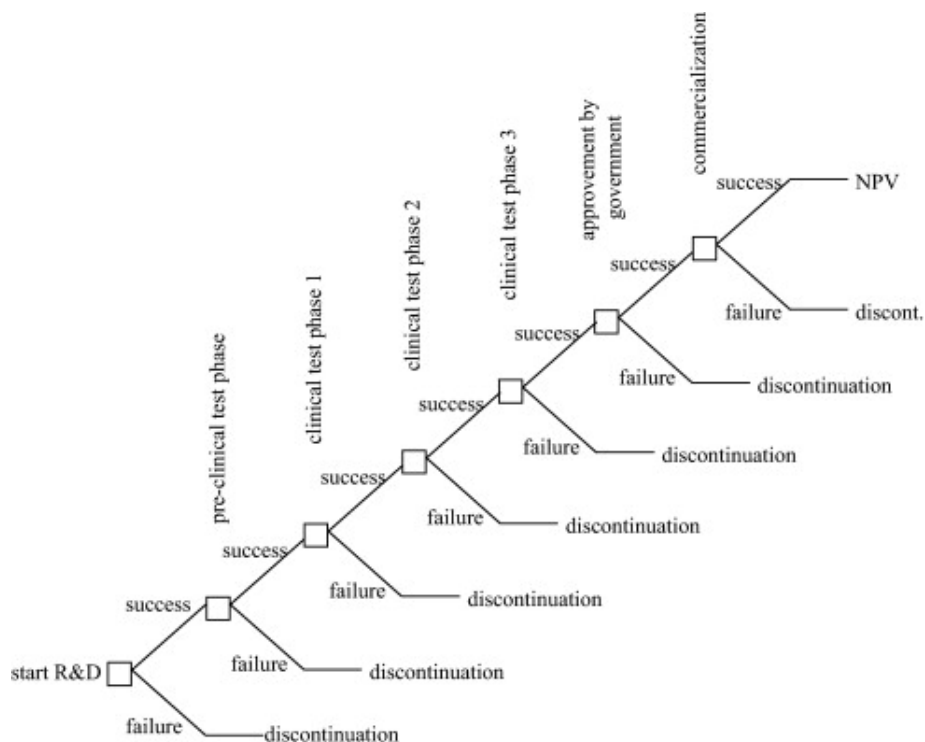


Source: [http://www.roche.com/research\\_and\\_development/r\\_d\\_overview.htm](http://www.roche.com/research_and_development/r_d_overview.htm). Last accessed 02/06/2013.

This example model used by the pharmaceutical company Roche, is composed of three main R&D stages, including, (1) R&D, (2) clinical development, and (3) commercialisation. This model can be considered a ‘thick’ description as it shows generic process stages and simplistically segments for example, an entire stage into ‘target selection’. It also does not show what happens if there is a failure at a specific stage of R&D, or if a stage has to be repeated. Representing R&D in the way shown by the Roche model can be helpful for capturing how one company carries out R&D, but it is simply not known at what level such a model can be extrapolated through the biological sector.

Although both the ‘consumer’ and technological’ models are ‘popular’ they arguably ‘suffer’ from how much ‘reality’ should be expressed within the model. A model can be simple and act generically and has a potential to widely used across sectors ‘as is’ or it can be sector or company specific, with a lower chance of generalisability. The model shown in Figure 2.6 is undoubtedly sector specific and an example of a ‘technological’ model but fails to show what happens when an R&D stage fails. The model developed by Cassimon *et al* (2011: 1203) explicitly shows stage failures albeit for a pharmaceutical drug model, and is shown in Figure 2.7.

**Figure 2.7. Technological R&D Model with Increased View**



Source: Cassimon et al (2011: 2103).

By showing stage failures, Figure 2.6 is arguably expanded into an increased view from that in Figure 2.7. Interestingly this increased view showcases success and failure for each R&D stage, with a potential of discontinuation. Arguably however, this expanded view also has limitations in representing the subjective and objective ‘realities’ of research, which are fundamentally that symbolic representation of mental and physical phenomena is always potentially challenging. For instance, looking at Figure 2.7, R&D is depicted as a linear event with the only potential outcomes being either a ‘success’ or a ‘failure’, which is an either/or event and could be argued as having some similarity with the Stage Gate Model. However, it is interesting to consider that this linear approach to such a model is itself perhaps misleading, as it is suggestive that if the product fails one stage, R&D will be discontinued, whereas it might perhaps be cycled back through an earlier stage to achieve a success on a previously failed stage. This is speculative on behalf of the researcher of this study, but does suggest the problems for how management interacted with constructed models, how they are interpreted, and how rigidly they

should be followed. To address this issue, the interview stage drew on this aspect to further understand the phenomenon as it relates to antiviral disinfectant R&D.

Of interest to this study was, does the antiviral disinfectant R&D sector, follow, customise or have its own completely unique processes and ergo model(s)? Further, does 'one size' fit all? This is a gap in the current literature, which this study has explored. Briefly, the advantage of using either the 'consumer' or 'technological' model is that they already exist, and have been examined by both practitioners and academics. They do however have the disadvantage of being non-sector and non-product specific. The alternative is for companies to devise and implement a phenomena (sector and/or product) specific model, which might capture more of the phenomenon of interest but is more complex for management to interact with. In the next section 'Management Interaction with R&D Models' is examined to more fully consider what prior literature has highlighted about this area.

#### ***2.4.5. Management Interaction with R&D Models***

R&D is a complex series of management and process events consisting of continuous and discontinuous elements. Within R&D is the aim for identifying, researching and developing a product that can be taken to market. PMI (2008) stated, that a project could be defined as '*a temporary endeavor undertaken to create a unique product, service or result*', but importantly over the past decades the number of high-cost, large and complex R&D projects and programs has grown significantly, creating further challenges for management (Winter *et al*, 2006). Throughout numerous sectors (beyond just those using R&D), '*projects are notorious for cost and schedule overruns, and insufficient management of them wastes the equivalent of billions of dollars around the world each year*' (Browing, 2010: 316). As a way of managing resource, process models are routinely relied on to understand and regulate the R&D stage. The challenge for process models, particularly in R&D is the nature of product development, as R&D processes can vary from product to product, meaning that a management model for one product is not necessarily transposable (although it depends what level of reality is required to be represented). Even though

there is a potential deviation within each stage of the process stage, it is still possible to standardise the broad information aspect of the processes, *i.e.* formulation and toxicology etc. Although there are numerous ways of representing a process model, particularly for management, it is usual for only one model representation to be used for any one process set (Browning and Ramasesh, 2007). Examples of views include flowcharts (IBM, 1969), network diagram (Moder *et al*, 1983), Design Structure Matrix (DSM) (Browning, 2001), Graphical Evaluation and Review Technique (GERT) diagram (Pritsker and Happ, 1966), textual narrative (SPC, 1996), IDEF0 diagram (NIST, 1993), IDEF3 diagram (Mayer *et al*, 1987), State diagram (Harel, 1987), Create-Read-Update-Delete Table (Kilov, 1990), value stream map (McManus, 2005), Supplier-Input-Process-Output-Customer (SIPOC) diagram (Browning *et al*, 2006), IPO diagram (Radice *et al*, 1985), extended Event-Driven Process Chain (eEPC) diagram (scheer, 1999), Responsibility Assignment Matrix (RAM) (PMI, 2008) and classic spreadsheets (Browning, 2010). Not all of these process models are suitable for R&D, particularly for the phenomenon of antiviral disinfectant process R&D. Before carrying out the interview stage it was simply not known which if any of these approaches were already being used, would find favour and the rationales behind these decisions. In principal, while any of the previously models could be used in antiviral disinfectant R&D (even if badly) the researcher utilising a phenomenological approach and staying close to the phenomenon of interest, allowed the experts within the sector of interest to define their realities of modelling R&D. Coupled with phenomenological bracketing the researcher attempted to reduce any induced bias on his part into the model building stage.

With numerous process R&D models available, managers in any sector must decide which model(s) to use, if any at all, as each model potentially communicates different information to management and the wider organisation. Examples of this are the use of flow charts to determine the length of a project and GANTT charts to assign tasks etc. The challenge for using models is how they reflect reality of R&D within an organisation, as arguably no model 'truly' reflects constructions of objective or subjective reality. On this basis, even though potentially advantageous to management, the model may distort the reality of R&D and associated processes. This may be through the emphasis or omission of certain process aspects of R&D.



Constructing a model is no small task, and as Bendoly and Speier (2008: 169) questioned: ‘*what information to include/disregard when making specific decisions*’. Management decision-making can therefore be linked to what the model contains, what reality it communicates to the manager, and how the manager uptakes the information from the model and makes sense of R&D. More simply put, what a manager decides is based on what they perceive and understand (Bendoly and Swink, 2007). At best, models exist that at some level mirror objective or subjective reality and facilitate successful R&D, leading to commercialisation, whereas at worst the models are not congruent with the purpose and tasks faced in R&D (Browning, 2010). From a management perspective, production of information, even in a symbolic model has a requirement for management to interact with the model, which necessitates organisational resource. Overly large and complex models can create information overload for both individuals and groups. Farhoomand and Drury (2002) argue that the presence of a ‘poor’ model can allow management to believe that information has been received and acted upon in a way that is desirable to management, when it has not been. Through a phenomenological approach and against a backdrop of numerous previous models used for R&D, this aspect was directly addressed in the interview stage and incorporated into the construction of an antiviral disinfectant model.

The potential outcome of information overload and the consequences of it must be taken into account for the construction of a process R&D model. To avoid this outcome, the aspect of information overload and how it occurs must also be better understood. Schick *et al* (1990) state that information overload occurs when a task’s information processing demands, exceed the individual’s capacity to process information in a given period of time. Studies have shown the negative consequences of decision-making for management faced with information overload, and include, (1) a reduction in the quality of decisions (Stocks and Harrell, 1995; Pennington and Tuttle, 2007); staff overlooking what they themselves may perceive as critical (Herbig and Kramer, 1994); obscuring relevant and known information (Wilson, 1995). For projects where the size and complexity of R&D increases, and models mirror this by having their size and complexity increased, management can become less able to critically engage with the model, which can further produce poor

decision making (Bendoly and Speier, 2008). This aspect was considered pivotal for the construction of an antiviral disinfectant model as biological R&D is often complex, opaque and with technical terminology, all of which can cause confusion, resulting in poor sense- and decision-making.

A potential way around the production of an information rich single model, which can cause information overload, is the production of a model with subgroups and subsets also known as an expanded view (Browning, 2010). This can allow information to be displayed in a format that more easily facilitates information uptake and management decision-making, but is dependent upon relevant subgroups and subsets being identified for use within the model. As Browning (2010: 318) stated: *'this motivates the concept of a "view". Whereas a model is an abstraction from reality, a view is a second layer of abstraction, an arrangement of symbols, a table, or another depiction chosen to display a selected subset of a model's attributes and assumptions'*. With two management respondent types being examined in this study (executive and R&D) this aspect was explored as a vehicle to enhance communication and sensemaking between managers in the same organisation.

A process model should be a symbolic representation of the processes carried out. While using model views can allow an increased representation of reality, there can often be a requirement for practical limits on the information displayed to inhibit management information overload. The advantages of a view according to Browning (2010) are that it enables users to focus on more detailed aspects of the phenomenon, and potentially show different attributes to different model users.

According to Parnas (1972), incorporating views into models can draw out information that can otherwise remain hidden and increase the ease with which decision makers interact with models. When deciding what information to include in a view, Browning and Ramsesh (2007) indicated that it should only include information that was perceived as useful for making a certain type of decision (which of course benefits and suffers from decision-making about what to include in a view). Beyond what information to include in a view, the way that the data is

presented in the view is also important, as ideally it will facilitate understanding, reduce complexity or ‘complicatedness’ (Tang and Salminen, 2001). It should also focus on the needs of specific users and their needs from the model views. Arguments have been made that ‘better’ views can be a significant driver of innovation in system design (Alexander, 1964, Simon, 1981; Zachman, 1987; Schätz *et al*, 2002; Keller *et al*, 2006); product development decisions (Krishnan and Ulrich, 2001); and decision support systems (Basu *et al*, 1997). The concept of views can be linked with ‘natural intelligence theory’, in which Minsky (2006) postulates that the human mind contains multiple models of any given system that an individual encounters. Such individually and mentally held multiple models can include physical, social, emotional, mnemonic, strategic, visual and tactile etc. According to Minsky (2006), rapid switching may occur between models depending on other internal and external stimuli, with multiple views of a complex model being found attractive in representing R&D (Keller *et al.*, 2005; Browning, 2009). In this study the use of expanded views was used to represent both executive and R&D manager subjective experiences of R&D which if not addressed has the potential to create confusion and problems for management sense- and decision-making. The ways that individuals can reach shared meaning through intersubjectivity is thus explored in the following section of ‘Intersubjectivity and Development of R&D Models’.

#### ***2.4.6. Intersubjectivity and Development of R&D Models***

One of the challenges of producing an R&D model based upon phenomenological research is that of intersubjectivity, which is based upon whether different individuals can achieve agreement on a given set of meanings or definition of a situation (bluntly, whether if in another’s ‘shoes’ we might see the world in the same way). Briefly, Scheff (2006: 196) defined intersubjectivity as ‘*the sharing of subjective states by two or more individuals*’. It can also be regarded as a ‘common sense’ view of situations. In producing an R&D model, intersubjectivity must be considered as multiple managers have been interviewed in this study to produce an R&D model. Heritage (1984) addressed this issue by raising the question, how can two or more individuals truly share an experience in the same way? Schutz (1967:

99) argued that the full subjective experience of another is '*essentially inaccessible to every other individual*', but that individuals assume that they share the same experiences and act as they are identical for all practical purposes. Heritage (1984) argued that individuals 'know' that the way they encounter objective reality is different from other individuals. This is based on two principles, with the first being that each individual approaches objective reality from a different place, and thus perceives objective reality differently from other individuals. The different position of individuals results in each individual interacting with objective reality in a different way, which alters the individual's perception of objective reality. Secondly, each individual approaches objective reality with a different view to the way that they would wish to engage with objective reality, meaning that they are 'interested' in objective reality in different ways. Considering these two principles an argument could be made that intersubjective knowledge is not possible, which in this study would hinder the production of an R&D model based on intersubjectivity. However, in practice, intersubjectivity can occur, as individuals perform two basic idealisations, which Schutz (1962: 11) refers to as '*the general thesis of reciprocal perspectives*'. Simply, these two idealisations are as Schutz (1962: 11-12) argued, based on if I change place with you, I see the world the way you do (the idealisation of the interchangeability of standpoints). Secondly until evidence is presented to the contrary, we take it for granted that most differences in perspective are irrelevant and we all see the world the same way (the idealisation of the congruency of the system of relevance).

Schutz's proposal is critical for the production of an R&D model based upon semi-structured in-depth interviews, as each manager being interviewed approaches their reality from a different standpoint and is 'interested' in reality in different ways. Using the proposal by Schutz and the assumptions previously detailed allows a 'common world', which arguably transcends individuals' private experiences. Looking at an example by Schutz (1962: 316), it is only through these idealisations, that: '*we both see the "same" flying bird in spite of the difference of our spatial position, sex, age, and the fact that you want to shoot it and I just want to enjoy it*'. It is only by sustaining and sharing these idealisations that knowledge can be established and maintained. As Heritage (1984) argued, a common world is

maintained by the contradictory assumptions of individuals accepting they share a common world, and that at the same time there are perspectival differences between individuals. By continually adjusting their perspectives, individuals can resolve discrepancies in their perspectives, facilitating a shared view. Importantly, as suggested by Schutz (1964), as there is often little quest for absolute certainty in the way that the world is viewed, meaning that a less rigid, softer and more shared view can be maintained, and even if this aspect is questioned, it is often not necessary for anything other than a simple view to be found, which finds synergy with sensemaking (Weick, 1995).

For the construction of a model based on executive and R&D manager interview-based perceptions of R&D, the aspects discussed in this section are pivotal. In the first place, with interintelligibility and shared meaning being possible, the construction of an R&D model can mirror R&D. In the second place, conceptual and methodological elements must facilitate this endeavour through fit-for-purpose interview questions. Utilising a phenomenological approach arguably enabled the researcher to get closer to the phenomenon of interest from respondent perspectives and ‘see’ the world through their eyes. Although many of the interview questions were based in a style to ask ‘what’, ‘how’ and ‘do you’ the discourse utilised by the researcher was more open as is fitting for semi-structured interviews. Thus, follow up questions could be asked to ascertain more information, with a continued awareness on the behalf of the researcher that he was there to guide the interview through questions but at the same time, allow the phenomenon of interest to be discussed with minimal bias from prior preconceptions. An example of this is question 20 from the interview stage, which asked ‘*How do you address different communication styles between management?*’ This question enabled a wide range of answers, which could be followed up by further questions and also acknowledged that individuals with different self-identifications can use different language styles (Boyatzis, 1998). Utilising warranting between managers would thus facilitate shared meaning through interintelligibility.

Summing up this aspect, it is possible to produce an R&D process model from management interviews. The validity and warrantability of such a model will be

discussed later in this study, along with the potential of generalising such a model. As the data collected from respondents was from semi-structured in depth interviews and was language-based within a phenomenological paradigm using explicitation, ‘Language, ‘Reality’ and Modelling’ is explored in the following section to further understand the foundations of these aspects.

#### ***2.4.7. Language, ‘Reality’ and Modelling***

Language as a vehicle of communicating about and describing the social world of R&D management is an important aspect of this study, due to the use of respondent interviews with subsequent explicitation. Research findings constructed from the explicitation process and used to model R&D has necessitated a philosophical understanding of how language can be used to develop a model, which is symbolically representative of the social world of R&D management.

The importance of communication in management is routinely spoken of, with estimates of the amount of management activity being taken up by communication being between 58 – 89 percent (Boden, 1994 [quoted in Bryman and Bell, 2011: 520]). Communication from one individual to another can take multiple forms, such as talking, writing and body language that allow the organisation to carry out business activities such as coordinating and allocating resources etc. Importantly and in this study, it is only verbal utterances, based on talking that are of interest and that have been examined. According to Shotter and Cunliffe (2003), in performing discourse-laden activities, managers become ‘practical authors’ who shape their organisational environments. As Boden (1994: 8) stated: ‘*talk makes the organizational world go round*’, and is ‘*the lifeblood of all organizations.*’ The act of communication has also been argued as allowing ‘institutional facts’ to come into existence (Searle, 2010). While the importance of language within organisations is commonly accepted, there can be a divergence between management theory and practice when it comes to the way language constructs organisational reality. While social scientists may hold the belief that language constitutes reality, management practice can often be embedded within a realist position, in that language functions

to provide labels that can be ‘stuck’, ‘rubber stamped over’ and ‘attached’ to objects without affecting them. An example of this within the sector being researched could be “*It is R&D, because that’s what it IS*”. An attachment of a label in this case could disguise that R&D isn’t being carried out, or that it is ‘R’ and not ‘D’ or vice versa. Simplistically, and from a social science view, the phenomenon is altered or changed, which may result in naive realist positions holding considerable ideological power. This study has approached this aspect by allowing respondents to define their own organisational realities of R&D, while the researcher bracketed his preconceptions. This fits within a phenomenological paradigm, where respondent language was examined to ‘see’ their organisational realities.

Many themes have been discussed in this chapter, which can be broadly split into the areas of ‘The Antiviral Market’, ‘Research and Development’ and ‘Modelling R&D’. A summary of the ‘Literature Review’ is pulled together in the next and final section of this chapter to draw together major research findings from the literature to produce a platform for ‘Chapter 3. Literature Synthesis’ is introduced.

## **2.5. Summary**

Antiviral disinfectant R&D exists in a highly complex and technologically focussed sector, where companies can take advantage of many market and technologically driven opportunities. Technological/scientific complexity and opacity within the R&D stage necessitates companies to engage in sense- and decision-making to further understand R&D challenges. The benefits of management developing an in depth understanding can be increased commercialisation and ROI, while a failure to address these issues can result in reduced R&D outputs and at worst failed commercialisation. Making sense and effective fit-for-purpose decisions by management is critical during the R&D stage, which has received great academic attention in the allied technologies of antiviral therapeutics and vaccines, but only limited attention for antiviral disinfectants. Antiviral therapeutics and vaccines are dissimilar to antiviral disinfectant R&D, due to both antiviral and vaccine-based products being used inside human and animal bodies, and antiviral disinfectants

being made chemically and used on surfaces such as table tops and kitchen floors etc. This impacts greatly on the nature of R&D, as there is a gulf between the technologies for the legislative requirements, which R&D aims to answer before commercialisation. Antiviral disinfectant is also more likely to magnitudes lower in financial investment and in time taken to commercialise a product in comparison to antiviral therapeutics and vaccines. This paucity in knowledge of the antiviral disinfectant R&D stage has led to this study being undertaken, which is exploratory in nature to develop a foundation of knowledge from managers (executive and R&D) from within the UK antiviral disinfectant sector.

Within any technologically orientated R&D company is a requirement for key stakeholders and managers to understand relevant aspects of R&D, particularly managers involved in R&D decision-making. While it is not expected for all managers to understand R&D equally, knowledge should be able to be shared meaningfully enabling effective and fit-for-purpose decision-making within a company's aims for R&D. One of the ways suggested for dealing with R&D complexity is through the development of R&D models, which symbolically represent the R&D stage and facilitate shared meaning, communication and decision-making. While modelling R&D is not without challenge, as many different models can be produced, they can be an informative way for management to make decisions, particularly in areas where they might not fully understand the scientific or management requirements of the stage. Previous models have not addressed antiviral disinfectants, but models such as the Stage Gate and Technological Model were perceived as potentially relevant in their overall structure to a model for antiviral disinfectants. The differences in the sectors coupled with an attempt to draw closer to the phenomenon of antiviral disinfectants via phenomenology necessitated this study to more fully understand what R&D processes are involved with this sector, and how different managers (R&D and executive) perceived R&D. This approach (although embedded within the literature) sought to be able to take 'nothing for granted' and thus construct a management model based on the perceptions of management, and more importantly warranted by management. Drawing on these aspects, the following chapter 'Literature Synthesis' has engaged with some of these aspects more fully to create a foundation for interview questions.



## **Chapter 3. Literature Synthesis**

### **3.1. Introduction**

The preceding chapter reviewed the literature regarding the significance of the scientific and management aspects of antiviral disinfectant R&D. This was alongside understanding how modelling processes in complex technological environments can aid in management communication, sense- and decision-making. In this chapter, these aspects have been synthesised to assist in refining the research question, aim and objectives, which is considered in the following section the ‘Research Gap in Antiviral Disinfectant R&D Management’.

### **3.2. Research Gap in Antiviral Disinfectant R&D Management**

Extensive research into R&D management has been carried out in numerous sectors over the past decades (Nobelius, 2004), with the management focus towards antivirals being through the allied technologies of *in vivo* antivirals and vaccines (Jurovcik and Holy, 1976; Fraise, 1999; Griffith, 2008; Cargill *et al*, 2011). Limited attention has been paid however to antiviral disinfectants and corresponding R&D, with research gaps being considered in this section, a rationale for research undertaken, as well as research implications from this study detailed.

The driving force for companies to carry out R&D is to produce new market ready products, which can be used to establish, maintain and/or expand their market share (Nobelius, 2004). This is in line with Verma, Mishra and Sinha, (2010) who argued that companies seek to achieve and maintain an advantage over their competitors through R&D. Technology companies often have a more intense focus on R&D to produce new products, in comparison to non-technology companies (Marcus and Segal, 1989; Dugal and Schroeder, 1995; Jobs, 1998; Schroeder and Purinton, 1998), as they seek to generate a financial return based on their knowledge and physical capabilities. These aspects can increase the pressure to produce successful products out of the R&D stage that are market ready (Haverila, 2013). Simplistically, R&D

can be considered successful if the product leaving the R&D stage ends up being sold in the market (Di Masi *et al*, 2003). There are many areas to be understood with the main aspects being, how is R&D carried out? And how is communication used to facilitate sense- and decision-making between managers? More than this though, where is prior research drawn on and where is the literature expanded? These elements are discussed in this section.

In practice, there has been a propensity for management to focus on reducing the time taken for the R&D cycle (Adler *et al*, 1995), which as argued by both Stalk and Webber (1993) and Gerwin and Barrowman (2002) focuses company resources on one R&D aspect, and negates many other important strategic considerations. For *in vivo* antivirals and vaccine orientated R&D, reducing the time taken to complete the R&D stage is not surprising due to the number of years taken to get through multiple clinical phases (Cassimon *et al*, 2011). However, regulatory requirements for antiviral disinfectants are much lower than in *in vivo* antivirals and vaccines, meaning that the R&D cycle is substantially shorter and lower in cost. Thus while potentially attractive for managers in antiviral disinfectant companies, reducing the R&D cycle is not as important as in allied technologies. Within antiviral disinfectant R&D are many other competing factors that need to be examined for successful management of R&D, where fit-for-purpose products are eventually sold. Thus it is important to draw out the process stages of R&D to highlight the areas that different managers engage with, and that might result in reduced sensemaking and difficulties in decision-making.

Before undertaking this study, it was not known to what extent R&D might vary from company to company within the antiviral disinfectant sector. While a micro-level examination of the science being carried out was not required (for example  $x$  grams of salt is added to  $y$  grams of acid), the business aspects of the physical processes were required, which can be considered as an overarching macro view. This element was explored in the interview stage to not only understand what goes on in the R&D stage but the management concepts of R&D *i.e.* what are your R&D stages? Understanding the business processes would enabled a greater understanding of the interpretations of R&D, and perceived necessity of each stage. Central to the

R&D stage is the product being developed, which is known to influence the R&D stage, and as Lager, Blanco and Frishammar (2013) stated, can be asset intensive, sector specific and strongly integrated in one or a few physical locations. This fundamental question of the nature of the product was explored in the interview stage to inform this study about demarcation points of antiviral disinfectants being made and relation to other technological products. In other words, what is the difference between the antiviral disinfectants and other products? It was not assumed that simple answers would be forthcoming to such questions, which necessitated a semi-structured interview approach within a phenomenological paradigm. Thus, a subjectivist stance was taken to 'see' the world through respondents' eyes to more fully engage with the phenomenon of antiviral disinfectant R&D.

R&D projects can suffer due to the scientific opacity in the eyes of executive R&D managers, who may not have the in depth scientific knowledge that R&D managers have at their disposal. Opacity can occur as a consequence of difficulties in predicting R&D outputs, particularly for what the output will be, and when it will occur (Anderson and Tushman, 1990). This can be coupled with the types of information communicated between executive and R&D management being unclear, with poor sense communicated. Where information from R&D management is not clear, it can be difficult for executive management to accept or refute R&D claims (Stein, 2003), complicating decision-making. Likewise poor sense given to R&D managers from executive managers can lead to confusion about company requirements from the R&D stage. Another way of looking at this is that both manager types are likely to have culturally relevant interpretive repertoires at their disposal to enable them to construct and share meaning. However, prior to the interview stage, it was apparent that both respondent types (R&D manager and executive manager) might use different repertoires and terminology, for the same processes, which in turn could result in confusion. This was therefore considered in the interview stage via the language used by both managers, which expanded the literature for language repertoires used at the R&D isthmus between executive and R&D managers.

The issue of sense- and decision-making and language used can be particularly pronounced for managers in technology companies, as they often exist in complex, opaque and uncertain environments. As Nobelius (2004) argued, a company's ability to understand its own R&D stage is pivotal, as with a greater understanding of R&D comes an ability to manipulate the R&D stage, thus allowing a greater opportunity to reap financial benefit. Being able to communicate effectively and create shared meaning between managers is therefore a way to achieve greater R&D rewards (Weick, 1995; Clark, Abela and Ambler, 2006; Pauwels *et al*, 2009). Although, R&D has numerous challenges for companies undertaking it, successful R&D has the potential to create '*greater market share, premium prices and dominant designs, leading to a much sharper competitive edge*' (Nobelius, 2004: 369).

A popular vehicle for understanding R&D is the use of models to mirror the R&D process stage, which can simplify complex technological aspects of R&D (Cooper, 1983; Adler *et al*, 1995; Bednyagin and Gnansounou, 2012; Popp *et al*, 2013). The development of R&D models is influenced by multiple social factors that exist at the time of R&D model construction, with these factors being more or less relevant at different points in time. Research has been carried out to examine the construction of R&D models (Kahn, 2004; Canongia, 2007; Kotler and Armstrong, 2010; Cooper and Edgett, 2013), which has highlighted three areas that are often addressed by R&D models and include, (1) strategic, (2) operational, and (3) methodological (Nobelius, 2004). There has been a propensity for modelling to focus on the physical processes carried out by the business and understanding how processes impact upon the business (Bednyagin and Gnansounou, 2012), but with less attention being paid to how models can be used to communicate shared meaning between different management groups based on the constructed model, which this study is considering. This was directly explored by enabling managers to warrant constructed models to increase the shared meaning derived from the model.

Constructing a model is no small task though and Bendoly and Speier (2008: 169) raised the question of what information should be included? And how should it be represented? The interview stage enabled these aspects to be explored and rationales provided by both respondent types, based on their use of language and backgrounds

(education and work). Examining both R&D manager and executive manager perspectives, sought congruence with the ‘reality’ of the purpose, tasks and decisions made about R&D (Browning, 2010). Practically, the production of a model requires management time to construct the model, as well as to operationalise and validate/warrant it, necessitating some management benefit for committing this resource. More than this though, companies involved in this sector and study trialled this model after it was constructed. Within all of these aspects was the issue of whether to produce an overly large and complex model (with multiple expanded views for executive and R&D managers), which could result in information overload and render the model practically unusable. At the other end of the spectrum would be the production of a model so simple that it would arguably miss the phenomenon of interest, and might allow management to believe that information has been received and acted upon in a way that is desirable to management, when it has not been (Farhoomand and Drury, 2002). For projects where the size and complexity of R&D increases, and models mirror this by having their size and complexity increased, management can become less able to critically engage with the model, which can produce poor decision-making (Bendoly and Speier, 2008). This study thus took the approach of raising this aspect with the respondents, particularly during the model warranting stage, to enable them to make changes to the model that would aid them in using it. Through interviewing both executive and R&D managers it was perceived as being able to address specific manager needs.

Beyond what information to include in a model, is the decision that needs to be made about how to visually represent the model, as ideally the model will facilitate understanding, reduce complexity or ‘complicatedness’ and increase shared meaning (Tang and Salminen, 2001). If using an R&D model, managers have a choice of using existing and potentially ‘popular’ models such as the ‘consumer’/‘marketing’ model (Cooper and Edgett, 2013; Kotler and Armstrong, 2010) with numerous variants e.g. the ‘time to market’ model (Kahn, 2004) or the ‘technological’ model (Canongia, 2007). It was not known until the interview stage, whether manager perceptions of R&D would be embedded within a technology push or market pull view, which might have altered the production of an R&D model. This study was however encompassing enough to take this challenge into account and although

questions were not put to respondents using the terms ‘technology push’ or ‘marketing pull’ they were considered.

Examining academic literature, antiviral modelling at the R&D stage has predominantly been within a scientific paradigm, focussing on the scientific mechanisms of antiviral activity (Ding and Wu, 1999; Takayanagi, 2013; Basta *et al*, 2014). The modelling of scientific interactions is important for management and particularly R&D managers but is only part of the R&D phenomenon, as the management aspects of the process stages must also be integrated. The construction of a model to integrate executive and R&D manager perspective was examined as a vehicle for creating shared meaning between different managers who have different views of the reality of R&D and who potentially use different language repertoires to communicate about R&D. This study sought to rectify these shortfalls of knowledge by the production of a management ‘ready’ process model.

The gap in existing knowledge for antiviral disinfectant process R&D management has been clearly established in this study. R&D management is a complex area, existing within a potentially opaque, uncertain and risk-laden environment. This has resulted in this study being exploratory and within the phenomenological paradigm, to dig deep into the phenomenon of antiviral disinfectant process R&D and management. The qualitative approach used, provided an insight into how different managers in R&D companies (executive and R&D) perceived R&D, communicated and made decisions about it. The process of explicitation aided in examining the communicated subjective inner worlds of executive and R&D management and facilitated the production of an R&D process model.

The information drawn out in this section, enabled the construction of a research question, research aim and research objectives, which are detailed in the following sections.

### **3.3. Research Question**

Examination of the literature has led to the following research question:

How do UK based SMEs carry out process R&D for antiviral disinfectants? From this we are able to derive a research aim:

### **3.4. Research Aim**

To examine current theory and practice in order to produce a model for process R&D used by UK SMEs producing antiviral disinfectants. From this we can produce a number of research objective(s):

### **3.5. Research Objectives**

In this study, there are three research objectives, with each objective building on previous objectives:

- a) Through a literature review and current practice, to determine the current scientific and business processes for UK SMEs engaged in antiviral disinfectant process R&D;
- b) Informed by a) above to produce an initial alpha model for UK SMEs engaged in antiviral disinfectant process R&D;
- c) Informed by a) and b) above, to verify/warrant the initial alpha model and so produce a beta R&D model.

## **Chapter 4. Research Methodology**

### **4.1. Introduction**

The preceding chapters have detailed the antiviral disinfectant process R&D in UK SMEs, and have shown a defined gap in academic and practitioner understanding of this area. The gap identified has shown a paucity of information regarding how different managers communicate about the complexity of the R&D process stage not only in antiviral disinfectant R&D, but also for technology products in general. The challenge for managers engaged in technology and biologically based R&D is how to communicate in an effective way that gives the intended sense to the recipient that enables ‘fit-for-purpose’ decision-making. While it has been acknowledged that R&D models can facilitate R&D sense- and decision-making, little research has been carried out into models that construct shared meaning between different managers with backgrounds in science and business, where language used may be culturally different. Thus as an exploratory study, a phenomenological paradigm to ‘see’ the world through respondent eyes was chosen that could create new knowledge, and link the use of ‘business’ and ‘science’ speak into one R&D process model that could be used by both manager types. By utilising this approach, and enabling the managers involved in this study (70 percent of the industry), ‘ownership’ of the constructed model could be taken by the managers involved as they move towards becoming practical authors of their respective R&D environments. This chapter therefore outlines the methodology utilised in this study to fill this gap, as well as addressing the research question, aims and objectives.

The practical elements of this study were carried out in two stages, with the first being a pilot study using exploratory interviews with three executive and three R&D managers. With there being ten UK based antiviral R&D SMEs, and with each SME having one R&D and one executive manager, the pilot studies captured 30 percent of each type of manager, to understand and refine questions for the main study. The second stage used semi-structured in-depth interviews and was with single executive and R&D managers from seven SMEs. Explication was used to examine transcribed interviews and produce an alpha model of antiviral disinfectant process



R&D. Verification/warranting was ‘achieved’ through further interviews with R&D managers to seek feedback on the alpha model, and where appropriate, modify the model, to produce a beta model, which subjectively reflected manager views of the R&D stage. To gain access to respondents, the letter shown in Appendix A was sent to prospective companies, detailing the nature of this study.

The next section explores ‘The Phenomenological Paradigm’, to construct an understanding of phenomenology within this study.

#### **4.2. The Phenomenological Paradigm**

There are two main research paradigms or philosophies that can be used to examine objective and subjective phenomena, and include positivism and phenomenology (Bryman and Bell, 2011). The choice of research paradigm is based on whether it is believed that social research can be carried out using the principles, procedures and the ethos found in the natural sciences (Bryman and Bell, 2011). Positivism (an ‘objectivism’ ontological stance) is a research paradigm that functions more within the natural sciences framework, where objectivity is preferred over subjectivity. In phenomenology (a ‘constructionism’ ontological stance) *‘the phenomenologist attempts to see things from that person’s point of view’* (Bogdan and Taylor, 1975: 13-14), which is more subjective than objective. Phenomenology can be considered a more holistic approach that can address aspects of ‘how’ and ‘why’, as well as potentially providing understanding in inherently complex phenomena. The use of a phenomenological paradigm was considered particularly relevant due to the issues of language discussed in section 2.4.7. Through the adoption of a phenomenological paradigm, it was expected that a high-level description and understanding of the phenomenon would be achieved (Kvale, 1996). The vehicle for drawing out an understanding of the phenomenon of antiviral disinfectant R&D was through semi-structured in depth interviews with managers from within the antiviral sector. Respondent views were used as the foundation to build alpha and beta models of the phenomenon. This research approach was therefore classed as ‘interpretative’ within the phenomenological paradigm.

There are two approaches to carrying out research, which are synonymous with positivist and phenomenological research philosophies, and include deductive and inductive research (Bryman and Bell, 2011: 11). The inductive approach focuses on studying the system or phenomenon of interest to the study and subsequently tries to produce a model (in this case) or results based on research findings, which is where this study is based. This is in contrast to the deductive approach, where existing theory is examined first and research findings are tested against accepted theory. The inductive approach was favoured, as this study is exploratory, and although R&D models have been constructed in other technology areas, it was not known how well the model produced from this study would replicate prior models.

In producing a model, ontological and epistemological stances have been considered, in light of how reality is viewed, as an argument could be made that the production of a model is creating or representing 'one reality' and is thus more embedded within positivist than phenomenological research. A positivist typically adopts the ontology of one reality, in comparison to a phenomenologist who adopts an ontological stance of multiple views of reality (Bryman and Bell, 2011: 11). In this study, the researcher has examined the subjective views of respondents, and subjectively interpreted these views of executive and R&D managers engaged in antiviral disinfectant R&D. This has presented multiple views of the reality of R&D based on the respondents interviewed. The model produced in this study, is not being claimed as a 'definitive' view of antiviral disinfectant R&D, but shows expanded views, which is arguably suited to the phenomenological study of multiple views of reality.

The epistemology of how research was captured was also considered. Typically, within positivist-based studies, an objective approach is used to limit the influence and interaction of the researcher on the subjects being studied. In this way, the positivist can often make the claim that their research has a greater closeness to objective reality. Phenomenologists however, reject the notion of their research being objective, embracing subjectivity and embedding themselves within their research methods (Bryman and Bell, 2011). Within this study, this meant that the researcher actively engaged with respondents throughout the interview process, as the researcher believed this had the potential to allow a more thorough exploration of

the phenomenon of interest, which was the ‘why’ of decision-making for R&D processes. The researcher being embedded within the antiviral disinfectant community thus took a combined emic and etic approach, utilising inner knowledge from working in the sector, but also contextualising this knowledge methodologically through the explicitation process. Case studies were used for the research strategy in this study, which is detailed more fully in the following section.

### 4.3. Research Strategy: Case Studies

Within social science research, there are several research strategies that enable phenomenon relevant information to be drawn out. These methods can be drawn on from both positivist and phenomenological research philosophies and include case studies, experiments, surveys and histories etc. Each research strategy has its own philosophy, routes to collect information, and examine data, as well as perceived advantages and disadvantages. With multiple methods available, it is important to consider why any method is preferable. According to Yin (2009), there are three conditions, which can be used to determine when to use a research strategy in social science. These conditions include (1) the form of the research question, (2) the amount of control the researcher has over behaviour events and (3) the level of focus on contemporary events. Table 4.1 shows the relationship between these three conditions and the different research strategy commonly used in business research.

**Table 4.1. The Relationship Between Research Methods, and when to Use them**

Strategy	(1) Form of research question	(2) Requires control of behaviour events	(3) Focuses on contemporary events
Experiment	How, why?	Yes	Yes
Survey	Who, what, where, how many, how much?	No	Yes
Archival analysis	Who, what, where, how many, how much?	No	Yes/no
History	How, why?	No	No
Case study	How, why?	No	Yes

*Source: Yin (2009: 8).*

To determine which strategy to use, Table 4.1 was examined with the three conditions and the areas of interest to this study. Taking condition (1) first, the ‘form of research question’, Yin (2009) stated that the case study method should be used primarily when there are ‘how’, ‘why’ or ‘what questions’, which fits with the research question of this research, which is: ‘*how do UK based SMEs carry out process R&D for antiviral disinfectants?*’ This aspect is particularly pertinent when the research question is exploratory, which it is in this study. As the researcher felt that he would have limited control over behavioural events (the second condition), the case study method was perceived as suitable. The overall design of this study, therefore, was based on an empirical approach using an embedded (multiple units of analysis) multiple case study design. Thiti (2010) suggested that this approach allows for contingencies (potentially from multiple cases) to be taken into account and for a range of factors to emerge as potentially relevant to the investigation, all of which may not be apparent from previous knowledge or research. Finally, as this study focussed on contemporary events and is exploratory, it is also in agreement with the case study method.

Case studies (an interpretivist methodological approach for developing theory) can be defined in many ways (Benbasat *et al*, 1987; Bonoma, 1985; Eisenhardt, 1989; Yin, 1994), with Meredith (1998: 443) using the following definition: ‘*A case study typically uses multiple methods and tools for data collection from a number of entities by a direct observer(s) in a single, natural setting that considers temporal and contextual aspects of the contemporary phenomenon under study, but without experimental controls of manipulations*’.

An important consideration for case study research is that any understanding developed by the research can only be considered knowledge, within the researcher’s perceptual framework. This distinguishes case study research from rationalist research, as understanding developed through case study research is not objectively ‘out there’, rather it is meaningful only within the constructs of assumptions, beliefs, perspectives, histories and language utilised by the researcher. Bonoma (1985: 203) argued that the goal of case studies was to understand as fully as possible the phenomenon being examined, through ‘perceptual triangulation’, where ‘*the accumulation of multiple entities as supporting sources of evidence [can be used] to*

*assure that the [institutional] facts being collected are indeed correct* (Meredith, 1998: 442).

Within case study research is the potential to use single or multiple cases to explore the phenomenon of interest (Yin, 1994). A single case may be relevant where one very large organisation can provide a high level of detail about the phenomenon being examined, with many possible sampling and an array of possible behaviours, such as the National Health Service. The antiviral disinfectant sector is not like the NHS, being made up of very few companies which are small, entrepreneurial and where few managers ('experts') have the 'knowledge' (Weiss (1994). A multiple case study approach was thus selected, with seven companies being examined in this study. Although seven companies may appear to be a low number, Payne and Cuff (1982) have argued that it is possible to generalise from a limited number of case studies, which was demonstrated by Fain, Kline and Duhovnik (2011) who used only two case studies as part of their study on the R&D/marketing interface. Importantly, the seven companies examined in this study, represent seventy percent of the industry in the UK.

Looking at the advantages, of case study research, Benbasat *et al* (1987) argued that there are three 'outstanding strengths' of this approach. The first is that the case study allows the phenomenon to be studied in its natural environment if required, and that relevant theory can be generated from interacting with and observing actors of interest in such environments. Secondly, the case study allows the more meaningful question of 'why' to be asked, rather than just 'what' and 'how' and be contextualised against the backdrop of the phenomenon being examined. Thirdly and most inline with this study, is that the case study is 'ideal' for early, exploratory based investigations, where the variables are not as yet well understood. An example of prior research that has demonstrated all three of the previously mentioned research strengths of case studies is that of Gerwin (1981). Other academic studies by Eisenhardt (1989), McCutcheon and Meredith (1993) and Yin (1994) have argued the advantages of case study research for producing in-depth explanations and understanding.

Criticisms have been raised against case study research, with the first being that of resource *i.e.* cost, time and ability of the researcher to access the phenomenon of interest. This can be coupled with *'the need for multiple methods, tools, and entities for triangulation; the lack of controls; and the complications of context and temporal dynamics'* (Meredith, 1998: 444). Academically, the case study method is less well known in comparison to rationalist based research, particularly in the areas of methodological procedures and how rigour is achieved. It has been argued that case study research may lack academic rigour (Larbi, 1998) due to difficulties in generalisation from small sample sizes. This criticism has been targeted not only against case study research, but often to numerous qualitative methods as well, which have been perceived as having tendencies for error, poor validation, and questionable validity. These issues can be linked to positivist researcher perceptions of qualitative and case study research. Numerous research papers and editorials have argued that there has been a relative lack of case study research in management studies (Wood and Britney, 1989; McCutcheon and Meredith, 1993; Meredith, 1998; Ebert, 1989). Meredith (1998: 441) argued that: *'This form of empirical research continues to be poorly understood and infrequently published in top journals. In part, this may be due to unfamiliarity with nature of theory building using case and field methods.'* However, when assessing the case study method and aspects such as rigour and sample size, it is important not to judge the case study method against more rationalist orientated research, where one is more 'rigorous' than the other. Although criticism can be made that there is a small sample size being utilised in this study, 70 percent of the sample was captured and linguistically 'triangulated' throughout the groups (all executive managers compared, and all R&D managers compared), alongside between groups (executive managers versus R&D managers). More fundamentally, and through a phenomenological case study approach, 'seeing' the views of the respondents was a key aspect, which was embedded within subjectivism.

Looking at more 'traditional' positivist approaches using optimisation, simulation and statistical modelling are still more favoured for building new management theories, and is potentially linked with a perception of the conclusions being drawn about phenomena are objectively 'out there' independent of the researcher (Klein

and Lyytinen, 1985; Guba, 1990). While these methods are valuable for developing management theories, they can be less beneficial for exploratory research, as is the case with this study. The next section makes a greater examination of research based theory development, with a particular focus on interpretive case studies.

In some ways though, theory development based on research findings can be argued to transcend the philosophical divide of positivism and phenomenology. Whetten (1989: 491) argued that: *‘during the theory-development process, logic replaces data as the basis for evaluation...This requires explaining the whys underlying the reconstituted whats and hows’*. In developing or extending theory, it is therefore important to gain an understanding of the ‘why’ of the phenomenon (Gerwin, 1981). Developing an understanding of ‘why’ is not without challenge, with Richardt and Cook (1979: 17) arguing that positivist methods are most appropriate for testing or verifying existing theory, whereas interpretive exploratory methods such as case studies are better used for generating or extending theory.

Arguably one of the most critical elements of case study research is the challenge of deciding upon and defining the area, parameters and population that will make up the case(s) to examine the phenomenon of interest. It is imperative that the case(s) selected closely mirror the phenomenon, which in this study are R&D companies engaged in antiviral disinfectant process R&D. Whereas in positivist methodologies, variables can be controlled, this is not possible in interpretive case studies, necessitating the selection of a sample frame of case studies that will provide insights into the phenomenon of interest. The following section, therefore examines the sample frame for this study, as well as theoretical aspects that informed the researcher about his choices of management respondents to interview.

#### 4.4. Sampling Frame

The sampling frame is the collection of entities that are examined in a research study to draw out information, close to and representative of the phenomenon of interest. In this study, the sampling frame chosen can be considered, pragmatic, non-probability based, and purposeful, where the researcher selected information rich cases (Patton 1990, cited in Wengraf (2004)) to closely represent the antiviral disinfectant R&D sector. It has been argued that this method of choosing the sample is biased but draws on Morse (1994: 220) who argued that qualitative research could be a biased activity, as well as rationalist studies. The choice of sample frame to discern ‘*different “types” of behaviour and distinguish the “typical” from the “atypical.”*’ (Mays and Pope, 1995: 110) is now explored. Where sampling is used to provide this information in qualitative and case study research, a choice must be made for whether to use probability or non-probability samples for interviewing respondents. A probability sample is selected at random to try to capture the population of interest, with a general perception that such samples can be more representative of populations where this technique is employed. A non-probability sample is not selected at random, and is utilised where some parts of a population are more desired than others for examination (Bryman and Bell, 2011).

The choice of sampling type can be based on numerous factors such as funds, time, and availability of interviewees, but with a critical consideration being the data that can be drawn out from any type of sampling. Due to the low number of R&D managers (‘experts’) in the antiviral disinfectant sector, it was not deemed wise to use probability-based sampling. Mays and Pope (1995) argued that using probability-based sampling (particularly with the use of statistical methods) is not the most appropriate methodology where the study is trying to elucidate and understand social processes. The use of non-probabilistic sampling does not intend to capture a population, but only the individuals who are of perceived interest to the researcher (Mays and Pope, 1995). Case study based sampling is also not necessarily aimed at trying to represent samples from a population, and can go ‘hand-in-hand’ with non-probabilistic sampling to examine specific phenomena (Meredith, 1988).



The sample should be representative of the phenomenon of interest, which in this study is the UK-based antiviral disinfectant R&D sector. This necessitated respondents to be selected from managerial positions from companies within this sector. Specifically, executive and R&D managers were chosen for interview, as they are both directly involved in antiviral disinfectant management. Only the UK was examined due to the researcher's sensitised perception from working within this sector that legal governance specific to individual countries, such as the UK, can influence R&D. An extension of this study outside of the UK may provide difficulties in comparing like for like for results produced, or may expand the model view constructed.

In language and explicitation studies, the nature of the sample being examined is just as important as in other methodologies including those based on rationalist thinking. Potter and Wetherell (1987) argued, that for discourse-based studies, it is the language being used that is of interest, as opposed to focussing too heavily on the language users. This is not to negate the importance away from the language users (as they can be considered the vehicle for attaining the language of interest) but rather to say that it is important to identify language users who can provide the language relevant to the phenomenon of interest. Wood and Kroger (2000: 79) suggested: *'Selection is thus provisional, but it is not haphazard, as long as it permits the inclusion of discourses that are relevant to the phenomenon of interest. The important point is to avoid unwarranted assumptions about the persons who generate the discourse'*. In case study and explicitation-based studies, it is always possible to increase or modify the sample size, if perceived necessary. The next section, examines the choice of sample size and philosophical aspects behind the choice made for this study.

#### 4.4.1. Sample Size

It is often questioned for case study research, what size sample should be used? Addressing this issue, Hycner (1999), suggested that sample size could be used to aid in determining methodological factors. In this study, a multiple case approach with interviews was used, which in turn was used to select the sample size. As Kvale (1996: 101) argued: *‘to the common question, “How many interview subjects do I need?” the answer is simply, “Interview as many subjects as necessary to find out what you need to know.’* While conceptually helpful, this does not answer the question about what size sample should be used. There are of course numerous suggestions on how many interviews to carry out, with the on-going debate being captured by Baker and Edwards (2012), where a number of between six and twelve interviews with elites (‘experts’) was considered ‘enough’. Looking at phenomenology-based studies, Creswell (1998) suggested between five to twenty interviews, Morse (1994) at least six, and Boyd (2001) between two and ten. In this study, one interview per company was carried out with an executive and R&D manager, with a total of seven companies participating, meaning a total of fourteen managers were interviewed. The companies examined in this study are generally small, with the executive management and R&D manager often being perceived as having the ‘knowledge’, with the rest of the organisational members being perceived as being less suitable as experts.

As well as the references cited above, the justification for the seemingly ‘small’ number lies in the argument of ‘quality not quantity’ *i.e.* to achieve ‘saturation’ enabling a thorough examination of the phenomenon. Practically, Glaser and Strauss (1967) argued that sampling could be carried out in qualitative research until the collection of new data revealed no new insights. In addition, Mason (2010) examined five hundred and sixty PhD’s over the last few decades, and found that there were nineteen studies that used phenomenological case studies, which is the same as this study, and they all used seven participants. Looking more specifically, at examples of product development processes, the prior studies of Adler, Mandelbaum, Nguyen and Schwerer (1996) interviewed twelve manager’s to develop their article on getting the most out of the product development process, which is not far from the

number used in this study. It was accepted by the researcher that should the study warrant it and information become available about other potential respondents, snowballing could be carried out to increase the sample size.

With this study using interviews with explicitation, it has to be recognised that these methods are relatively time-consuming activities, which limits the sample size for practical reasons. However as explicitation studies focus on language as well as language users, the main concern is the nature of sample producing material to go through the process of explicitation, rather than focussing heavily on sample numbers. This is not to negate the importance of sample size, as there have been criticisms that small sample sizes in comparison to other types of studies, can limit generalisability of findings produced (Wood and Kroger, 2000). It must be noted though that in this study, the unit of analysis is not the respondent as in survey work, but the individual and distinct utterances being explicated in terms of distinct meanings. This issue is explored more thoroughly in the section '4.7.4. Generalisability'. Moving beyond the sample size is the 'Interview Stage' in the following section, which directly examines the 'Pilot Study', the 'Main Study' and 'Verifying/Warranting the Model'.

#### **4.5. Interview Stage**

To understand the R&D process stage, necessitated interviewing respondents, who are actively involved in managing the business and scientific aspects of this process R&D. The individuals interviewed were regarded as 'experts', who are *'persons who have a high degree of skill and knowledge in a certain domain, field or industry due to long-time experience and have status, power-to-act and decision-making opportunities based on these skills and knowledge.'* (Belting 2008). According to Weiss (1994) and Belting (2008) the 'expert' interview is a specific form of semi-structured interview which focuses on expertise in a certain field of activity with the intent of reconstructing the knowledge of experts interviewed (Robson, 2002). Interviews are well known for being able to provide a deep and rich understanding of complex phenomena, and can be useful for providing multiple subject views

(Gubrium and Holsetin, 2002). They are also useful where the study is exploratory (King, 1994).

Before the interviews were carried out, a series of questions was developed for the (1) the pilot study and (2) the main study, (based on the sensitisation of the researcher to the literature and practical experience within the sector), which were taken into the interviews. These questions addressed numerous aspects of the process R&D stage and are detailed in section '4.5.1 Pilot Study' and '4.5.2. Main Study'. Using semi-structured interviews enabled a clear focus for discussions but also allowed respondent flexibility. The interview sheet formed the basis of all interviews in the main study, which enabled a comparison between interviews. Although each question was explored in each interview, flexibility was allowed during the interviews to allow questions to be asked in different orders if perceived as pertinent. As Bryman and Bell (2007) argued, this method allows fuller explanations to be sought by the researcher, when required. In the next section, the 'Pilot Study' is discussed with the methods of this activity being explained.

#### ***4.5.1. Pilot Study***

Before the main study was carried out, exploratory interviews were used to define the questions to ask in the main study and to potentially add new areas of investigation *i.e.* a 'pilot study'. As stated by Sehdev (1996) and Sehdev, Parker and Reddish (1997), exploratory interviews can be used as pilot studies to further define an area of interest, which is particularly helpful in areas that are potentially perceived as under researched. The areas and questions explored throughout the pilot study are detailed in Section 5.2 (page 104) in Table 5.1.

A pilot study using semi-structured interviews was carried out with three executive and three R&D managers ('experts') from three R&D companies (one R&D and one executive manager from each company). An 'expert' is an individual with a perceived high-level of knowledge about the phenomenon of interest. Three companies were examined as they represent 30 percent of SMEs involved in the

antiviral sector in the UK. The pilot study was used to inform the topic areas and questions asked in the semi-structured interviews carried out on the main study. Although ‘snowballing’ was a potential method to increase the sample size and ‘further’ inform the researcher (Bryman and Bell, 2011), this was not carried out, as (1) no further respondents were suggested, and (2) the researcher felt that the responses had been saturated, within the aims of the pilot study.

The pilot study was also used to understand aspects of the ‘experts’ being interviewed, such as whether they would perceive themselves informed ‘enough’ to discuss and describe their company’s R&D processes. This decision to interview individual interviewees was based on the belief that *‘individuality is reduced when the individual participates in a group’* (Lipnan, 1959: 126) and more ‘open’ responses could be attained by interviewing individuals as opposed to groups. In part the difficulty of interviewing an individual to understand organisational processes is based on it being that individual’s view of the organisation. However, according to Lipnan (1959: 126): *‘...interpretations of individuality vacillate between the notion that an individual is an elementary unit of some larger complex and the notion that an individual is a single composite organization of parts’*. The extent of decision-making for process R&D was more fully explored, with other aspects within the ‘Main Study’, which is considered in the following section.

#### **4.5.2. Main Study**

The main study consisted of interviewing fourteen managers (seven executive and seven R&D managers) ‘experts’ from antiviral disinfectant R&D companies, to allow the collection of primary cross sectional data. The interviews directly posed the research question amongst others, with the questions being defined by the sensitisation of the researcher to the literature and the ‘pilot study’. In-depth semi-structured interviews were carried out with all interviewees in a private room at the R&D companies. Open and expansive questions were used to allow the interviewees to explore the topic being discussed (Smith *et al*, 2009). As Benney and Hughes (1970: 176) stated, interviewing is the ‘favoured digging tool’ of social scientists.

From examination of academic and business literature, which was used as the basis of this proposal, the following a series of topics being pulled together to investigate with interviewees through semi-structured interviews. These topics were used to guide the conversation between interviewer and interviewee, with the areas and questions explored throughout the main study being detailed in Section 6.1 (page 113-114) in Table 6.1.

Through the use of semi-structured in depth interviews: *'the interviewer leads the subject to certain themes, but not to certain opinions about these themes'* (Kvale, 1996: 34). The questions asked were used to act as a flexible interview guide (Warren, 2002). Following the work and suggestion of Rapley (2004), the researcher of this study attempted to genuinely engage with the interviewees rather than asking a large number of tightly bound questions. No more than three, two-hour interviews were carried out per day, as recommended by King (2004). Once the data was collected, 'The Process of Explicitation' was used to examine the recorded information, as detailed in the following section. The author perceived that enough material was gathered in the interviews to permit saturation and proceed to the explicitation stage (and this was reconfirmed during the process of explicitation).

#### **4.6. The Process of Explicitation**

Meaning was made clear by carrying out the following processes of: (1) collecting and recording respondent interviews (pilot and main study), (2) transcribing the interviews, and (3) subjecting the transcribed interviews to a form of content analysis, which in this case was explicitation (Hycner, 1999). Through the use of explicitation it is possible to explore the difference between linguistic meanings, for instance (1) conventional and semantic meanings, and (2) for an individual, the pragmatic meaning. Pragmatic meanings are invaluable for understanding the subjective world of an individual, but drawing out their meanings from an individual is not without challenge. While the speaker making the communication may understand their meaning, the researcher may interpret other non-intended meanings. Subjectively, and for a researcher aspiring to make discourse clearer, it could be

argued that explicitness leading to research meaning is not without ‘wobble room’ for any meaning produced. Schiffrin (1994: 199) stated that explicitness is concerned with: *‘presentation of information that actually enables [the researcher] to correctly identify a referent, i.e. the lexical clues that allow [the researcher] to single out whom (or what) [the researcher] intends to differentiate from other potential referents’*. Schiffrin (1994), stated further that explicitation can be argued as being relative to the researcher and their background. In other words, whatever conclusion one researcher arrives at, there is no guarantee that another would reach the same conclusion. Perhaps a different way of looking at this is that the explicated meaning will be influenced by the researcher’s cognitive store of information regarding the phenomena. This aspect was reinforced by Vinay and Darbelnet (1995: 185) who stated that explicitation requires a: *‘solid background of knowledge which ultimately depends on the [researcher’s] general education, breadth of knowledge, philosophical outlook, etc’*. The researcher of this study believes that his background of working in antiviral disinfectant R&D had the potential of inducing a dyadic closeness during the interview stage via language, and allowing a fuller examination of the phenomenon to aid in the process of explicitation of the phenomenon. While an emic approach may be beneficial for cultural awareness that may allow rich data to be discovered, an etic approach was also utilised to ground research findings within prior literature and minimise bias. It could be argued that a phenomenological explicitation study should consider researcher bias, and while this is necessary, the foundations of bias within this type of study must be considered. This study is embedded within a subjectivist approach towards ‘seeing’ the R&D reality from respondent views and as such may well be considered biased. The phenomenological paradigm directly challenges positivist claims of researchers as non-biased objective participants and through the use of phenomenological bracketing and reflexivity engages with bias and attempts to show where it exists. Thus, it can be argued that phenomenological research is ‘more honest’ as it attempts to show bias, and drive exploratory research towards greater rigour.

Moving on, the method of explicitation is defined by Hycner (1999) as having five-stages, which include:

- 1) Bracketing and phenomenological reduction.
- 2) Delineating units of meaning.
- 3) Clustering of units to form themes.
- 4) Summarising each interview, validating it and where necessary modifying it.
- 5) Extracting general and unique themes from all the interviews and making a composite summary.

These aspects are examined in the following sections:

#### ***4.6.1. Bracketing and Phenomenological Reduction***

In the natural sciences, the term reduction can often be equated with splitting the phenomenon into constituent parts to establish cause and effect, whereas in phenomenological research this is not the case. Hycner (1999) has regarded the original term reduction in the phenomenological context as unfortunate as it suggests the use of a paradigm from the natural sciences. In the phenomenological context reduction can be taken to mean a finding ‘*in its own right with its own meaning*’ (Fouche, 1993; Hycner, 1999). It is important for the researcher to undertake bracketing of their own preconceptions of meanings and interpretations, to reduce induced potential bias between researcher and respondent. An example of bracketing is the researcher limiting their perception that R&D has to be carried out in a certain way. Through the use of bracketing, any such judgement is suspended, which might bias their interpretation and use of the explication process.

Once the interviews were completed, Holloway (1997) and Hycner (1999) stated that the researcher should listen to the recorded interviews multiple times to more fully imbibe the interviews was followed. It is through this process that aspects such as the ‘how’ and ‘why’ may be drawn out and discerned. Unlike quantitative research, where the unit of analysis could be a person’s behaviour, object or measure e.g. sales per contact, in phenomenological research used here, the researcher is looking for units of meaning. This meaning is found from R&D manager responses and could be many ‘units’ rather than a single one. This is expected from the research. As Pope,



Ziebland and Mays (2000: 115) point out: *‘Indexing the data creates a large number of “fuzzy categories” or units. Informed by the analytical and theoretical ideas developed during the research, these categories are further refined and reduced in number by grouping them together. It is then possible to select key themes or categories for further investigation— typically by “cutting and pasting”—that is, selecting sections of data on like or related themes and putting them together.’* It is therefore important to be able to carry out the process of ‘Delineating Units of Meaning’ as examined in the following section.

#### ***4.6.2. Delineating Units of Meaning***

Delineating units of meaning is the first step towards drawing out information from the interview stage that is pertinent to the researcher further understanding the phenomenon of interest. Carrying out this process is not without challenge but as Groenewald (2004: 18) stated, it: *‘is a critical phase of explicating the data, in that those statements that are seen to illuminate the researched phenomenon are extracted or isolated.’* Moustakas (1994) suggested that this is the stage where meaningful units of interest are extracted, with the process of removing data of limited importance being started. An example of delineating units of meaning could be a respondent justifying an R&D process based on there being *‘a clear financial driver for this process’*. In this example, the delineated units of meaning could be the financial driver for an R&D process. Utilising this unit of meaning would require the use of methodology described throughout this section to draw out further meaning and contextualise the meaning. Carrying out this procedure is inherently subjective with the potential for construing greater or lesser importance to a unit than should be afforded. Factors such as the literal content of the interview, frequency for statements and terms and non-verbal communication are important for making decisions about which are the units of relevance and importance. As Hycner (1999) emphasised that the context and environment of verbal statements to be taken into account throughout this stage.

#### ***4.6.3. Clustering Units to Form Themes***

The process of clustering units to form themes involves grouping similar units together, which can be used to form significant topics (King, 1994; Moustakas, 1994; Creswell, 1998). It has been suggested that rigorously assessing interview material (including aspects potentially perceived as having limited value) can be of great benefit for the formation of themes from units of meaning (Holloway, 1997; Hycner, 1999). It is intended that examining the data in this way may result in central themes being exposed, which for this study may lead to ‘why’ R&D processes are carried out in the way that they are, and how management perceives these processes. An example of clustering units to form themes could be that management believes that *‘there is a market demand for antiviral disinfectants, based on low product toxicity.’* Like delineating units, the process of clustering units to form themes is also subjective and personal, without a numerical benchmark to assess decisions by. Care must be taken throughout this stage, to cluster not only within the same interview but also between interviews, to enable cross themes to be identified, which aids in determining the significant elements to draw out of the respondent interviews.

#### ***4.6.4. Summarising each Interview and Warranting***

In phenomenological studies, the researcher often aims to reconstruct and potentially mirror the inner and subjective worlds of the respondents as closely as possible. Groenewald (2004) has argued that summarising each interview moves towards goal in a holistic way. As Hycner (1999: 153-154) argued: *‘Whatever the method used for a phenomenological analysis the aim of the investigator is the reconstruction of the inner world of experience of the subject. Each individual has his own way of experiencing temporality, spaciality, materiality, but each of these coordinates must be understood in relation to the others and the total inner ‘world’.*

At this stage in the research process, a ‘validity check’ or ‘warranting’ of findings is carried out, by returning to the interviewees so that the researcher could determine if

they perceive that the essence of the interviews had been captured. Modifications carried out at this stage are part of the validity/warranting process.

#### ***4.6.5. Extracting Themes and Summarising***

Once the previous explicitation processes had been carried out for all interviews (section 4.6.1. to 4.6.4.), the researcher examined ‘*themes common to most or all of the interviews*’ (Hycner, 1999: 154). One of the challenges of clustering common themes is based on how to deal with ‘significant’ differences between themes. Although challenging for how to deal with differences between themes, this is one of the strengths of phenomenological research, as it enables ‘*minority voices [which] are very important counterpoints to bring out the phenomenon [being] researched*’ (Groenewald, 2004: 21) and should not be ignored.

As Hycner (1999) and Moustakas (1994) argued, at this stage, the researcher must conclude the explicitation by writing a composite summary, which reflects the context from which the themes emerged. According to Sadala and Adorno (2001: 289), the researcher: ‘*transforms participants’ everyday expressions into expressions appropriate to the scientific discourse supporting the research*’. However, Coffey and Atkinson (1996: 139) emphasise that ‘*good research is not generated by rigorous data alone... [but] ‘going beyond’ the data to develop ideas*’. Importantly, and linked to this is the thought that initial theorising is often linked to qualitative data such as derived by this method and in this study. Linked with these aspects (although not directly labelled as being part of the explicitation process) are the aspects of the reliability and validity of data collected, which are explored in the following section.

## 4.7. Reliability and Validity of Data Collected

The ‘quality’ of data collected and examined, is a vital part of many research studies, with reliability and validity often being regarded as pivotal to the study. Achieving reliability and producing data, with a high-level of validity is not necessarily easy, and it is important that these processes are included in the research design. The following sub-sections therefore consider the following aspects of ‘Rigour’, ‘Validity’, ‘Warrantability and Trustworthiness’, ‘Generalisability’ and the ‘Researcher Background’.

### 4.7.1. Rigour

Achieving ‘rigour’ through research design, data collection and methods such as explication is often perceived as being pivotal for case study research. Producing enough rigour is not simple, and there is often much criticism across the research method spectrum that some methods, particularly those based within qualitative research are not rigorous enough. Lee (1989: 39-41) has argued that there are four factors for research rigour as shown in Table 4.2.

**Table 4.2. Factors for Research Rigour**

	Controlled observation	Controlled deduction	Replicability	Generalisability
Rationalism	Laboratory or statistics	Mathematics	Results	Assumptive
Case study	Natural	Logic	Theory	Theoretic

*Source: Lee (1989: 39-41).*

Although this study has not carried out rationalist research, rationalist factors have been left alongside the case study aspects, as it was perceived as informative for understanding case study rigour in comparison to the more commonly used methods found in rationalism. Examining Table 4.2, rationalist research typically utilises laboratory testing or statistics, whereas case study research utilises natural methods,

with arguably the same ‘controls’ that astronomers and geologists use (Meredith, 1998). It is not possible to control interpretive case study research in the same way that rationalist studies do, in that the ‘control’ is more through selection of cases for interview for cases studies. Although there is also the potential for interpretive case study researchers to control the questions asked, general discourse and the interview environment.

There have been criticisms against qualitative research (including interpretive case studies), based on the lack of mathematical (often statistical) analysis on behalf of the researcher carrying out the research. This is an interesting point and looking at Table 4.2 the column labelled as ‘controlled deduction’ listed rationalism as using ‘mathematics’ and case studies as using ‘logic’. Considering that formal logic encompasses mathematics, the requirement in Table 4.2 for controlled deductions can be applied by applying the rules of formal logic to verbal propositions arising from case study interviews. Beyond arguments of mathematics being useful for ‘precision’, which is a term more suited to rationalism, it is not necessary to mathematically quantify all variables in a study. It is worth pointing out that not all rationalist based theories were developed using mathematics, with some such as evolution being deduced by logic using words. Looking at business examples of theory deduction using words and not numbers, the studies of Pressman and Wildavsky (1973), Hayes and Wheelright (1979), Meredith (1981) and Gerwin (1988) can be cited.

Linked to mathematic and verbal examination is replicability, which is regarded differently in rationalist and case study research. In rationalist studies, replicability has the aim of achieving the ‘same’ quantitative results, when a study is ‘precisely’ duplicated, and is often measured mathematically. In other words, if the study is duplicated, and is replicable, the same results should be obtained. However, in case studies, the same conditions can never be exactly duplicated (arguments can also be made in the direction of rationality for this aspect), which means that replicability is attained by examining resulting theory from the first case studies, under a different set of conditions in the replicability test. This has the potential of producing

different predictions and means that although the prediction is different, the same theory is still being tested.

In this study, various researcher processes were carried out to increase study rigour. For instance, interviewee deception in interviews was reduced by the use of informed consent, which also aided in ensuring ethical research (Kvale, 1996; Holloway, 1997), as Bailey (1996) believes that it may be counter-productive. Bailey (op. cit.) suggested that deception on the part of the interviewer might act as a barrier to information, whereas the combination of honesty and confidentiality has the potential to reduce suspicion and promote more sincere responses.

In the next section, the validity of this study and research methods utilised are examined.

#### **4.7.2. Validity**

In conventional and rationalist research, validity is based on an assumption that research findings can closely and objectively mirror the 'real' world, with the 'real' world having an independent existence, outside of the researcher's notions about it. Discourse researchers including those using explicitation do not necessarily share this view, as via the discursive perspective, they perceive the world to be constructed discursively, as not only is their discourse about the world, it is also part of the world. With discourse being socially constructed it can have multiple meanings, with it being possible to construct an argument that discourse researchers findings are only one meaning, within a sea of many, and are neither true nor false.

Wood and Kroger (2000: 166) suggested that: *'Truth and realism are themselves social, that is, discursive constructions. There is no basis for selecting one account over another on the grounds that one is a truer or more valid version of the world'*. This argument does not suggest that reality is not real, or deny the existence of physical objects, but rather that the evaluation of discursive research should not be based purely on correspondence to objective reality. It is noteworthy that this stance

does not itself mean that there are no criteria for selecting among versions of discourse, or that some discourse may be considered ‘good’ or ‘bad’. Although Bashir, Afzal and Azeem (2008) have suggested that reliability and validity are pivotal in qualitative research, for reasons explained in the following section: ‘Warrantability’ is preferred in this study.

#### **4.7.3. Warrantability**

*‘Warranting consists of providing justification and grounds for one’s claims’* (Wood and Kroger, 2000: 163), and is a process often used in discourse and phenomenological studies. This approach is quite different to subjects embedded within positivism, where warranting can be taken to mean ‘reliability’ and ‘validity’ (Rosenthal and Rosnow, 1991), and is often linked to a need for claims to be backed up by statistics. The way that the researcher views subjective and objective reality is pivotal for whether warrantability or reliability and validity are used as a measure of research ‘quality’. The belief in a single ‘true’ objective reality can be difficult to incorporate within phenomenological and discourse studies, as the way that individuals describe the phenomenon often varies, making a singular-view unlikely.

In language and phenomenological studies such as this, there can be multiple representations of reality, all of which are discursively presented and all of which may be valid. The variation described is not argued as being linked to error, but more the discursive process, which produces multiple accounts of examined phenomena. This necessitates the use of warranting rather than validity as a check upon the research carried out.

Conventionally, reliability can be considered by itself and in relation to validity, where simplistically, reliability is taken as repetition. In such research, the phenomenon is examined multiple times as a variable within a sample and throughout samples, which can be problematic in discourse-based studies, as simply repeating an examination in discourse studies does not necessarily create a higher level of repeatability. In studies based in positivism, there is the belief that although

the values of the variables might change, their nature will not, and that they are thus the same variable. This is not to say that discourse-based studies do not engage in repetition, particularly of repeated readings of text, but that the use of respondent warranting of transcribed and explicated data, as well as models produced can be used to increase the validity of researcher constructions and findings. In the following section, the issue of generalisability is also considered as a measure of validity.

#### **4.7.4. Generalisability**

Generalisability (also known as ‘external validity’) is often perceived as a critical part of research rigour (Wood and Kroger, 2000). Hedrick *et al* (1993: 40) defined external validity as the ‘*extent to which it is possible to generalize from the data and context of the research study to broader populations and settings*’. There is a difference in the way that researchers using different methods perceive generalisability and draw conclusions from their research based on this aspect. Many case study researchers believe that the developed from case studies can be applied to similar situations and even dissimilar situations at times (Meredith, 1998).

Discourse and case study research ‘*claims are as generalizable as those generated in other forms of research, particularly in experimental social psychology*’ (Wood and Kroger, 2000: 76). There are differences between the ways that claims of generalisability are made and justified, which in turn influence the way that the sample size is viewed. Looking at more ‘conventional’ and non-explicitation research, claims can be made about statistical relationships between variables. In explicitation, ‘*claims are not about variables...they are framed discursively*’ (Wood and Kroger, 2000: 76). Another way of looking at this is that more ‘conventional’ work is based more on externality *i.e.* quantifiable variables whereas explicitation is focussed on the meaning of the inner subjective world of the respondent. As Douglas (1970: 11) stated, discourse researchers try to avoid the: “*fallacy of abstractionism, that is, the fallacy of believing that you can know in a more abstract form what you do not know in the particular form*”.



Sample size in case studies has been criticised for low generalisability in explicitation work, as well as sample randomness (Wood and Kroger, 2000). The question of whether a sample should be random, was partially addressed by Rosenthal and Rosnow (1991: 205) who argued that a lack of random sampling was often not an issue in many studies, because unlike surveys, experiments are not supposed to provide estimates of population values, which is the same in explicitation. As Rosenthal and Rosnow (1991) further argued, problems can occur with random sampling that over uses an unrepresentative sample, where authors conclude research findings on incorrectly sampled populations. It is important however to understand that with different explicitation studies, there is variability within and across the approaches, with regard to the generality of claims, which must be acknowledged within this method.

In the following section, a consideration is made of the ‘Researcher Sensitisation’ to the aspects explored throughout this study.

#### ***4.7.5. Researcher Sensitisation***

The researcher’s sensitisation and prior engagement with the phenomenon of interest in this study is a complex issue and potentially influences data explicitation, as well as the construction of the study as a whole, and is thus explored in this section.

Academically, the researcher has carried out post-doctoral research, examining and carrying out antiviral disinfectant R&D. This has been as well as working as both an R&D and executive manager in an antiviral disinfectant R&D SME located within the UK. This meant that all of the respondents interviewed in this study were aware of the researcher, although they had not met him prior to this study. Importantly, the researcher felt that his background allowed him a high level of access to respondents that might not have been possible if the researcher was viewed as an outsider.

Using theory suggested by Layton (1998), the researcher suggests that he has been sensitised to the sector of interest to this study before and throughout the study, and

the bias from this sensitisation has to be taken into account. Although, there was a prior sensitisation to the sector and reality of R&D from the researcher's experience of working as an R&D manager and executive manager, it is noteworthy that arguably all interactions are at some level biased, with varying preconceptions. Examining the thoughts of Schutz (1932), who through the use of ethnography claimed that interpretive methods (as used in this study) meant that a researcher's awareness and meaning are obtained by 'reflecting' back, or casting a retrospective glance upon lived experience. Thus on this basis, any researcher would have an inherent and constructed set of preconceptions about antiviral disinfectant R&D.

The high-level of researcher sensitisation to the phenomenon of interest, may have aided in closeness through similarity of language, symbolism and meaning (Owusu, 1978) between researcher and respondents, which may in aid in drawing out information relevant to this study.

Although an argument has been put forward by this researcher about his own background and reasons for his suitability for carrying out this research, there are counter arguments, such as researcher sensitivity to the phenomenon being examined. Briefly, these differences are based on individuality and experiential closeness to the phenomenon being researched, with the issue of sensitisation being one that can occur through the research process irrespective of researcher background, but must be considered throughout the research process.

In the following section, a brief examination of 'Ethical Considerations, Data Storage and Protection' is made for this research.

#### ***4.7.6 Ethical Considerations, Data Storage and Protection***

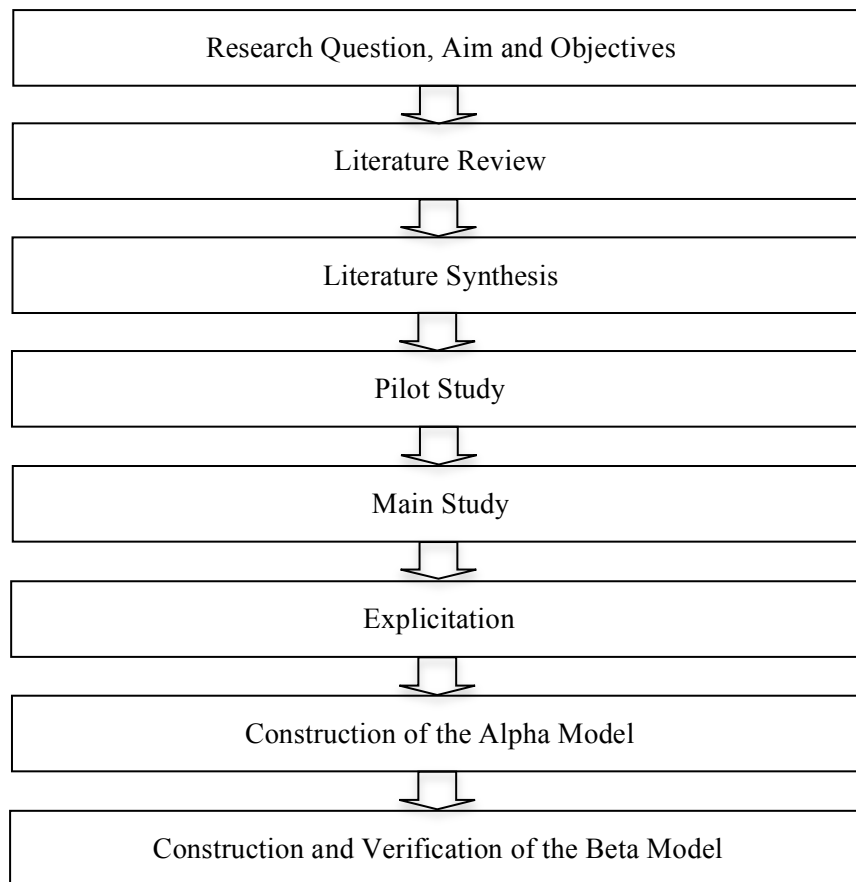
The researcher undertook all research in line with the rules, ethics and regulations of Heriot-Watt University and Edinburgh Business School. All research processes were carried out in a professional manner, and information collected from interviews was recorded via audio digital recording equipment, and was stored in accordance with

the Data Protection Act 1998. All interviews were transcribed for analysis, with transcribed data also being stored in accordance with the Data Protection Act 1998. Beyond data protection, information collected from interviews can be protected under intellectual property laws, including, patent, copyright and trade secret. Information protected by these laws was made accessible through non-disclosure agreements (NDAs) with the respondent companies. All information was anonymised to protect the companies and interviewees. To protect interviewees, all interviews were carried out after interviewees had signed informed consent forms. This followed the suggestion of Saunders *et al* (2009) who argued that organisations are less likely to cooperate with research that negatively impacts upon their business activities, ergo necessitating the protection of sensitive information. In line with the suggestion by Easterby-Smith *et al* (1991), the amount of time and resource required from interviewees was detailed in advance of interviews and was kept to a minimum. To aid in developing a relationship between researcher and interviewee, interviewees were allowed to schedule the date and time for their interviews. It was made clear to interviewees that data collected from interviews would be made available to each interviewee upon request.

#### **4.8. Summary**

In this chapter the research methodology was examined through the phenomenological research paradigm and with the use of multiple case studies, by semi-structured in-depth interviews with R&D and executive Managers. Practical and theoretical aspects were explored for carrying out the research via a pilot and main study, alongside explicitation. Finally research rigour was considered to increase the confidence in research findings. All of these aspects are depicted in Figure 4.1.

**Figure 4.1. The Research Process**



The following chapter, details the pilot study, which is followed by the main study, data analysis and conclusions chapters.

## **Chapter 5. Pilot Study**

### **5.1. Introduction**

This chapter, the ‘Pilot Study’, focuses on the exploratory stage of the semi-structured in-depth interviews, including the ‘Introduction’, ‘Findings from the Pilot Study’, and ‘Pilot Study Conclusions and Adjustments for the Main Study’. This aspect of the study was carried out to examine not only the appropriateness of the methodology, but also to gain further insight into the phenomenon of interest, which in this study is antiviral disinfectant process R&D. Beyond understanding the pilot study stage, the researcher also reflected on how these findings led to adjustments in the main study, to more fully reflect the pilot study findings.

### **5.2. Findings from the Pilot Study**

Examination of academic and practitioner literature highlighted the lack of research into how UK based SMEs carry out process R&D for antiviral disinfectants. The pilot stage was therefore perceived as pivotal for drawing out the relevant issues to be explored in the main study.

Initial contact with respondents was made by telephone, where the prospective interview was detailed, and which was followed up by a written request to participate. Dates and times were arranged to suit the respondents and took place in the respondent’s office.

Individual interviews were carried out with one executive manager and one R&D manager from three R&D companies, which formed the basis of the pilot study. In each case, the interview was recorded using a Dictaphone, to increase reliability and warranting of data when examined and explicated. Each interview commenced by the interviewer outlined the study, scope of the research and what the perceived participation of the respondent might achieve. Before the interview was started, a

final assurance of confidentiality was made. The pre-prepared interview questions were segmented into the following areas as shown in Table 5.1.

**Table 5.1. The Areas and Questions Explored in the Pilot Study**

Area of Interest	Questions	Rationale
Viruses and antiviral disinfectants, with regard to management understanding.	<i>'Could you tell me about antiviral products and how they relate to viruses?'</i>	A foundational step to determine what products are being developed in R&D, and whether the phenomenon of antiviral disinfectants is separate or a part of <i>in vivo</i> antivirals or vaccines.
R&D management, including management segmentation of decision-making.	<i>'How do you perceive your role within your company? And what is your relationship to R&amp;D?'</i>	To determine the decision-makers within these companies and explore this in regard to the sector. This verified the respondents for the main study.
Process R&D, including, how and why processes were carried out, as well as potential modelling.	<i>'What processes occur during the R&amp;D stage, and who carries them out?'</i>	A determination of the process stages and managers/staff involved. This enabled a preliminary examination of what would be used to model R&D.
Other areas of interest for the respondents	<i>'Are there any areas or aspects pertinent to this study of antiviral disinfectant R&amp;D process management that you feel have not been discussed?'</i>	Finally, respondents will be asked to detail any areas or aspects that they feel are important beyond what the researcher raised during interview.

These areas for discussion were not raised before the interview, and were posed during the interview to allow the fullest consideration of these areas, with minimal constraint on the respondent. Using semi-structured interviews, allowed the interviewees to engage as much as they felt they wanted to, with flexibility and to allow information to be fed back to the researcher (Robson, 2002). Interviews were on average 23 minutes in duration.

### ***5.2.1. Viruses and Antiviral Disinfectants***

The first discussion focussed on management perceptions of viruses and the business ‘solution’ of antiviral disinfectant products. Executive and R&D managers were asked the following question which was used to guide this stage of the pilot study:

*‘Could you tell me about antiviral products and how they relate to viruses?’*

This question was intended to draw out the perceptions of both executive and R&D managers for the way they regarded antiviral products, but also their relationship to viruses (with potential answers being embedded within science, business or other frames). All respondents defined their products as being primarily antiviral in nature (as opposed to a generic cleaner/sanitiser), which was linked to marketing claims (based on the scientific testing) being made about the products. It appeared that executive management was keener to extend marketing claims about the products beyond the R&D testing that had been carried out, with R&D managers being cautious about extended claims for anything not tested. This theme was prevalent throughout this stage and showed a preference for R&D managers to base management decision-making upon scientific ‘facts’ that could be verified in a laboratory. In this way, R&D managers saw a more limited application for products coming out of R&D than executive managers.

The way that both types of management discursively framed products and their applications appeared to be based on their individual backgrounds, as well as individual perceptions of the way that they ‘should’ use language to describe this phenomenon. Beyond this, there was uniformity in that all managers described their antiviral products as being liquid based and to be sold as market ready, although there were comments made that their products were potentially being incorporated into other products later in the supply chain, to enhance the functionality and marketing claims that could be made. Importantly R&D managers were much less aware of how products entered and were used in the market in comparison to executive managers.

### **5.2.2. R&D Management**

The second discussion examined the management of R&D, with both executive and R&D management being interviewed in this area. The main focus driving this section was:

*‘How do you perceive your role within your company? And what is your relationship to R&D?’*

This question drew out that all three managers working directly with R&D defined themselves as R&D managers, who had biologically-related undergraduate degrees, but had had no formalised workplace or academic training in management. The other managers used variations of the term executive management to define themselves but all agreed that they were in executive management and in positions senior to the R&D managers (the R&D managers also perceived executive managers as senior). The executive managers all had undergraduate degrees in business-related subjects, with no formalised workplace or academic training in science. Both types of manager regarded the lack of knowledge transfer between managers as problematic for communication about R&D and its wider company contextualisation. It was thus argued that there were difficulties in constructing shared meaning for technical terms and management knowledge and processes from R&D.

Upon probing further to understand how managers interacted with each other and R&D, it appeared that R&D managers had a far greater involvement with the technical aspects of management, which spanned all of the process stages. Perhaps not surprisingly, R&D managers perceived themselves as custodians and pivotal for the regulation and success of R&D. Executive managers saw their roles as being to oversee R&D in relation to wider company objectives, which they argued created a less focussed view of the minutia of R&D, but allowed a greater focus towards market opportunities, which had the potential to bring them into conflict with R&D managers. This appeared to be a crucial aspect of the process of R&D management, as R&D managers felt that they were not always aware of wider company aims, and changing drivers, which could be costly for products going through R&D. There was



a universal agreement from all managers (albeit expressed separately) that confusion of aims, successes and failures could only damage R&D in terms of product failure, and slowing down products successfully leaving the R&D stage.

### **5.2.3. Process R&D**

The third main discussion focussed on the aspect of process R&D, and explored what R&D encompassed, its goals, and who carried it out. The question driving this exploration was:

*‘What processes occur during the R&D stage, and who carries them out?’*

While the aim of this section was to encourage both types of manager to segment and state the R&D process stages, it also enabled decision-making for the micro and macro elements of R&D to be considered. Importantly, this question showed a difference of views between executive and R&D management, based on the segmentation of the R&D stage. R&D managers were keen to segment the R&D stage into several smaller stages and predominantly scientifically orientated stages, and for which they made decisions. These stages were geared for whether a product should proceed to the next stage or re-enter a failed stage. The basis for R&D manager segmentation appeared to build upon differences of scientific testing, so that formulation and antiviral testing would have different scientific testing protocols and would thus be classed as different stages. Executive management, possibly due to their backgrounds and knowledge being more based in business, segmented the R&D stage differently to R&D managers. Executive managers were conceptually aware of the different stages, but with variations of R&D manager segmentations. Executive manager decision-making for R&D was on a macro-level for whether to enable R&D to start, or whether to stop it, and with their decision-making being reliant upon feedback from R&D managers, as well as other industrial actors and decision-makers such as potential clients. This is an important finding, and suggests that R&D and executive managers have potentially different views, with a blunt

differentiation being that executive managers are more macro-orientated and R&D managers micro-orientated.

Finally, the aspect of manager comprehension of R&D processes and their contextualisation to wider company R&D goals were considered, alongside the potential use of a model. While R&D managers felt that they were well versed in R&D and what goes on, they did feel that others working within R&D were often less aware of how their stage fitted in with the whole of R&D, and that a model could aid in increasing understanding. Importantly none of the companies examined at this stage used an R&D process model. R&D managers also felt that it might be useful for executive managers to be able to visualise the R&D stage in the form of a model and not just see everything as a singular i.e. “it is just R&D”. Executive managers, were less aware of the minutiae of R&D and of some of the stages of R&D, and stated that due to their senior positions was not comfortable asking “less-senior” managers what the stages were, or what their relevance was. Executive managers thus positively perceived the use of a model to be conducive towards creating shared meaning and understanding, as well as potentially being able to facilitate increased executive manager management of the R&D stage.

Both types of manager seemed aware of using models to represent complex phenomena, but it was suggested that the differences in manager backgrounds might result in the different manager types approaching models from different perspectives. This area was therefore deemed worthy of further investigation, within the main study.

#### ***5.2.4. Other Areas of Interest***

In this final section, respondents were given the opportunity to bring up other areas that they perceived relevant to this study through the following question:

*‘Are there any areas or aspects pertinent to this study of antiviral disinfectant R&D process management that you feel have not been discussed?’*

The first area that arose out of this questioning was based on perceived difficulties of communicating information between R&D and executive management. Both manager types perceived this as a knowledge-based issue where each type of manager was utilising knowledge-based frames of prior experience to communicate, which was not always helpful for creating shared meaning and understanding. At worst it was speculated that the use of ‘science’ and ‘business’ speak potentially confused R&D and was not conducive to the success of products leaving the R&D stage. All managers ventured that the use of a model, incorporating management specific views could address this shortfall and contextualise R&D towards company objectives. Beyond these aspects, nothing was suggested for the main study that was not already there. Practically, each of the participants interviewed in the pilot study, was also interviewed in the main study, which is not uncommon in qualitative research.

### **5.3. Summary**

The pilot study showed that for the three companies examined, management was split into R&D and executive management, with day-to-day decision-making for R&D being taken by R&D managers, and with R&D managers potentially acting similarly to stage-gates in the Stage Gate Model. Executive managers functioned more as a ‘stop/go’ decision-making aspect, where they could enable a product to enter R&D, or stop the project altogether. Both R&D and executive management felt that this split was often intentional, and was due to commitments that managers had with their self-perceptions, and the roles they felt obligated to carry out. For instance R&D managers felt a strong compulsion to use scientific language to describe R&D phenomena, and executive management felt a need to use business language to describe the same phenomena.

The issue of management backgrounds, knowledge and language used for decision-making through R&D was raised numerous times during the pilot study, with all managers expressing concerns for a lack of shared meaning and understanding. The main study has therefore explored this aspect more deeply.

The construction of a potential model was well received by all managers for aiding in shared meaning, setting objectives and creating closer understanding. The potential of a model simultaneously showing science and management processes were suggested as being useful. The researcher perceived that managers might have different mental constructions of what a model is based on their different backgrounds. This aspect was also drawn in to the main study, for further exploration. The most pertinent points for the summary have been depicted in Table 5.2.

**Table 5.2. Summary**

Main Study Areas	Findings
Viruses and Antiviral Disinfectants	All respondents regarded their products as predominantly antiviral, with discursive framing by executive and R&D managers being through business and scientific language respectively. Both manager knowledge sets appeared to be embedded within their own expectations of how a business or R&D manager should perceive antiviral products and viruses.
R&D Management	A management divide was argued by all respondents as being executive managers, who had a senior overseeing duty for R&D, and R&D managers, who were responsible for the day-to-day running of R&D. Both managers described difficulties in communication and creation of shared meaning, based on different language used and a low-level of wider business drivers influencing R&D decision-making.
Process R&D	Both manager types segmented the process stages of R&D differently. Executive managers were conceptually aware of the stages of R&D, but often did not know what led to a stage being successful or not, and only being involved with stop/start decisions. R&D managers had a much more in depth view of the R&D stages, and made nearly all day-to-day decisions, but were often less aware of the business drivers for each stage. Both manager types expressed a positive perception of using R&D models, although none had used models in R&D.
Other Areas of Interest	Difficulties in communicating about business and scientific phenomena pertinent to the R&D stage was expressed by all managers, particularly as being difficult for creating sense between executive and R&D managers. It was argued by some managers that a model utilising facilitatory language could be used to aid in sense and decision-making.

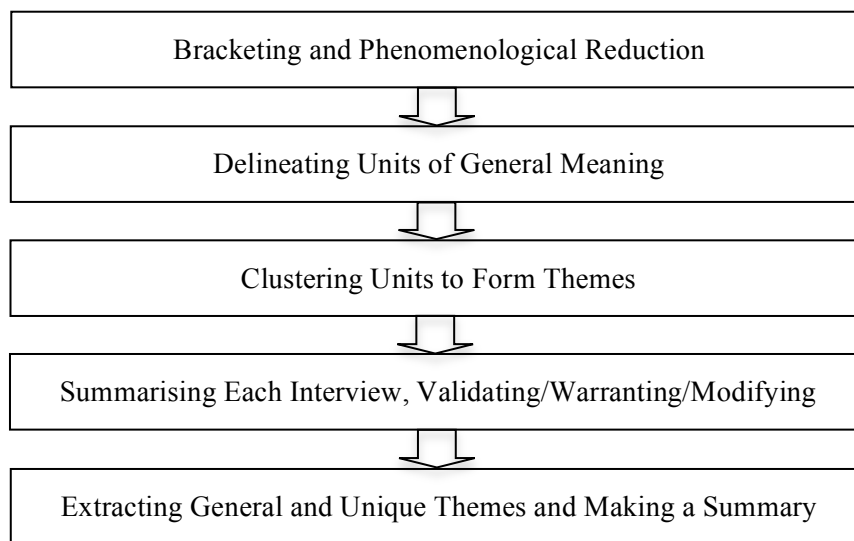
The following section explores the main study for respondent interviews carried out with executive and R&D managers, as well as the explicitation process.

## Chapter 6. The Main Study and Construction of the Alpha and Beta Models

### 6.1. Introduction

In this chapter ‘The Main Study’ there is a focus on the explicitation of data collected from semi-structured in-depth interviews with executive and R&D managers. This stage built on the pilot study detailed in the previous chapter. Briefly, data from the respondent interviews was transcribed and underwent the process of explicitation using the methodology described by Hycner (1999). Using Hycner’s method, the following processes were carried out, as is shown in Figure 6.1.

**Figure 6.1. Explicitation Process**



The following section considers the ‘Data Collection and Handling’, which leads onto other sections for the results from the explicitation process.

## **6.2. Data Collection and Handling**

Data was collected in one phase for the ‘main study’, with ethical considerations and the collection and explication of data being a priority to maintain the integrity of this research and findings.

### ***6.2.1. Data Collection: Semi-Structured Interviews***

Data was collected from interview respondents via in-depth semi-structured interviews, where questions were prepared before the interviews took place, and followed a pilot study detailed in the previous chapter. Pilot study respondents were interviewed in this the ‘Main Study’ and were facilitated to answer a wider variety of questions than engaged with in the pilot stage. As mentioned previously, this is a common practice, where main themes drawn out in the pilot study are subsequently expanded on in much greater detail in the main study (Yin, 2009). Importantly, the discourse provided in both the pilot and main stages was compared from the same respondents and arguably created a further warranting stage for this study. Practically however, and with ‘low’ numbers of respondents being used for interviews, it was considered ‘necessary’ to interview the same respondents in both stages. Due to the ability to warrant discourse from both pilot and main study respondents engaged in both interviews, this was perceived as strengthening the methods used.

Looking at the main study, and as with the pilot study, participants were not provided with the interview questions before or during the study, other than by the researcher verbally asking the questions. The research questions are detailed below in Table 6.1.

**Table 6.1. The Questions Explored in the Main Study**

Questions	Rationale
<b>1:</b> <i>‘What is your job title? And how would you define your job? And position?’</i>	To understand the respondent’s background in work, education and other areas that they perceive relevant to defined positions.
<b>2:</b> <i>‘How is management segmented? * Does your academic or work experience play a role?’</i>	A background contextualisation to the organisation, and individual managers responsible for R&D will be explored to set up the rest of this study.
<b>3:</b> <i>‘What is your role with regard to R&amp;D?’</i>	Respondent self-identity and how this relates to their role in R&D, via language and sensemaking can be examined by and between managers (Weick, 1995).
<b>4:</b> <i>‘What do you believe is the purpose of R&amp;D within your company?’</i>	The purpose of R&D as ‘it is’ and ‘could be’ provides an understanding of respondent macro-structures that may influence R&D. In other words, is R&D following a marketing pull (Schmookler, 1966) or technology push strategy? (Schumpeter, 1947).
<b>5:</b> <i>‘What do you believe the purpose of R&amp;D should be within your company?’</i>	
<b>6:</b> <i>‘What products do you make in R&amp;D?’</i>	What products are made in R&D will be used to examine respondent companies and contextualise R&D strategies.
<b>7:</b> <i>‘Could you tell me about your understanding of viruses and antiviral disinfectants?’</i>	Product understanding can be pivotal for the language used with complex high technology products (Mohr, 2001; Sperry and Jetter, 2009).
<b>8:</b> <i>‘How do you carry out R&amp;D?’</i>	The main thrust of this study to elucidate how process R&D is carried out, with an explicit examination of each stage, and components.
<b>9:</b> <i>‘Could you tell me what the R&amp;D processes are within the R&amp;D stage? And detail what each stage is composed of?’</i>	Following prior R&D models will enable the construction of an R&D model. Following this the order of the stages was sought to understand how different companies within this sector carried out R&D. The ability to determine what happens when a stage is passed or failed would allow a comparison to prior R&D models particularly technologically orientated models such as the Roche Model.
<b>10:</b> <i>‘What order do you carry out R&amp;D processes? * How does a stage pass/fail? And what happens then?’</i>	
<b>11:</b> <i>‘Are R&amp;D processes isolated from other departments?’</i>	Isolation may impact on the language used between managers in relation to R&D (Davies, 2011).
<b>12:</b> <i>‘Do you validate R&amp;D? * And if so, how?’</i>	Validation is important for the way that complex information is communicated for sense- and decision-making.
<b>13:</b> <i>‘Do you have specialists in each R&amp;D stage?’</i>	Specialists are likely to utilise specific terminology which may impact of sense- and decision-making.
<b>14:</b> <i>‘Do you subcontract any R&amp;D stages? And who makes these decisions?’</i>	Decision-making is being explored in light of complex stages that are sub-contracted, and for example virology. This creates a potential need for managers to engage in inter- and extra-organisational discourse where complex information about the nature of products, company aims, customers and the process R&D stage is highlighted.
<b>15:</b> <i>‘How are results interpreted in the context of R&amp;D? * Who interprets and communicates this?’</i>	Coupled with validation, the interpretation of complex results between R&D management and executive management may show linguistic vehicles for simplifying communication to aid in complex

	areas (Davies, 2011).
<b>16:</b> <i>'Who makes R&amp;D decisions?'</i>	Linked to decision-making (Mudambi and Swift, 2009) to determine the 'who' and 'why' for why decisions are made. Further to this, a link can be made between the language used by managers, their promoted self-identities and the sense they make of complex situations (Weick, 1995).
<b>17:</b> <i>'Do you or have you ever used an R&amp;D model?'</i>	R&D models are known for being able to create shared meaning and understanding for complex phenomena (Lyles and Mitroff, 1980; Morgan, 1980). This aspect thus considered the use of models within respective companies and respondent perceptions towards their use to provide favourable or less complex views of reality. More than this it explored how R&D models can be used to aid in sensemaking and views that might not be 'right' but are 'right enough' to work.
<b>18:</b> <i>'Could you tell me how you regard R&amp;D models?* And what you believe them to be? Do they have any importance?' And how do you think your background influences your opinions?'</i>	
<b>19:</b> <i>'Do you think the language and pictorial representation of an R&amp;D model might be understood differently by different managers?* How might you address this?'</i>	
<b>20:</b> <i>'How do you address different communication styles between management* i.e. different managers?'</i>	Similar communication styles can lead to dyadic closeness, with the opposite being the case for dissimilar communication styles and can be linked to an individual's background (Rogers, 2003).
<b>21:</b> <i>'Are there any areas or aspects that I have not covered that you feel are important to process R&amp;D within your company?'</i>	Finally, respondents will be asked to detail any areas or aspects that they feel are important beyond what the researcher raised during interview. This is a pivotal part to address perceived shortcomings.

\*If prompting of the respondent was required the following questions were asked.

The duration of each interview was between 50 and 68 minutes, with each interview being recorded by a Dictaphone. All interviews were transcribed within one day, thus following the "24 h rule" set out by Eisenhardt (1989). To increase the validity/warrantability of this research, transcripts were returned to respondent to confirm whether they were perceived as a reflection of the interviews carried out. No significant amendments to the transcripts were required.

Although the interviews were primarily focussed on understanding antiviral disinfectant R&D processes, and were thus project driven, they were left open enough for respondents to provide additional insights, which they felt appropriate (Verma and Sinha, 2002).



Throughout the interviews, discourse relating to sensemaking arose and was recorded. Deciding what might fall within a sensemaking paradigm was the first challenge and discourse driven repertoires given by the respondents were used as a method to hone in on potential sensemaking. Fitting within the suggestions by Weick (1995) that there are seven sensemaking properties, repertoires relating to these aspects, and using a hypothetical example ‘*my identity helps me make sense of the world and make good enough decisions*’ would be indicative of potential sensemaking. This however would not be ‘enough’ to demonstrate sensemaking, and through the use of further discourse given in interviews, could be contextualised with other discourse (where appropriate) to show instances of sensemaking.

### **6.2.2. Findings: Semi-Structured Interviews**

After carrying out the semi-structured in depth interviews with executive and R&D managers from seven companies, the following explicated information was synthesised from all the responses to briefly highlight what the researcher perceived to be the most important and common findings from the answers given. The questions asked are shown below, with responses beneath each question for both executive managers (denoted as EM) and R&D managers (denoted as R&DM). Importantly, the respondents involved in the interviews carried out a warranting process for their individual discourse, to check it was a fair reflection of what had been transcribed, but also interpreted by the researcher. As a secondary warranting process, the synthesised answers were also shown to respondents to take feedback on their perceptions of conclusions drawn, which could be used to consider the researcher’s findings in relation to respondent perceptions of the antiviral disinfectant sector. This approach was considered to be more in line with a phenomenological paradigm than using coding or counting, which is arguably more suited to methods more based within rationalism.

Question 1: *‘What is your job title? And how would you define your job? And position?’*

EM: The title of executive manager or terms synonymous with this such as senior manager were preferred, with positions all being ‘above’ R&D and R&D management, and perceived as more strategic. Respondent answers appeared to be more formalised than R&D managers *i.e.* *“I am an executive manager of this company, and as such, I am at the highest level of management.”*

R&DM: The title of R&D manager was used by all respondents, with their jobs being defined as custodians and managers of the R&D stage and staff engaged in R&D. These positions were all stated as being below the executive management being interviewed. Answers from R&D managers were typically less formalised than R&D managers, with more descriptive and humorous descriptors being used *i.e.* *“Well...you know, I run R&D, and I guess this means, that I erm... manage it...or try not to. More seriously, I’m in charge of R&D, but am not captain of the ship, that’s what they do in senior management.”*

Question 2: *‘How is management segmented? Do factors such as your academic/work background/experience play a role in this?’*

EM: Segmentation occurred based on resource and need, in that all major business activities had managers. Areas such as accounts, R&D and marketing were not considered executive posts and had limited interaction with R&D. Knowledge of business from academic and practical knowledge was considered pivotal to hold a senior post (such as executive management). Importantly, EM respondents downplayed what were often higher-level qualifications of R&D managers (frequently R&D managers held PhD qualifications, with EM managers having lower qualifications *i.e.* *“It’s all very well being a doctor and it sounds great for our business. We love saying to clients, that we, well, we have a very well qualified R&D manager,*

*with all of the technical know how, but we wouldn't want them to run the company!"*

R&DM: All major business activities were perceived as having managers. Importantly, although R&D managers regarded executive management as senior to R&D management, it was not universally respected, as R&D managers preferred in depth knowledge that could be demonstrated in areas such as R&D and accounts. Again, academic and practical knowledge was regarded as pivotal to being an R&D manager (*i.e.* there was a need for a scientific background). R&D managers often argued the relevance of a PhD to their ability to do their work and management *i.e.* *"High level knowledge is imperative! You couldn't do this job without it! I look at senior management, and erm...what do I see? Guys with business qualifications, who...who...couldn't do any of what we do in R&D, and they are in charge of us...in a round-about way of course!"*

Question 3: *'What is your role with regard to R&D?'*

EM: This role was described as being to oversee and manage from a distance rather than having in-depth knowledge about day-to-day activities. Interestingly, answers required from R&D staff and R&D managers were often based around simplicity such as "it works", rather than in depth explanations *i.e.* *"We just want to know it works, we don't want product failures, or suing...just things that work...and feedback should reflect this!"*

R&DM: R&D managers perceived their role as crucial to company performance and R&D and closely overseeing the R&D stage, which included managing different R&D staff, sub-contracting and orientating a pathway through to successful completion of the R&D stage. These managers also perceived their role to scope for new technological advances outside of product development (no mention of this was made by executive managers) and when R&D managers were asked about this aspect, they spoke about advancing science, and developing new technologies, which may or may not be relevant to

current company goals. An example of R&DM feedback is: *“Its like steering a ship across a rough sea!...There is always far, far too much to do...And it’s my job, my job...to erm...make sure it is done. It never ends, and holding all this info, all of it in my head, well you know, it’s just not easy, and never ending.”*

Question 4: *‘What do you believe is the purpose of R&D within your company?’*

EM: This question produced a variety of answers that were predominantly based around finance and market share; *i.e.* that successful R&D could result in more product sales, greater market share and customer satisfaction *i.e.* *“Its money, pure and simple, we are here to make money...and lots of it. Keep those shareholders happy. The scientists want to do science, and we let them, but we are here...to...ah...make money!”* Technological discovery outside of specific product development was not mentioned.

R&DM: R&D managers produced a more uniform answer than executive managers and saw R&D as a vehicle to produce technological innovation through products that would be market ready by the time they left the R&D stage. Importantly, the R&D stage was framed as a way to solve technological problems experienced in the marketplace *i.e.* *“We are technical wizards, fixing oh so many...problems. Senior management doesn’t get this, we are technically driven, have to be, where would we be without it? Bankrupt that’s where!”*

Question 5: *‘What do you believe the purpose of R&D should be within your company?’*

EM: The answers from executive managers were almost identical to that produced in question 4, and there was a strong belief that R&D in its current format was how it should be. Some minor comments were made that it could be more optimised and better communicated however *i.e.* *“The thing is, we all know...how to do R&D and make money. But ah..well..erm...sometimes the communication is useless,*

*and we...lose lots of money! Stupid really...we just don't talk properly!"*

R&DM: All R&D managers suggested that R&D should be more encompassing to explore technological innovation (similar to 'blue sky' research carried out in universities), which has the potential to bring forth serendipitous discovery for products currently not in R&D. Beyond this, there was a general consensus that R&D should be more focussed on understanding the scientific aspects of how the product works. It was argued that these two aspects received virtually no attention within the current R&D system *i.e.* "I'm continually hacked off [annoyed] by this! No long-term vision...no thought for the future and how to knock out the competition, we can do it with better science. But no! Not even on the agenda!"

Question 6: *'What products do you make in R&D?'*

EM: There was little deviation in this answer and discussion, as the response was that R&D produces liquid based products to destroy viruses are made, and for numerous sectors.

R&DM: Again, like executive managers, R&D managers described products as being liquid based and to destroy viruses in numerous sectors.

Question 7: *'Could you tell me more about your understanding of viruses and antiviral disinfectants?'*

EM: Viruses were predominantly perceived as similar to other microorganisms such as bacteria, but much smaller and harder to kill. Little was known about them as physical entities or as disease causing agents. Antiviral disinfectants were argued as being liquid products to sanitise areas where viruses were and kill them. Linguistic tools such as metaphor were used to describe antiviral products, with an example from one respondent being that using a product is like "*carpet bombing the enemy*".

R&DM: Perhaps not surprisingly, R&D managers used scientific terminology to describe both viruses and antiviral products, and claiming that their

knowledge of science enabled them to get closer to the reality of these phenomenon, which it was further stated that executive managers were unable to do. Scientific language was predominantly used to describe antiviral disinfectants *i.e.* “*antiviral disinfectant products inactivate viral particles.*”

Question 8: ‘*How do you carry out R&D?*’

EM: R&D was argued as being carried out by technical staff within the R&D department, with some aspects being sub-contracted to specialist companies and with day-to-day management being by R&D managers. The information forthcoming was somewhat limited *i.e.* “*This is more of a question...for R&D...of course we know what they do, but specifically, you’d be better asking R&D.*”

R&DM: It was stated that specific technical staff (qualified academically and through past experience) carry out each relevant stage. Sub-contracting was argued as necessary for highly specialised work, where there was a lack of knowledge and physical capability in R&D *i.e.* “*There are...erm...technical specialists for each stage here. Or as best they can be specialists, money...well there is never enough, and when...erm...we need to, we subcontract. Of course our bosses [executive managers] perceive this as a failure on our part. You know what I mean? That we aren’t skilled enough!*”

Question 9: ‘*Could you tell me what the R&D processes are within the R&D stage? And detail what each stage is composed of?*’

EM: The number of process stages ranged from between five to six, with six out of the seven executive managers arguing that they use a total of six stages. These stages and synthesised shared definitions are as follows:

1. **Decision-making meeting:** This is to scope the potential for the product (whether it is client/market or technology driven) and the perceived likelihood for success and return-on-investment;

2. **Formulation:** This is where the product is made (little was forthcoming about this stage);
3. **Efficacy:** Testing how well the product kills viruses (little was forthcoming about this stage);
4. **Safety:** Testing how safe is the product for the environment it will be used in (little was forthcoming about this stage);
5. **Stability:** Testing how stable the product is for its journey to the market, and in use (little was forthcoming about this stage);
6. **Decision-making meeting:** The main perceived relevant points were described as being discussed at this meeting, such as how well the product performed at each stage, whether it was fit-for-purpose, and economic considerations. If the product has passed all stages, this is where the decision is made for whether to send the product to market.

R&DM: The number of process stages ranged between four and five, with six out of the seven R&D managers arguing that they use a total of five stages. These stages and their synthesised shared definitions are as follows:

1. **Formulation:** This is where the chemistry is carried out to make and analyse the product;
2. **Efficacy:** This is where molecular biology techniques are carried out to analyse what percentage of viruses are deactivated by the product;
3. **Safety:** This is where the safety of the product is scientifically tested, to understand if it is safe for what it comes into contact with *i.e.* human skin, different manmade and natural surfaces and whether it is fit for purpose;
4. **Stability:** This is where the stability of the product is tested, to ensure that it will not “fall apart” and remain stable throughout transportation, storage and use;
5. **Decision-making meeting:** This is where R&D managers meet executive managers to discuss how the product performs at each

stage and the economics. R&D managers perceived the economics to be pivotal to whether a product would be commercialised.

Question 10: *‘What order do you carry out R&D processes? And could you say more about how you decide whether a process stage is passed or failed? Do you even regard it as a pass or fail? And if there is a failure, what do you do?’*

EM: The predominant order of R&D is as follows: (1) decision-making meeting, (2) formulation, (3) efficacy, (4) safety, (5) stability, and (6) decision-making meeting. R&D managers were argued as making decisions for whether a stage passes or fails, and scientific criteria is used to determine this (although the criteria was not always explicitly known by executive managers). If there is a failure, the stage is repeated.

R&DM: The predominant order of R&D is as follows: (1) formulation, (2) efficacy, (3) safety, (4) stability, and (5) decision-making meeting. R&D managers stated that they made decisions for whether a stage passed or failed, with detailed scientific criteria (such as industry standards) often being used to determine this. If there is a failure, the stage is repeated.

Question 11: *‘Are R&D processes isolated from other departments, such as marketing? And if they are, could you tell me more about this?’*

EM: The technical stages of R&D were argued as being separate from all other departments, but with a marketing influence before and after the R&D stage. To expand on this further, executive managers described a combination of technology push (for where they considered a market opportunity and would need to locate a buyer) as well as market pull (where a customer had a specific requirement for a product). It was felt by executive management that technical staff and R&D management preferred not to engage with other departments, as they felt that they were not relevant to R&D. This was not a view held by executive managers, who showed concern that R&D potentially



suffered from being decoupled from other departments and individuals who may bring insight to the R&D stage *i.e.* “*Getting those guys in R&D to work with any other department...anybody else is a complete pain. Never seen anything like it. Refuse to engage. They obsess over science..and..ah..ah...want leaving alone to do their science.*”

R&DM: R&D managers all used similar language to state their belief that R&D was separate from other departments, and should remain so. This appeared to be based on R&D being framed as a technical set of stages, and with individuals from other departments not understanding what was carried out in R&D, and thus could provide little benefit to it *i.e.* “*The last thing we need in R&D is anybody else who doesn’t understand it! Everybody wants to be involved...marketers...accountants...we wouldn’t mind if they helped! But they really don’t understand what we do...and we are not science teachers.*”

Question 12: *‘Do you validate R&D? And if so, how?’*

EM: There appeared to be some confusion over what it meant to validate R&D or any of the stages, with most of the managers believing that “everything” was validated. Statements were made that it was scientifically tested, so R&D, as a consequence must be validated. Numerous suggestions were made by executive managers that questions of validation should be posed to R&D managers as they would be best placed to answer them.

R&DM: Most R&D managers felt that R&D was not “properly” validated. R&D managers made arguments that they were breaking the “principle rules of science”, in that standard practices to validate the R&D stages were not carried out. A simple example of this would be not carrying out replicates for samples tested and using language that suggested that statistical testing had been carried out, when it had not been. This practice raised concerns among all R&D managers, but they felt that executive management wanted to reduce the cost of

R&D, which due to a lack of validation created higher R&D failures than should have been the case.

Question 13: *‘Do you have specialists in each R&D stage?’*

EM: From the view of executive management, each stage had a scientist carrying out the testing required for the stage, and was thus a specialist. Probing deeper, executive managers stated that they often found it difficult to determine what should constitute a specialist, but as far as internal and external communications about these individuals was concerned, there was a deliberate promotion of the use of specialists to increase confidence in R&D *i.e.* *“It is very important for us to show the company and customers that our technical specialists, are what I said, specialists.”*

R&DM: R&D managers did not necessarily believe that the scientists in each of the R&D stages were specialists. It was argued that scientists were used who understood what to do but often did not know the underlying theory, so could not interpret the data from their stage. The issue of a high cost for employing more knowledgeable individuals was cited as being a barrier to addressing this issue *i.e.* *“There is always an argument going on in here...we always want the best people...specialists...but...I...well...they aren’t easy to come by. Within itself, this might not be a problem. The R&D scientists we have are good, but it is the way that senior management sells them to the company as experts in everything. Who can be that? And then senior management misunderstand what they say, then I get a problem!”*

Question 14: *‘Do you subcontract any R&D stages? And who makes these decisions?’*

EM: It was stated by all executive managers that all R&D was carried out internally apart from the efficacy testing, which was subcontracted to external companies. This was argued as being related to high costs of purchasing equipment, insurance for handling pathogenic viruses and

a general lack of virologists. It was also speculated that a virologist would not find the idea of working for an antiviral disinfectant company an attractive proposition.

R&DM: Importantly, the views of executive management was mirrored by R&D managers, but with a heavier emphasis of virologists not wanting to work for antiviral disinfectant companies *i.e.* “*So many virologists are in academia...an easier life than here I suppose. Why come here, when you get paid more there? So we make do as best we can! [Laughs] It’s all branding, we sell our microbiologists as virologists, everyone does!*”

Question 15: *‘How are results interpreted in the context of R&D? Who interprets and communicates these results?’*

EM: The results were stated as being communicated and interpreted by R&D managers, which was regarded as potentially problematic. It was felt that R&D managers did not always seek to aid executive management (or non-scientist) understanding of results. Importantly however, where projects were customer driven, the customer would often interpret results through the use of hired specialists, and R&D managers would be obligated to communicate with these specialists *i.e.* “*There are so many advantages of external clients interpreting results...we can’t be blamed for what R&D says, what they haven’t said to us. Client paid scientists...can fight it out with our R&D manager...it all sorts itself out in the end.*”

R&DM: R&D managers generally collected data from R&D staff, with R&D managers thus communicating this information to executive management of customers. R&D managers argued it was easier to speak to hired specialists as they were scientifically trained, in comparison to executive management, who they felt it was difficult to communicate and create shared meaning with. Contextualising results was often perceived as difficult as R&D managers did not always feel well informed about the desired outcomes of R&D *i.e.* “*Y’know...I’m blamed for everything that comes out of R&D. I spend my days telling*

*stories...trying to find ways to speak to management who don't get it!  
At least if I speak to a client scientist, we are on the same page...same  
language. Its important!"*

Question 16: *'Who makes R&D decisions?'*

EM: Executive managers argued that they made the decision for what products to send into R&D. Importantly, feedback from R&D managers and other staff was sought during the scoping stage, to more fully inform management decision-making. Executive managers also stated that they could stop R&D for numerous reasons such as poor economics, continued stage failures, but that they often sought the feedback from R&D management over this. It was felt that R&D managers were often too positive about failures in R&D and often did not factor in the need to take advantage of market opportunities. However, due to the nature of R&D being predominantly scientific and technical, most decisions were left to R&D managers. A telling comment about R&D decision making was: *"Senior management makes the important R&D decisions, stop, start, but the everyday stuff, that's what the R&D manager is for."*

R&DM: Day-to-day operational decisions were made by R&D managers, as well as whether a stage should be passed or failed. Critically, information from customers and the scoping stage prior to R&D was relied upon for decision-making (such as what percentage of viruses needed to be inactivated). It was acknowledged by R&D managers that executive managers made decisions for what products to send into R&D and whether to terminate R&D. This was argued as a source of conflict, as the information being used to make these decisions was not always shared with R&D managers *i.e.* *"Go with me on this, we don't get the information for what we are supposed to be doing...its all piecemeal...ad hoc...and then people wonder why mistakes are made, or erm...we go in the wrong direction! We need clear instruction! Then I can manage."*

Question 17: *'Do you or have you ever used an R&D model?'*

EM: None of the executive managers had used an R&D model, but all had academic and practical knowledge of using models for other business aspects.

R&DM: All but one of the R&D managers had experience of using an R&D model, which ranged from stage specific models to models for the entirety of R&D.

Question 18: *'Could you tell me how you regard R&D models? And what you believe them to be? Do they have any importance?' And how do you think your background influences your opinions on modelling?*

EM: Perhaps not surprisingly, all executive managers felt that their academic and practical backgrounds in business management influenced their perceptions of R&D models, as they were based on business models used in different areas. The feeling towards models appeared positive; upon the condition that all parties could use them involved and were beneficial to R&D. Most executive managers perceived R&D models to pictorially represent R&D in the form of a flowchart, which they felt could be helpful to their understanding, particularly when explaining R&D to potential customers.

R&DM: R&D models were almost universally regarded as useful vehicles to communicate complex information, particularly to non-scientists. This was coupled with the thought that it helped remind other managers the order of stages carried out in R&D. R&D managers perceived R&D models to be a symbolic representation and often simpler than the reality that they communicate. As scientists, the respondents felt that they were more used to scientifically orientated models, even if they did not use them in their current work.

Question 19: *'Do you think the language and pictorial representation of an R&D model might be understood differently by different managers? Might you suggest a way to address this? If any, what type of model would you like to use?'*

EM: It was agreed that the language and pictorial representation might well influence the way that the model was understood. It was suggested that both executive and R&D managers construct a model that jointly communicate different aspects, but with a focus on making the scientific aspects of R&D easier to engage with. A flowchart model with boxes was generally perceived as being the simplest to understand *i.e.* *“There is...um...so much technical information coming out of R&D, we need simple information. Flowcharts work...we can make quick decisions on simple information.”*

R&DM: R&D managers generally perceived executive managers as having difficulty in understanding the scientific and technical aspects of R&D, which led R&D managers to believe that an R&D model might be misunderstood, if not constructed to take this into account. It was argued that many practical aspects of R&D are modelled in testing protocols by flowcharts, so this method would facilitate understanding not only between manager types but staff undertaking R&D. Finally, the idea of using expanded model views was perceived as beneficial to individuals more versed in science, and the model could thus communicate different aspects to different individuals involved in R&D *i.e.* *“I can see a model showing different info to R&D staff and senior manages. Yes...yes...this could be an improvement.”*

Question 20: *‘How do you address different communication styles between management i.e. one manager is a scientist and the other an accountant?’*

EM: This was regarded as a particularly problematic area, as there were perceived cultural aspects that scientists were dismissive of executive management’s lack of scientific and technical knowledge. Likewise, executive management felt that there were difficulties in communicating various business aspects, such as being customer focussed to R&D managers. There were claims that language based tools such as metaphor and story telling were beneficial for

communicating complex ideas between individuals with different levels of knowledge *i.e.* “*Unofficially we are...all looking, looking to communicate more...erm effectively. It’s a real problem, different worlds, different language, much confusion. Simple communication works.*” More than this though, EM felt that miscommunication had a potential to increase risk and potential R&D failure. More effective communication was perceived as a way around this aspect.

R&DM: The majority of R&D managers were dismissive of communicating science to executive management, as they felt EM could not understand it. Interestingly, they R&D managers used language-based tools such as metaphor and science fiction based narrative to communicate complex ideas. R&D management felt that although they did not necessarily understand the business aspects of executive management, but that it was not as important as the science of R&D *i.e.* “*Communication needs to be better! But communicating the complexity of science is hard! They have no background in it.*” The inability to communicate effectively was however perceived as a potential risk to R&D success, in that directives from senior management were argued as often not clear *i.e.* “*Senior management says, do this, do that, and they never think...what did we understand...but by the same token...we don’t have...have...a great attitude for making sure we...are...um...um understood either.*”

Question 21: ‘*Are there any areas or aspects that I have not covered that you feel are important to process R&D within your company?*’

EM: There was little suggested that had not been discussed in previous questions.

R&DM: R&D managers mirrored executive manager comments, in that nothing new arose.

The next section focuses directly on the processes of explicitation for all transcribed respondent interviews carried out in this ‘The Main Study’.

### **6.3. Data Explication**

Once interviewees confirmed the transcripts as a reflection of their interview, they were used as the basis of explication, with Appendix B showing an excerpt of a transcribed interview. Alongside a literal transcription of the interviews, the researcher examined perceived significant verbal and para-linguistic communications recorded during the interview process (Hycner, 1985). The explication of data is shown in the following sections.

#### ***6.3.1. Bracketing and Phenomenological Reduction***

In this the first stage of explication, the researcher approached the transcribed data from the recordings and transcriptions ‘*with an openness to whatever meanings emerged*’ (Hycner, 1985: 250). This is an important aspect of phenomenological reduction that would be used to elicit units of general meaning later in the process of explication. As Keen (1975) argued, this route helps the researcher become more open and see the phenomenon in its own right. In other words, an attempt was made by the researcher to suspend or ‘bracket’ his preconceived meanings and potential interpretations of the data being examined. Arguably though, bracketing encompasses more than an attempt to suspend preconceived research ‘realities’ about the phenomenon being researched, as it also covers the researcher endeavouring to enter the world of the respondent, and see the phenomenon through their eyes. As Hycner (1985: 281) stated: ‘*it means using the matrices of that person’s world-view in order to understand the meaning of what that person is saying, rather than what the researcher expects that person to say*’.

Importantly, the bracketing process does not enable the researcher to exist in an absolute subjective space occupied by the respondent or in a place of complete objectivity. This is an important aspect of phenomenological studies, and is based upon the perceived difficulty for a researcher to exist in either of the previously mentioned states or to achieve a complete or absolute phenomenological reduction (Hycner, 1985). Merleau-Ponty (1962: xiv) expanded on this by stating: ‘*The most*



*important lesson which the reduction teaches us is the impossibility of a complete reduction. ...that radical reflection amounts to: a consciousness of its own dependence on an unreflective life which is its initial situation, unchanging, given once and for all.*

Determining, what if any prior presuppositions about the phenomenon this researcher had was examined by the researcher before the main study interviews. Using this method allowed the researcher to explore his presuppositions that he may not have been aware of. Once the researcher considered he had ‘bracketed’ his interpretations as much as possible, he sought to get a sense of each interview as a whole, and in other words as a gestalt (Giorgi, 1975). This process involved the researcher listening to the recorded interviews and reading the transcribed interviews several times. While the researcher listened to and read the recorded and transcribed interviews respectively, notes of specific issues considered important were also recorded. Recording such impressions, allowed further examination of issues that might influence the researcher’s bracketing. After these processes were carried out, the units of general meaning were delineated as described in the following section.

### ***6.3.2. Delineating Units of General Meaning***

After the prior explicitation stages of bracketing and phenomenological reduction, the researcher sought to draw out and explicate intended meanings expressed by managers during the interview process. This stage is ‘*a crystallization and condensation of what the participant has said, still using as much as possible the literal words of the participant*’ (Hycner, 1985: 282). Throughout this stage the researcher attempted to stay close to the literal data, and by doing so produced ‘units of general meaning’. Hycner (1985: 282) defined a unit of general meaning as ‘*those words, phrases, non-verbal or paralinguistic communications which express a unique and coherent meaning*’. The challenge for the researcher was to determine what might constitute a unit of general meaning, and where there was ambiguity, the researcher included it. An example of this process is shown in Table 6.2 where the processes of R&D were discussed with one R&D manager.

**Table 6.2. Delineating units of General Meaning.**

Full Text	Units of general meaning
<p><i>‘Hmmm, let me think...[pause]...we have several R&amp;D stages<sup>1</sup>. They are relatively separate<sup>2</sup> from each other, but, but they also feed into each other<sup>3</sup>, and er, are not entirely separate<sup>4</sup>. We start at the beginning<sup>5</sup> with a customer telling us what they need, and so we put the idea into R&amp;D<sup>6</sup>. So this is the first stage<sup>7</sup>, an idea stage<sup>8</sup> and from this we start formulating a product, and this is the formulation stage<sup>9</sup>...[pause]...So, so, from here, we, erm, move the product into the antiviral testing stage<sup>10</sup>, y’know, does it work? All going well, and often it doesn’t...[laughs]...we have stages to test product safety<sup>11</sup>, stability<sup>12</sup>, and let me think, if this works, we do the numbers<sup>13</sup> and, er, er, see if it is financially viable. So not too many process stages<sup>14</sup>, but all-important!</i></p>	<p><sup>1</sup> Several R&amp;D stages  <sup>2</sup> Relatively separate  <sup>3</sup> Feed into each other  <sup>4</sup> Not entirely separate  <sup>5</sup> Start at the beginning  <sup>6</sup> Put the idea into R&amp;D  <sup>7</sup> The first stage  <sup>8</sup> An idea stage  <sup>9</sup> Formulation stage  <sup>10</sup> Antiviral testing stage  <sup>11</sup> Product safety [process stage]  <sup>12</sup> Stability [process stage]  <sup>13</sup> We do the numbers [process stage]  <sup>14</sup> So not too many process stages</p>

Prior to this, the respondent had discussed various other R&D aspects that led up to the response detailed in Table 6.2 of the process stages of R&D. As can be seen from this table, there is a continued emphasis by the respondent of the R&D stages, through repetition of the word ‘stage’ and explicit references to specific process stages throughout R&D. As Hycner (1985: 282) stated: *‘At this stage these meanings are those experienced and described by the participant irrespective of whether they later are determined to be essential, contextual, or tangential to the structure of the experience of wonder’*. An example of one of the challenges was segmenting the units of general meaning, which are subjective decisions made by the researcher. Simplistically for instance, the researcher of this study may have segmented the discourse into one unit of general meaning, whereas another researcher may have segmented the same discourse into two units. *‘Given different perspectives among*

*phenomenological researchers there are bound to be minor differences even when utilizing the same general method'* (Hycner, 1985: 284). While there are challenges for determining the units of general meaning, the researcher can amend their choices later and throughout the explicitation stage.

Beyond the brief demonstrative delineation of units of general meaning as shown in Table 6.2, this process was applied to the all manager-based interviews carried out in this study, to draw out units of general meaning for the research question, aim and objectives of this study, and as shown in the following sections.

#### ***6.3.2.1. Units Relevant to the Research Question***

The prior stages to delineating units relevant to the research question, has created a platform to address the research question, which in this study is:

*'How do UK based SMEs carry out process R&D for antiviral disinfectants?'*

This is a critical stage of the research, and in the process of explicitation towards addressing and understanding the phenomenon. Again, as this is a subjective process, the question of which units are relevant to the research question is not necessarily clear at this stage of the explicitation process. On this basis, and when in doubt, the researcher included units which appeared of value, with the potential of removing unnecessary units at a later point if required. Directly addressing the research question to the units of general meaning produced the following examples of units of general meaning shown in Table 6.3.

**Table 6.3. Addressing Units of General Meaning to the Research Question**

Units of general meaning
<sup>1</sup> <i>Several R&amp;D stages</i>
<sup>2</sup> <i>Five R&amp;D stages</i>
<sup>3</sup> <i>Six R&amp;D stages in total</i>
<sup>4</sup> <i>We formulate, test product activity, safety, stability, and economics</i>
<sup>5</sup> <i>The R&amp;D has five scientific component stages</i>
<sup>6</sup> <i>Six linked stages to get a product to market, that's R&amp;D!</i>
<sup>7</sup> <i>The market drives what we do in R&amp;D</i>
<sup>8</sup> <i>The customer has an idea, and we use R&amp;D to make it a reality</i>
<sup>9</sup> <i>We work with the client to get the product to market, R&amp;D is the vehicle</i>
<sup>10</sup> <i>Our company is market and customer driven, we respond to both</i>
<sup>11</sup> <i>When a stage fails, we rethink, and cycle back through, we get there in the end</i>
<sup>12</sup> <i>R&amp;D is somewhat linear, but with decision gates...to decide what stages pass and fail</i>
<sup>13</sup> <i>Sat with R&amp;D is the economic analysis, this is important</i>
<sup>14</sup> <i>If the finances of the product are wrong, R&amp;D has failed, we have no product</i>

With fourteen respondents having been interviewed, Table 6.3 is only a snapshot of the units of general meaning, but is intended to demonstrate this stage of explicitation. For the research question, units of meaning were considered relevant that either directly or indirectly interacted with the R&D process stage. On this basis, aspects such as the total number, order and naming of process stages was of interest for example. Only examining units related to the physical aspects of R&D as in the previous example, would have potentially biased any eventual constructed model of R&D. It was therefore necessary to examine units with a wider meaning, which could result in the researcher understanding the management aspects of R&D, market and customer drivers for R&D and what happens after the R&D stage. The units of general meaning drawn out of this stage were in practice much greater than shown in Table 6.3. With the wealth of data drawn out in this stage, it was important to be able to undertake the process of 'Eliminating Redundant Units of Meaning', which is explored in the following section.

### ***6.3.2.2. Eliminating Redundant Units of Meaning***

In addressing the units of general meaning, with a view to eliminating redundant units, it was important to consider the relevance of each unit and their wider contextual aspects, to create a greater clarity to meaningfully engage with and understand the phenomenon of antiviral disinfectant R&D.

Within these aspects are elements such as the frequency of units, are non-verbal and paralinguistic cues, which can alter the relevant meaning of the discourse given. An example of this is a respondent giving the same two units of meaning, but having different non-verbal or paralinguistic cues, which could be standing and shouting while giving one unit, and sitting laughing while delivering another. It was therefore important for the researcher not to place too much emphasis on literal frequency of units of meaning without examining a wider context.

The process of eliminating redundant units of meaning was a long and repetitious task, where the researcher continually examined the transcribed discourse and units of meaning, in light of the research question, aims, objectives and chronology of discourse to try to draw out the ‘more’ relevant and important units. After eliminating redundant units, the researcher clustered the units to form themes relevant to this research, which is shown in the following section.

### ***6.3.3. Clustering Units to Form Themes***

After removal of the redundant units of meaning, the researcher again bracketed his preconceptions to cluster units into themes. The number of processes in the R&D stage, their segmentation and management perceptions were examined in the context of clustering units to form themes. In-depth clustering was carried out to rigorously interrogate the phenomenon of the R&D stage. This stage of the work involved the researcher’s subjective interpretations of the importance of themes and it is worth drawing on the thoughts of Colaizzi (1978: 59): *‘Particularly in this step is the*

*phenomenological researcher engaged in something which cannot be precisely delineated, for here he is involved in that ineffable thing known as creative insight’.*

As there were a number of units relevant to the phenomena of interest, it was possible to cluster units of relevant meaning, for example, into the ‘number of R&D stages’, ‘R&D stage segmentation’ and ‘whether there was stage decision-making’ and ‘the use of feedback loops’, which is shown in Table 6.4, with numbers 1-7 being linked to the respondent number in this table.

**Table 6.4. Clustered Units to Form Themes**

Theme	Executive Management	R&D Management
R&D Stage Number	<sup>1</sup> Six, <sup>2</sup> Six, <sup>3</sup> Six, <sup>4</sup> Six, <sup>5</sup> Six, <sup>6</sup> Five, <sup>7</sup> Six	<sup>1</sup> Five, <sup>2</sup> Five, <sup>3</sup> Five, <sup>4</sup> Five, <sup>5</sup> Five, <sup>6</sup> Five, <sup>7</sup> Five
Stage Order	<sup>1</sup> Decision-making, Formulation, Efficacy, Stability, Safety, Decision-making. <sup>2</sup> Product meeting, Formulation, Efficacy, Health, Stability, End meeting. <sup>3</sup> Product meeting, Formulation, Efficacy, Safety, Stability, Decision-making. <sup>4</sup> Meeting, Formulation, Efficacy, Safety, Stability, Meeting. <sup>5</sup> Formulation, Efficacy, Stability, Safety, Stability, Meeting. <sup>6</sup> Meeting, Formulation, Efficacy, Safety, Meeting. <sup>7</sup> Product meeting, Formulation, Efficacy, Safety, Stability, Product meeting.	<sup>1</sup> Formulation, Efficacy, Stability, Safety, Decision-making. <sup>2</sup> Meeting, Formulation, Efficacy, Health, Meeting. <sup>3</sup> Product meeting, Formulation, Efficacy, Safety, Decision-making. <sup>4</sup> Meeting, Formulation, Efficacy, Safety, Stability, Meeting. <sup>5</sup> Formulation, Efficacy, Safety, Stability, Health & Safety. <sup>6</sup> Formulation, Efficacy, Stability, Safety, Meeting. <sup>7</sup> Product meeting, Formulation, Efficacy, Safety, Product meeting.
Stage Decision-Making	<sup>1</sup> Yes, <sup>2</sup> Yes, <sup>3</sup> Yes, <sup>4</sup> Yes, <sup>5</sup> Yes, <sup>6</sup> Yes, <sup>7</sup> Yes	<sup>1</sup> Yes, <sup>2</sup> Yes, <sup>3</sup> Yes, <sup>4</sup> Yes, <sup>5</sup> Yes, <sup>6</sup> Yes, <sup>7</sup> Yes
Feedback Loops?	<sup>1</sup> Five, <sup>2</sup> Five, <sup>3</sup> Five, <sup>4</sup> Five, <sup>5</sup> Five, <sup>6</sup> Four, <sup>7</sup> Five	<sup>1</sup> Four, <sup>2</sup> Four, <sup>3</sup> Four, <sup>4</sup> Four, <sup>5</sup> Four, <sup>6</sup> Four, <sup>7</sup> Four

In Table 6.3 all the units of relevant meaning have been clustered by the researcher, which involved examining Table 6.1 And Table 6.2, as well as revisiting the interviews several times. For brevity, discrete units of measure were used for aspects such as the total number of R&D stages, which in conjunction with interviews, was used to produce a stage order of R&D processes. Whether the stages were gated for decision-making and whether feedback loops were employed were also considered. Throughout the process of clustering units to form themes, the research question was continually posed to the data, and the data posed to the research question, in a resonant fashion, to draw out important themes for this study. In doing this, the central theme was the production of an R&D process model (for antiviral disinfectants).

Table 6.3 showed that R&D managers tended to more thoroughly segment process stages into individual aspects and more easily describe each stage, which was linked to be closer to the phenomenon and their management practices. Executive managers were used slightly different segmentations, but which were similar to those used by R&D managers. Under a thick description, both management types used similar descriptions for R&D, in that both manager types perceived that feedback loops were used throughout R&D, when a stage failed, to potentially rectify the failure. However, when digging deeper into management knowledge of R&D, differences between managers were observed, but at this stage, were recorded but not more fully examined until the next stage in the explication process.

Finally, after the process of clustering units to form themes, the explication stage of ‘Summarising each Interview and Warranting’, was carried out and is examined in the following section.

#### ***6.3.4. Summarising each Interview and Warranting***

After completing the previous stages, the researcher went back to the interview transcripts and wrote a summary of the interviews incorporating the themes drawn out from the explicitation process, to give a greater sense of a whole context for the emerging themes (Hycner, 1985). A second interview with all interviewees was conducted to verify and warrant research findings produced so far. These findings were discussed with the respondents, and additional information perceived relevant by the researcher and respondent were discussed as perceived appropriate to more fully capturing the phenomena of interest. This further information provided further knowledge for the final stage of the explicitation process of 'Extracting Themes and Summarising', as shown in the following section.

#### ***6.3.5. Extracting Themes and Summarising***

After carrying out confirmatory interviews with respondents, the procedures utilised in the explicitation process prior to this stage were repeated, which produced minor changes to the research data. Although there were minor modifications, the themes were not changed, only the contextualisation, which is discussed in Chapter 7.

Summarising the extraction of themes, there were two groups of managers assessed in this study, including executive and R&D managers, with variations between and in groups being produced from the interview stage about the R&D process stage. Using a thick examination and description, there was a similarity of the surface-based phenomena being examined, but as a greater depth of understanding was sought, this varied between executive and R&D management. Chapter 7 shows the differences more explicitly through expanded model views, for the construction of models built on different manager perceptions, understanding and construction of the reality of the R&D process stage.

The following composite summary was composed to '*capture the essence of the phenomenon being investigated*' (Hycner, 1985: 294). The main themes drawn from



this stage was that there are differences in the number of perceived R&D stages from executive and R&D managers, but that there are many similarities between management perceptions. R&D managers showed a much deeper knowledge of R&D processes, particularly from a scientific viewpoint, but were often less aware of the wider organisational and business aspects that R&D interacted with. The converse of this was shown for executive managers who were less aware of the scientific processes but much more knowledgeable about the interaction of R&D with other organisational aspects. Executive managers stated that they were less involved with the day-to-day running of R&D and particularly decision-making, which was confirmed by R&D managers who appeared to act like stage-gates for all R&D management decisions. Importantly however, executive managers had an overriding decision-making capability of stopping and starting the R&D stage. It was noted that this led to conflict between executive and R&D managers, due to different perceived drivers for R&D (executive managers being more profit driven than R&D managers who often focussed on ‘advancing’ science). Coupled with this was the difficulty that both types of managers described for communicating complex business and scientific aspects, to each other, and which were both considered pivotal for successful R&D. Importantly, no company used a model for R&D, although some of the managers had experience of models for R&D from previous employment. Upon questioning the managers, there was a general feeling that a model may aid in developing understanding throughout the company, but concerns were raised about how it could be constructed to enable sense to be made of complex phenomena. The researcher detailed the potential of using expanded model views to encompass both scientific and business phenomena, which appeared to be well received as a vehicle of addressing this issue.

Table 6.5 highlights the themes extracted and summarised between executive and R&D managers.

**Table 6.5. Extracting Themes and Summarising**

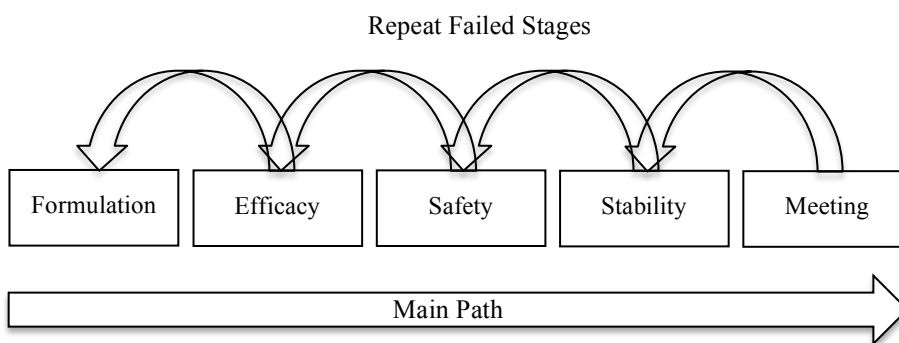
Summarised Themes	Response by Executive Managers	Response by R&D Managers
Perception of R&D	Predominantly a scientific activity leading to product commercialisation to satisfy market requirements.	Predominantly a scientific activity leading to new knowledge and subsequent product commercialisation
Organisational Interaction	Carry out organisational management including overseeing R&D.	Limited to R&D, with interactions mainly coming from executive management.
Knowledge of R&D	Limited to process stage names with basic understanding of what goes on in each stage.	In depth knowledge of the scientific process stages of R&D but with less understanding of business drivers for R&D.
Decision-Making	Focused towards stopping and starting the R&D stage. Executive management does not deal with decision-making for scientific aspects.	Focused towards the day-to-day decision-making for R&D, and where business aspects are relevant, executive management is involved.
Management Communication	Discursive framing is predominantly through business language.	Discursive framing is predominantly through scientific language.
Perceptions of R&D Models	Viewed through the lens of management drivers, but perceived as a way of increasing sense between executive and R&D managers.	Viewed through the lens of R&D/scientific drivers but perceived as a way of increasing sense between executive and R&D managers.

In the next section, the ‘Construction of the Alpha Model’ is considered.

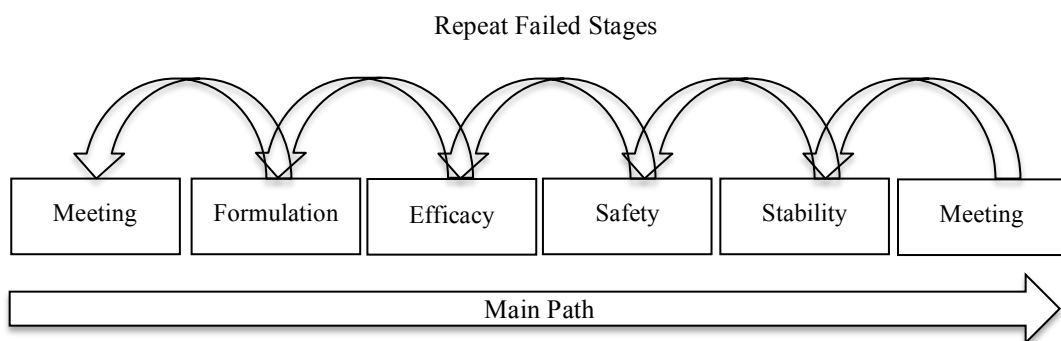
#### 6.4. Construction of the Alpha Model

The explicated information was used to construct the alpha model shown below for both R&D and executive managers. Both executive and R&D managers expressed that the alpha model should be constructed pictorially and represented using a flowchart, which encompassed the different process stages. Alpha models for both R&D and executive managers were constructed using the explicated R&D stages, and are shown in Figures 6.2 and 6.3 respectively.

**Figure 6.2. R&D Manager Initial Process Alpha Model**



**Figure 6.3. Executive Manager Initial Process Alpha Model**



Importantly, both Figure 6.2 and 6.3 showed a progression of the R&D process stages in the same order, with the only difference between the models being the additional 'meeting' stage in the executive R&D model. The decision of the order of the stages was made based on the majority of R&D and executive managers arguing that R&D occurs in this order. A main path has been shown in both models, with a

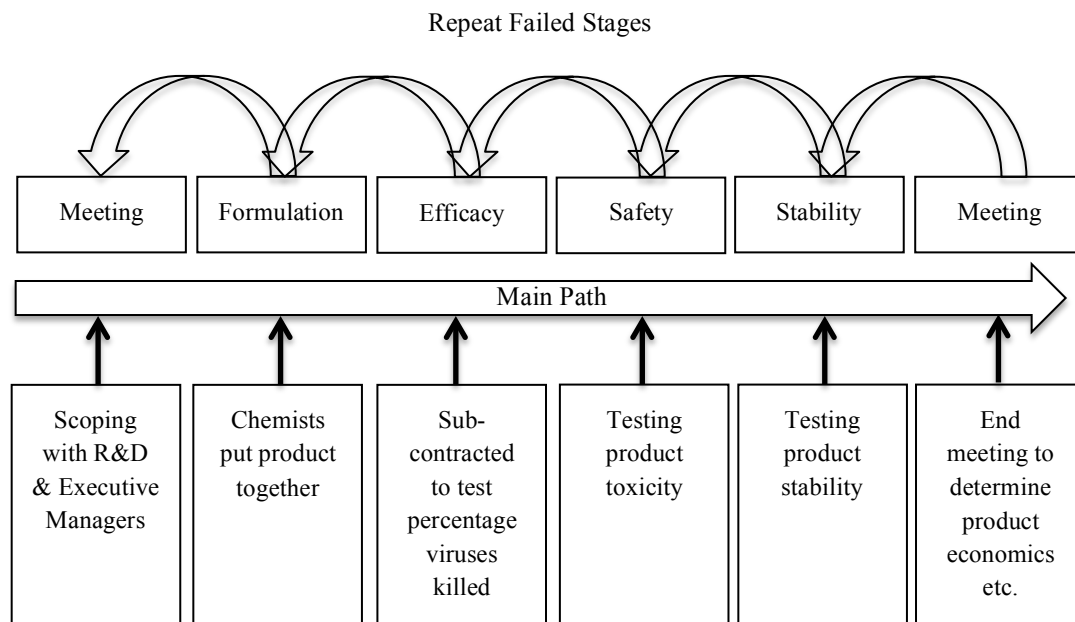
potential to cycle back through the stages if a stage fails. There is also the potential to terminate R&D, if required. Between each stage is a decision-making gate where R&D managers decide to go forward to the next stage, repeat a stage or an executive manager might terminate R&D.

After the construction of both models, these models were firstly shown to respective managers to seek their opinion on the representation of R&D (*i.e.* the R&D model to R&D management, and the executive model to executive management). After feedback was taken, both models were discussed with R&D and executive managers to synthesise these models into a single model, with an expanded view, which is shown in the following section ‘Construction of the Beta Model’.

### **6.5. Construction of the Beta Model**

Upon showing R&D and executive managers both alpha models constructed from the previous section to verify them as a reflection of their perceptions of R&D, a synthesis was undertaken to construct one model (the beta model). Simplistically, this involved adding the first stage of the ‘meeting’ from the executive model into the R&D stage. Although, not a scientific stage, upon further discussion, there was a general consensus that this additional stage should be added to the R&D model. Upon this addition, the models became identical, while under a non-expanded view. This warranting stage, also considered an expanded model view, which enabled the additional shared meaning for each of the stages that would make sense for executive and R&D managers. The reconstructed model with expanded views is therefore shown in Figure 6.4.

**Figure 6.4. Beta Model of Process R&D**



The wording and pictorial representation was drawn on from the explicitation stage but also directly from manager feedback to enable the production of a model to facilitate shared meaning, and aid in the R&D stage. Shared meaning between managers was examined by the language used by managers as a proxy to their sensemaking on an implicit level, and in other words similarities between repertoires used (Weick, 1995). A more explicit approach was also used in the warranting stage to directly ask respondents about shared meaning, which enabled an examination within the R&D manager and executive manager groups, as well as a totality of all managers. Directly posing the question about shared meaning and the model, as well as the consideration of repertoires used, enabled the researcher to feel confident from discourse given that shared meaning was being achieved through the model. The notion of enabling the managers to act as practical authors for the R&D model was argued as being pivotal by the managers for creating shared meaning. Thus although the model was constructed by the researcher, it was heavily guided by the respondents in the pilot and main study as well as warranting stages.

Importantly and to increase shared meaning technical terminology and descriptions beyond what executive management used, were predominantly left out of this model, as they were not perceived as being constructive. R&D managers expressed an

interest in being able to create a second layer of the expanded view to define what was carried out in their respective stages. It was however felt that this was a task that should be undertaken by R&D managers in respective companies, due to the sensitivity of the minutia that might be detailed. A perceived advantage of this potential addition is based on this additional view not being necessary for executive managers to understand or engage with, but is more of a practical guide for those engaged directly with R&D.

Warranting of the beta models with individuals beyond executive and R&D managers was not undertaken, as attempts at snowballing into other organisational members was rejected by the respondents, as it was argued that they had the knowledge. This mirrored earlier discourse in the study from initial engagements with the respondents, where executive and R&D managers presented themselves as the 'experts'. Importantly, no mention was made of other individuals that should be engaged with throughout the interview stages, and on this basis, no further attempt to warrant the model was made with any other individual.

After respondent warranting of the beta model, the model was utilised by three different respondent companies and trialled for its suitability, which at the end of this study was still on going. Preliminary feedback from executive and R&D managers was positive and although a greater length of testing was argued as being required to demonstrate the longer-term suitability of the model, short-term findings supported the use of the antiviral disinfectant beta model. As one R&D manager stated, it is '*an easier way through R&D that makes more sense*' that '*means we speak to each other better*'. A longer-term study of the implementation of this model, particularly if utilised by other companies may well be of academic interest. However, as was described by one executive manager of a company not yet trialling the model '*R&D is not set in stone, but it takes time, it takes time to move to a different system. We need to wait until an R&D cycle is finished, then we start, start with a product and see how the model works*'. This respondent highlighted the practicality of trialling this model and need to wait until a new product R&D cycle can be started to minimise the disruption to current operations.

Looking beyond the previously discussed aspects, Table 6.6 highlights the similarities, differences and contribution between the antiviral disinfectant process R&D model produced in this section and prior examples of R&D models.

**Table 6.6. An Examination of this R&D Model against Others**

Prior Models	Similarities	Differences	Contribution of the Antiviral Disinfectant Model
Stage Gate (Figure 2.3.)	Both are stage gated and split into process stages.	The antiviral disinfectant model has a predominant focus on scientific testing stages, with an expanded model view.	Elucidation of technical stages specifically for executive and R&D managers with an expanded model view. Facilitating technical stage sensemaking for antiviral disinfectants.
Design Thinking (Figure 2.5.)	Both show a linear route through R&D.	The Design Thinking model has a greater focus on the mental aspects of R&D, in comparison to the antiviral disinfectant model, which is physically orientated.	The showcasing of physical stages enables managers to target mental processes such as found in the Design Thinking Model towards ‘practical’ goals as in the Antiviral Disinfectant Model.
Technological R&D Framework Model (Figure 2.6.)	Both scientifically focused towards physical stages to develop a product and take it through R&D to commercialisation.	The Technological R&D Framework Model is more focused towards achieving legal compliance in comparison to the Antiviral Disinfectant Model. This is a consequence of the different legislative requirements, which echo into the different process stages ‘legally’ required.	A sector specific R&D model for the antiviral disinfectant sector, highlighting a simpler legislative system in comparison to the ‘harder’ legal requirements from drug R&D in the Technological R&D Framework Model.
Technological R&D with Increased View (Figure 2.7.)	Both models have a linear path through technical R&D, with physical stages being shown, which are gated.	The Antiviral Disinfectant Model shows greater flexibility, in that a failed stage does not mean failed R&D as in the Technological R&D with Increased View Model. The Technological R&D Model with Increased View is more focused towards achieving legal compliance in comparison to the Antiviral Disinfectant Model. This is a consequence of the different legislative requirements for the products being developed.	An expanded model view for all stages, with failed stages being repeated. The technological model frames outcomes as ‘success’ or ‘failure’ which is linked to the cost of the R&D stage, and where failure occurs R&D stops. A sector specific R&D model for the antiviral disinfectant sector, highlighting a simpler legislative system in comparison to the ‘harder’ legal requirements from the Technological Model.

In the next section, the ‘Summary of the Results’ is discussed to draw together and build on the findings in this chapter.

## **6.6. Summary of the Results**

This study investigated the research question: *How do UK based SMEs carry out process R&D for antiviral disinfectants?* From the seven R&D companies examined, R&D was shown to have an executive management structure, which oversaw R&D but often with limited decision-making beyond stopping and started R&D. The day-to-day management of R&D was undertaken in these companies by a single R&D manager, who had been scientifically trained, and who made nearly all R&D management decisions, and oversaw technical staff in this stage. Both sets of executive and R&D managers used different language to communicate about R&D based on their knowledge and experience, which was a perceived source of confusion and conflict. This extended into which stages were considered part of R&D. For example, R&D managers argued that only technical and scientific stages were part of R&D, whereas executive managers considered pre-R&D scoping, decision-making and meetings as part of R&D. Importantly, all managers considered the R&D stage to be linear from start to finish (albeit with different stages involved), with each stage being gated by decision-making for whether to proceed, repeat the stage, or stop. This enabled the production of an alpha and beta model (with the beta model having been warranted) and with expanded views to show more detailed information. The model produced (with six stages), has elements of other models (such as the Stage Gate), but is unique in that it incorporates two management constructions (executive and R&D) and created shared meaning for management. These and other aspects are discussed more thoroughly in the next section for the ‘Discussion of the Results’.



## 6.7. Discussion of the Results

The purpose of this study and thesis was to examine and understand antiviral disinfectant R&D, at a sufficient depth that would enable the construction of alpha and beta R&D models. The objectives were thus:

- a) Through a literature review and current practice, to determine the current scientific and business processes for UK SMEs engaged in antiviral disinfectant process R&D;*
- b) Informed by a) above to produce an initial alpha model for UK SMEs engaged in antiviral disinfectant process R&D;*
- c) Informed by a) and b) above, to verify/warrant the initial alpha model and so produce a beta R&D model.*

This research produced the following outcomes to address the objectives:

1. An understanding of how antiviral disinfectant process R&D is managed and carried out in UK SMEs, with the different types of management interactions within R&D being drawn out;
2. An understanding of the perceptions of executive and R&D managers for how R&D is carried out in their companies, as well as the difficulties in communicating between different managers;
3. The Construction of an alpha and beta model of R&D that was warranted by both R&D and executive managers;
4. The Production of an expanded model view for the process stages to aid in the construction of shared meaning between managers.

This study examined seven R&D and seven executive managers employed in UK SMEs engaged in antiviral disinfectant R&D. The themes used to draw out the questions during the interview stage were based on the literature review in Chapter 2 and the sensitisation of the researcher to the sector.

Both executive and R&D managers perceived the R&D stage to consist of almost identical stages (using similar language to label and describe each stage), and ordering the stages similarly and in a linear fashion. The main difference between manager views was based on executive management regarding the initial scoping as being part of the R&D stage and R&D managers, not regarding this stage as part of R&D. Interestingly however, both manager types regarded the end meeting as part of R&D. Importantly, upon warranting being carried out and the two alpha models being shown to the different managers, the R&D managers opted to include the initial scoping meeting as part of R&D. By doing this, a synthesised singular R&D model was produced as the foundation of all other model aspects that would be added. Arguably, it was an important finding that both types of manager across several companies constructed R&D in such a similar way, indicating that the model produced from this study has a potential to be used by other antiviral disinfectant R&D companies.

It was important to study this model and contextualise it in light of prior R&D models. As a starting point, the antiviral disinfectant process model constructed in this study, herein referred to as the ADP model is focussed towards a different sector than models previously examined, which echoed into the process stages constructed by respondents and model view expansions. Thus, the ADP model reflects the phenomenological paradigm used in this study, where the phenomenon of interest, *i.e.* antiviral disinfectants was ‘true to itself’ and was modelled accordingly. More explicitly, this approach differed from the philosophical basis of other models, which have been grounded in methodologies geared more towards the physicality of R&D, but have not given as much attention to the constructing lens of R&D respondents as within a phenomenological approach. This is an important aspect and arguably extends the theory of R&D process models, as the model produced may more closely mirror the management reality of process R&D than other models.

Looking at the ADP model, it appears to be embedded within both the technological model (Canongia, 2007) and market/consumer model (Cooper and Edgett, 2013). This claim is made, as there are elements of the ADP model, which are encompassed within both technological, and market/consumer models, which will now be more

fully explained. Looking at the Stage Gate Model first as an example of a market/consumer model, the ADP model is gated, with decision making being made on a day-to-day basis and between stages by R&D managers, with the potential for executive managers to terminate any failed stage. Importantly, within the ADP model, there is no discovery stage at the beginning, as the R&D companies either utilise customers to drive demand, through specific requests for product development (market pull) or, alternatively, develop technology without a specific customers (technology push). The first stage in the ADP model is the meeting (scoping) stage and which is the second stage in the Stage Gate Model. The third stage in the Stage Gate Model (Build Business Case) is rolled into the meeting (scoping) stage of the ADP model. The next stages of ‘development’ and ‘testing and validation’ are expanded in the ADP model into ‘formulation’, ‘efficacy’, ‘safety’ and ‘stability’, which are all the technical stages. Importantly, the expansion of the ADP model differs from the Stage Gate Model in that although both have expansions, the ADP model is more orientated towards isolated use by a limited number of managers. Finally in the Stage Gate Model, there is a ‘launch’ stage, which is not present in the ADP model, as the ADP model is focussed on the pre-commercialisation aspects of R&D. Arguably however, and although there is a final stage in the ADP model of a meeting to discuss economics and potential customers etc. it is conceivable that if the ADP model went beyond the pre-commercialisation aspects of R&D, the final Stage Gate Model stage of ‘launch’ could be used.

Although there is a similarity to the Stage Gate Model, upon examining the technological model used by Roche (2013), there is also a similarity between the ADP model and the Roche model, as both models have a focus on displaying the technical stages and aspects of R&D, including expanded views. Looking also at the technological model by Cassimon *et al* (2013), this is also a gated model, with options of success, failure and discontinuation for each stage. Examining the fundamentals of all of the models discussed so far are commonalities, in that they are all linear progressions through R&D, with a potential for success, failure and discontinuation at each stage. The technological models are perhaps not surprisingly more orientated to displaying the process stages of R&D, which is the case for the ADP model. There is also less focus with the technological models for displaying

business or market aspects, but which the ADP model takes into some account at the beginning and end of R&D. Importantly, however the recycling elements back into failed stages for ADP model enabled a 'new' view of a 'failed' stage, as due to what is often a chemical simplicity of the product, it could be used to start a new product R&D cycle. In other words, a failed stage may well be repeated to complete an R&D cycle, but it may also generate new potential products suitable for other products.

The ADP model uses expanded views to communicate shared meaning between different managers for all of the stages within the model. This is similar to the Roche (2013) model, which also appears to communicate shared meaning between different industrial actors. Creating shared meaning between R&D and executive management was raised as being crucial to the R&D stage by many of the respondents, during the interview stage. This is an important finding, as it arguably enabled a foundation for the giving and making of sense between executive and R&D managers, where the focus can be made towards creating a simpler or preferred view of R&D in comparison to one that is more complex. In other words, although different managers have their own constructed views of R&D, a model can be used to aid management working together towards the goal of a product successfully leaving the R&D stage into commercialisation. This has the potential to decrease the time and cost of a product going through R&D as well as removing some of the communicated 'fuzziness' of the R&D stage. Warranting the ADP model through respondent discourse, while making the respondents practical authors of this model, could be argued as an attempt to more deeply embed this model within the shared subjective realities of respondents in comparison to prior models. It is important to recognise that while no objective claim can be made about which R&D model is 'closest' to the phenomenon of R&D, the approaches taken in this study were all focussed towards closely mirroring the ADP model with constructed respondent realities of R&D. This is argued as increasing the strength of a claim made by one respondent that this model is '*something that works*'.

Nobelius (2004) has argued that the technological model has advanced into the sixth generation, whereas the consumer model is a mixture of the second and fourth generations, with a particular focus on cost, quality and particularly time to market

(Chaudri, 2013). Examining the consumer model in greater detail however (Liedtka, 2011; BRIDGE Collaboration, 2013) indicated that due to a desire to collapse the process time, the first stage at least, requires that all actors in the R&D process are identified and utilised. This is certainly the case with the ADP model in both of the meeting stages (at the beginning and end of R&D), which has some resonance with the sixth generation of R&D, with an emphasis and networking and collaboration. Also the efficacy stage (antiviral testing) was in all cases sub-contracted to perceived specialists, who would work closely with the R&D company, which also draws in elements of the sixth generation of R&D. Considering that the APD model appears to have aspects of both the consumer and technological models, it is perhaps not surprising that different generations of R&D appear at different stages of R&D. Looking at the ADP model, where the model mirrors the technological or consumer models, the respective generation of R&D is also mirrored. Many of the respondents felt it important to capture the phenomenon of R&D, but to be able to modify it as they saw fit through further expanded views. Thus while the stages of R&D and expanded views reflect the R&D experience of the respondents, it is also reflexive enough to be able to evolve as required by respondents. Again and drawing on the phenomenological paradigm, this is a perceived strength of this model, and showcases a difference between the ADP and prior R&D models. This is not to suggest that other models cannot be adjusted but that using phenomenology enabled a core foundation of the R&D experience to be captured, allowing adjustments while maintaining the core reflection of antiviral disinfectant R&D.

There is of course no one size fits all for R&D, and the question of how to model R&D is subjective, and with no one model having gained industrial acceptance of how to carry out R&D. While technological models enable a greater view of process stages, they potentially complicate and confuse, and in this study, it was perceived as critical to make the model useable. Thus it was discursively framed and warranted to enable shared meaning between managers, with a potential for further expanded views if required to convey greater in depth knowledge about specific process stages.

In the final chapter of this study, ‘Conclusions and Recommendations’ are made for this and future work, and is examined in the following section.

## **Chapter 7. Conclusions and Recommendations**

### **7.1. Introduction**

The preceding chapters have established the research framework, detailed the collection and explicitation of data, and presented the research findings. Based on a review of the literature and the researcher's sensitisation to the phenomenon, a research gap regarding antiviral disinfectant process R&D was identified. The research question, aims and objectives were constructed to address the research gap. Through the use of a phenomenological approach, this study was designed and implemented to provide an answer to the research question that also enabled the construction of an R&D process model. The model has extended academic literature and has already been utilised by companies within the antiviral disinfectant sector, who have described it as of 'practical benefit'.

This chapter has focussed on drawing conclusions and recommendations from this study. Study limitations are also recognised and discussed in light of this study, and recommendations for future work are made. In the following section, a summary of the results is made.

### **7.2. Conclusion of the Study and Recommendations**

From the results drawn out from this study, the following conclusions and recommendations, are highlighted in this section for UK based antiviral disinfectant SMEs. This is alongside demonstrating the key contributions for the advancement of knowledge, theory and managerial practice for each conclusion.

## **Conclusion and Recommendation 1**

Key theme: R&D.

Conclusions: R&D was cited by many of the respondents as being a confusing environment to work within, where there was often conflicting departmental, and wider organisational drivers and discourses. Although the purpose of R&D varied between respondents, there were two separate discourses, which were prevalent within each management group (executive and R&D managers). Executive managers were keen for R&D to be a vehicle of taking a specific product to market, often to satisfy a perceived customer need and arguably fitting more within a market pull view of R&D. R&D managers felt that R&D was a vehicle to discover new insights for the technology being developed, which may have longer-term benefits beyond the product being developed, with unknown products waiting to be discovered, and thus sits more within a technology push view of R&D. Importantly R&D managers did not always feel that they understood executive manager requirements for products being in R&D, and coupled with this, they perceived executive managers as ignoring technological discovery. Conversely, executive managers argued that R&D managers did not appreciate customer requirements. This point raised an important issue about the communication between management, as all managers argued that they did not always do well to communicate effectively about R&D, which was a perceived limitation by the managers to R&D being more effective.

Key contributions: Respondent discourse about R&D explicitly drew attention to the different views espoused by different managers, and highlighted a technology push/marketing pull divide. These opposing views resulted in confused action about what stage to do when, when to repeat a stage and what it meant to pass or fail a stage. A synthesis of these views was achieved by the

use of a model, which facilitated a more fit-for-purpose view of R&D for both managers that could include elements of technology push and market pull. This was coupled with the managers deciding to be more proactive in problem solving through discourse. This was argued by the managers as having been facilitated by the approach used in this study, which was perceived as a 'more forgiving' view of organisational life. This can be linked to sensemaking being learning based, where a right answer is not necessarily sought, but more something that is good enough.

**Recommendation:** The use of a sensemaking and reflexivity based system within an often chaotic and uncertain technologically based R&D environment has potentially much to offer these respondent companies. This is particularly the case where a move can be made in many instances for a view that is not right but good enough. This deviates from the Technological Models examined in this study where a heavier legislative requirement is arguably much less forgiving of this stance. However, with a softer approach to antiviral disinfectant regulation that is often determined 'in house' this approach may be beneficial. It may also find synergy with the move to consider technology push and market pull aspects of R&D, which has received little discourse prior to this study. Engaging with this aspect further may well enable more open discourse where product failure can result in new product R&D cycles, without the fear from R&D managers as having to report a failure. Due to the R&D cycle being relatively quick and adjustable, this approach has the potential to deliver products to customers and in line with a market pull strategy, but also be more 'blue sky' for the R&D managers who are interested in technology push.



## Conclusion and Recommendation 2

- Key theme: Creating shared meaning within R&D.
- Conclusions: R&D management is split into executive and R&D managers, where executive managers predominantly take a macroscale view of R&D and are responsible for stopping and starting R&D. R&D managers engage with R&D at a much deeper level and are responsible for the day-to-day running of R&D, decision-making and communication of technical aspects of the R&D stage in comparison to executive managers. Executive managers had backgrounds in business and self-identified as such, whereas R&D managers were keen to self-identify as scientists managing R&D *i.e.* R&D managers. Importantly, a divide was recorded for the education and workplace backgrounds that both respondents constructed. Simply, executive managers had a cultural background from ‘business’ and R&D managers from ‘science’ with much discourse being provided by all respondents about how little cross over there was between these areas in their respective workplaces. In practical terms, this meant that both manager types used language-based repertoires to promote their organisational identities, and all aspects of R&D. This created a conflict between ‘business’ and ‘science’ speak where repertoires were used to increase the power of the person using them to legitimise their view of R&D as ‘correct’. R&D suffered from this style of discourse, resulting in limited shared meaning, which in turn impacted on sense- and decision-making. It was recognised by all managers that this was problematic for R&D as well as the wider organisation, and also impacted upon managers’ ability to effectively manage.
- Key contributions: Identification was made that repertoires were resulting in cultural confusion based on the language used *i.e.* science repertoires versus business repertoires. Through the

phenomenological paradigm, this area was honed in on to highlight how conflicting repertoires could cause confusion within R&D and result in R&D cycle failure. Thus respondents were facilitated to actively engage with trying to draw closer to the phenomenon of R&D, rather than perceiving the construction of an R&D model as a 'box ticking exercise'. Importantly the researcher promoted a view that there were no 'right' or 'wrong' answers and that if reflexivity was engaged with alongside phenomenology, this may enable a more fit-for-purpose view of R&D that was close to the respondents 'real' views. Thus, respondents actively engaged with the research process producing much rich discourse about the phenomenon, and in conjunction with warranting processes led to a model being constructed to promote shared meaning.

**Recommendation:** Creating shared meaning and understanding of the R&D stage between executive and R&D managers has the potential to facilitate sense- and decision-making (Billig, 1996). Most importantly a distinction was made by managers from this study that greater understanding and shared meaning could be achieved by 'talking more' using 'good discourse'. Although a model has been constructed in this study, more academic and managerial data still remains to be explicated, including repertoires that inhibit or increase sense- and decision-making between managers. This area has received little attention in a technology context for R&D. It is interesting to draw on the work of Davies (2011) from a B2C consumer sales study, which considered the linguistic tools where metaphor, narrative and science fiction etc. have all been found to aid in the communication of complex phenomena particularly through repertoires (Davies, 2011), and can be linked to improved decision-making. While no claim is being made about how this might work for an R&D cycle, it is

conceivable that an exploration of the linguistic tools linked to repertoires may well facilitate increased shared meaning, due to the increased cultural similarity of discourse being used. Practically and considering wider organisational aims, it is suggested that executive managers work to disseminate company objectives to R&D managers, and likewise R&D managers disseminate the more in depth R&D aims and realities to executive management using lower levels of ‘business’ and ‘science’ speak than might normally be used in R&D orientated organisational life.

### **Conclusion and Recommendation 3**

Key theme: Modelling R&D.

Conclusions: Due to differences in cultural backgrounds including education and work experience, all respondents viewed models differently. A divide existed between executive and R&D managers in the way that both groups viewed R&D, and was linked to prior experience with executive managers having experience with business models, and R&D managers with science models. Importantly, none of the companies were using R&D models at the time of the study or had any direct experience of using them. More than this though, no company had put together a system from start to finish of what was encompassed in R&D prior to this study. Although no company was using an R&D model, all expressed a willingness to undertake a study examining this aspect, with three company’s trialling the developed R&D model. This was argued, as needed on the basis that ‘we will do anything to resolve the communication problems in this company’. Expanding on this aspect, all managers considered themselves experts, but unable to rectify the issue of a lack of fit-for-purpose communication, which was, perceived as damaging

R&D. Through the construction of a warranted R&D model, a synthesised view of R&D was constructed by the researcher in conjunction with the respondents. The high level of interaction from the respondents was argued by the respondents as increasing their positive perceptions towards being creators of a model they might use. The phenomenological approach with the method of explicitation aided in this aspect, by helping make the meaning clear for respondents engaged in this study. In other words, it helped the respondents become practical authors, and take ownership of the model. It is accepted that the model developed in this study has a similarity to other models such as the Stage Gate Model and Technological Models, but there are aspects of the antiviral disinfectant model that are different from prior models. The philosophical basis is arguably closer to the perception of R&D from respondent views in comparison to other models, although this claim cannot be verified, but is made on the nature of the phenomenological method in comparison to other methods used for model building. The high level of interaction with respondents was argued by respondents as essential to making them take ownership of the model and as one executive manager stated '*we don't want someone else's model, we want something we made*'. Practically this appeared to make a difference for this respondent as the respondent's company has trialled this model.

Key contributions: The model produced in this study was argued by respondent's as being authored by them, and as such useable. This suggests that there is a potential that high technology companies engaged in complex and opaque research may prefer to be involved in the model building stage. The method of phenomenology found favour with the respondents as it placed respondent perceptions as key, thus validating their identities as experts in their respective areas. More than this

though, the approach taken in this study was argued as being pivotal for achieving a high level of interaction and a desire on the part of the researcher and respondents to closely mirror the reality of R&D in a model. This led to an antiviral disinfectant model being produced that was claimed by all respondents as being fit-for-purpose for this sector and has been trialled, with positive feedback at this time from three companies. The strength of this model is the closeness to the phenomenon of interest and high-level of respondent participation and warranting. It is therefore suggested that a phenomenological approach with warranting may have much to offer to gain access to respondents as well as securing their active participation to facilitate model building.

**Recommendation:** A further investigation into the reasoning behind high levels of respondent interaction may well be worthwhile. This is particularly the case for phenomenological research using respondents who perceive themselves as experts. As one R&D manager stated *'you can't do some silly stats on what I know, its what I know that's important'*. While not attempting to undervalue the potential value of rationally based research, allowing respondents to reinforce their own self-identities might be important for drawing out phenomenon related data. Coupled with this is the status of the researcher who has a background as an executive and R&D manager, who was given a high level of access to respondents, argued by respondents as based on his background. Managers in this sector appear to expect someone with a similar background to speak to them using promoted repertoires to show a comparable background and legitimacy. Thus for further studies in such sectors, utilising specific researchers with favoured backgrounds might be advantageous.

#### **Conclusion and Recommendation 4**

Key theme: The R&D Model.

Conclusions: All managers had what appeared to be a varied set of criteria for how to construct a model, but preferring simplicity, a linear flowchart was preferred, with boxes to enable expanded model views as this preferred to aid in sense- and decision-making. In comparison to other models, this model is more reflexive which can be linked to the phenomenological paradigm, and as such has a higher level of respondent interaction for their perceptions. The antiviral disinfectant model was warranted to produce the synthesised model between executive and R&D managers, and found acceptance by all respondents. Explicitly the issue of sense- and decision-making was addressed within the warranting stages, via further discourse between the researcher and respondents. Evidence of sensemaking was drawn out by the researcher collating repertoires suggestive of the stages of sensemaking (Weick, 1995) and by direct questioning of sensemaking. From the model constructed, there was much predictive discourse from respondents that the model should be able to enable a higher level of sensemaking albeit often not couched in the term sensemaking. Coupled with the potential for sensemaking was the argued potential for more fit-for-purpose decision-making based on increased sensemaking. While important for the models grounding within phenomenology and the respondent perceptions of the models reflecting of R&D, and potential for sense- and decision-making, an objection could be raised that although warranted (a discursive process) it had not been physically verified. Thus three companies undertook to examine the model in their R&D product cycles from start to finish, which had the potential to include R&D failure, or recycling through failed stages. This aspect occurred at the end of this study and feedback has so

far highlighted initial success for enhancing clear communication leading to more desirable sense- and decision-making. It is expected that this stage, although now outside of the DBA study will be followed up as more information becomes available from the R&D companies.

**Key contributions:** The antiviral disinfectant model is based within prior literature from executive manager, R&D manager and joint perspectives. Importantly, the environment within which R&D is undertaken has echoed into the model construction and for example, with lower regulatory requirements, the path through R&D can be more reflexive and is arguably more open to manager introspection regarding each process stage. This was shown from the ability to recycle through failed stages, where other models had to stop the R&D cycle as the product had failed. A failure within the antiviral disinfectant model does not mean a classical failure as with the allied antiviral technologies of vaccines or *in vivo* drugs, but creates an opportunity to learn more about the R&D stage and product. More than this though it may result in new R&D product life cycles being undertaken to generate new products from a failed stage. In other words, a failed stage may lead to new product opportunities, which are more likely to be exploited due to the quick R&D cycle time, and low resource costs from failures. The issue of verifying the model as a physical aspect beyond discursive warranting is in the process of being examined. It will be carried out in more depth outside of this study as more data is relayed from respondent companies and will act as a greater verification of the suitability of this model.

**Recommendation:** The construction of the beta model was through the consensus of all managers, with all managers stating their satisfaction with the model itself and method of constructing it. The most pertinent recommendation for the R&D model is the external

verification that can come from data relayed from respondent companies carrying out testing on the model by using it in their R&D cycles. Beyond the three companies using this model and comparing it to past R&D cycles (which will give quantitative data) is the potential for other companies in this sample to use the model. At present a further two companies (which will give 50 percent of the total UK sector if added to the other three companies already using the model) have stated they will test this model, upon completion of their current R&D cycles. In a practical sense, the researcher will continue his engagement with these respondent companies to collect further data from the implementation of this model and its suitability. It will be interesting to see how respondent companies use this model based on their perceptions of how it should be implemented, whether changes are made, and how it holds up against prior practices, and what merit a phenomenological approach to modelling R&D has in comparison to other methods and respondent company verification.

In the next section, ‘The Contribution to the Knowledge Base’ have been considered and addressed.

### **7.3. The Contribution to the Knowledge Base**

This study has contributed to the literature on process R&D, with a particular focus on the research gap identified in antiviral disinfectant R&D, in the following ways:

1. An R&D process model was developed and warranted from interviews with R&D and executive managers. Although there was a heavy emphasis on the technological aspects of R&D, the model was based not just within the concept of technological models but also



within the consumer/market model. Through the warranting of the model, it was possible to produce an increased view of technological aspects discursively framed to facilitate executive manager understanding of R&D.

2. The issue of management communication, to give shared meaning for R&D, was continually cited as being problematic. It was felt by both manager types that the challenge for communication was based on R&D managers and executive managers having been trained in science, and business respectively, with little cross over of knowledge and language. This study extended that of Davies (2011), which explored the use of linguistic tools such as storytelling, metaphor, narrative etc to communicate complex technological ideas to non-scientists. In this study, it was found that R&D managers utilised such tools to communicate complex knowledge from R&D to executive managers.
3. The process stages of R&D had a high similarity between all companies, and the managers interviewed to ascertain this data. This suggests that within the sector, there is conformity for how to carry out R&D, even though the companies do not carry out R&D together.
4. The model produced in this study highlighted elements of the sixth generation of R&D models, in that there was a high-level of inclusionary input, and decision-making in the meeting stages at the beginning and end of R&D. Importantly there were also elements of earlier generations (second and fourth), with a focus on aspects such as cost and time. As the model developed in this study has aspects of both the technological and consumer models, this is perhaps not surprising.
5. The attitudes of many of the respondents based on their background and use of corresponding language was explored. It was found that both manager types appeared to have a negative bias to the others knowledge, based on the challenging of effective communication and creating shared meaning. R&D managers also promoted their right to

speak about R&D, based on their scientific knowledge, which also extended into executive management not having a right to speak.

6. At a macro level the beta R&D model has provided an explicated pathway through the R&D processes, which has been argued by respondents as creating shared knowledge between managers for the stages included in R&D as well as their order. In this simple way, the R&D model is functioning in a comparable way to a flowchart, guiding the way through R&D. Practically this may reduce confusion about which stage is being carried out when, and may echo into wider discourse from both types of manager throughout the R&D company and out to customers. The creation of this macroscale view has the potential to facilitate executive management sensemaking of the processes of R&D, where discursive repertoires can be linked to action. More than this, it has a potential to provide a good enough view for executive managers who are seeking a lower level of the practical elements of R&D than R&D managers. However, through the expanded model 'micro' view, a greater insight and knowledge of the R&D cycle can be achieved, which as a reflexive element can be further expanded on for individual companies using the model. Through a sensemaking perspective, the aim of the model is to enable enough sense to be made by respondent managers, whereby organisationally suitable decisions can be made about R&D, that support a knowledgeable culture within R&D and its management.
7. The construction of the Beta R&D model was developed to facilitate sensemaking, but also decision-making based on respondent manager sense made. Primarily, by using a phenomenological approach, it was perceived that the constructed model would closely model the experience of management experiences of R&D, and thus enable more fit-for-purpose decisions made. When approaching the R&D model, it is expected that it will function to facilitate sense made through the different stages shown, whereby decisions can be made. Importantly any claim about the model improving the practicality of R&D would have to be externally verified by the respondent

companies, where their experiences could be monitored and potentially measured. At the end of this study, three respondent companies, with another two companies having agreed to test this model, are carrying out this process. Preliminary feedback from the three companies testing the model has been favourable, but a more detailed examination and expansion of this work is required to ascertain the validity of the claims being made.

8. The R&D model developed in this study has similarities to models such as the Stage Gate and Technological models but with a different philosophical foundation. The foundation of the antiviral disinfectant model varies from prior models, as rather uniquely for an R&D model it was constructed through the use of a phenomenological paradigm. The basis of the model echoes into the constructed reality the model mirrors from R&D, with a phenomenological approach arguably mirroring the respondent reality of R&D more closely than other philosophical approaches. Importantly the antiviral model was constructed using the explicated phenomenologically based views of respondents, by the respondents and for the respondents. The respondents argued that this created a sense of ownership and will result in 50 percent of the companies in this sector testing this model. Within the approach used to construct the antiviral disinfectant model is a high level of reflexivity, and coupled with a sense of respondent ownership has the potential to allow the model to evolve particularly through expanded model views, which may become bespoke within testing companies. In comparison to other Technological models, increased reflexivity within the model, which can potentially be coupled with greater regulatory freedom, has the potential to enable this model to be further honed to more closely mirror R&D in an evolving process.

After drawing together ‘The Contribution to the Knowledge Base’ in this section, the following section explores ‘The Limitations of the Study’.

#### **7.4. The Limitations of the Study**

This study was not without limitations, and it is worth pointing out that limitations arguably exist within all research studies. Specifically though, the following potential limitations were identified in this study:

Researchers from positivist and rationalist backgrounds may raise the claim that this study is non-scientific, and uses qualitative and subjective methods (Yin, 2003; Saunders *et al*, 2009). This aspect was addressed throughout this study, but it is worth recognising that this was an exploratory study that was language based, and was interrogating the mental and subjective realities of the respondents, to further understand antiviral disinfectant R&D. Coupled with this was the use of low numbers of respondents (seven executive and seven R&D managers) but who made up 70 percent of the UK-based industry in this sector.

There is the issue of the ability to generalise research findings from these companies to other R&D companies carrying out antiviral disinfectant R&D, and companies carrying out other types of R&D. This is an important aspect that needs digging into to more fully understand what it is to be able to generalise data between different groups and companies. Firstly, in this study, both executive and R&D management were interviewed, which make up 70 percent of this type of management in the UK, and it is logical to assume that this study is generalisable to the other 30 percent of the same sector group as used in this study. Looking beyond antiviral disinfectant R&D, the issue arises for how reality is potentially being symbolically represented by a model. For instance, in the model developed in this study, there are scientific and technical stages directly taken from the phenomenon of antiviral disinfectant R&D that may not exist in other types of R&D. It is of course possible to step back from such a close representation of reality and use more generic R&D models such as the Stage Gate.

This study utilised a multiple case study method (different antiviral disinfectant R&D companies), and there are arguments that could be made that it is difficult to replicate data. As this study was language based, warranting was used instead of

validation and is in agreement with the suggestion by Wood and Kroger (2000). The warranting process was carried out in conjunction with respondents to check on the data collected from interview, and the construction of the model. Thus, multiple checks were made by respondents to check on their perceived ‘validity’ of the data.

In depth semi-structured interviews were used as the source of data collection, which can be criticised for producing bias in the responses given. To mitigate and limit this potential difficulty, the researcher spoke to the respondents on more than one occasion for the warranting of the data produced, which is believed to have aided in producing more ‘robust’ data.

Importantly, the researcher was sensitised to the antiviral disinfectant sector prior to this study. Due to the method of explicitation used in this study, the researcher did not need to be knowledgeable about the phenomenon being examined (Urquhart *et al* (2001). It was however necessary for the researcher to continually bracket his perceptions about the phenomenon and make mental checks of feelings and thoughts that may have resulted in bias. This was a subjective process, and it was not possible for the researcher to make any substantive claim of how successful his bracketing was.

In the next section, ‘The Implications of the Study’ is addressed:

### **7.5. The Implications of the Study**

This study has produced contributions to academic knowledge as well as insights for business practitioners, particularly for those involved in R&D management. Specifically, the R&D landscape was described as being potentially opaque, uncertain and complex, with it being difficult to communicate shared meaning between key managers for high-level business or technological R&D aspects. These following areas are therefore addressed within this section:

1. **The environment of R&D:** Throughout this study, the difficulty of carrying of complex technological R&D was described as challenging due to the varied number of factors interacting with the R&D stage. These factors can range from the physical location of the R&D company, to its customers, suppliers and staff within the company. The language used to communicate sense and understanding of the phenomenon of R&D was often cited as being particularly troublesome, as many managers felt that there was a wide difference between the perception of what was communicated and the perception of what information was up taken. The use of an R&D model specific to antiviral disinfectant R&D was well received by R&D and executive managers as a vehicle of communicating some of the complex ideas behind R&D, particularly through the use of expanded model views.
2. **Increasing clarity and shared meaning:** Importantly, when the alpha models were constructed for R&D and executive managers, R&D managers did not regard the initial meeting (scoping) stage as being part of R&D and attributed a low importance to it. Upon the researcher detailing the theory expressed from executive managers about this stage to R&D managers, the stage was included in the beta model. Interestingly, this addressed a concern from R&D managers of not necessarily understanding the goal of R&D beyond scientific aspects. Arguably, this enabled R&D managers to step outside of prior constructions of R&D and examine customer requirements, rather than being too technologically focused.
3. **Business versus science driven R&D:** Both manager types expressed a concern that the other manager type was too focused on their own perception of R&D and how it should be carried out. For example, executive managers believed that R&D managers were too focused on producing non-profitable scientific discoveries, and likewise R&D managers thought that executive managers were too shortsighted, with no interest in longer-term discoveries that could be profitable. Through the construction of the model and particularly the model view (with a potential for further views to be attached) enabled, the managers to openly consider their own, and other manager perceptions of R&D

The examination of these factors within antiviral disinfectant R&D has the potential to improve R&D output, customer satisfaction, management, and communication.

The following section draws on information drawn out so far in this chapter to consider ‘The Recommendations for Future Research’.

## **7.6. The Recommendations for Future Research**

This study addressed the identified research gap in how UK SMEs carry out pre-commercialisation based antiviral disinfectant process R&D. Further research in this area should explore the processes of the closely allied R&D areas of antibacterial, antiyeast and antifungal disinfectants. As these are all highly technically specialised areas, with arguably similar processes to antiviral disinfectants, it will be important to draw out similarities and differences in the processes and to understand the how and why. This could be carried out as a comparative study, and has the potential to lend itself to quantitative as well as qualitative methods and analysis. Beyond these areas is the aspect of a more in depth examination of how language is used between management using different knowledge to communicate business and scientific sense, enabling decision-making. This could also draw on elements of linguistic tools to communicate and how sense is made of potentially complex areas between different industrial actors. This would have the potential to expand on work carried out by Davies (2011) who examined the use of metaphor, storytelling and science fiction to convey shared meaning for high technology. These linguistic ‘tools’ have been shown to be important for creating dyadic closeness in communicating complex information, particularly where science and technological flows from an individual with a high-level of knowledge to an individual of low-knowledge. An expansion of this study would be able to directly examine this flow and linguistic tools used for scientists communicating complex information to non-scientists, but also for executive management to communicate complex business phenomena to scientists, which has not previously been examined. Thus, it would be possible to compare language-based tools in these different settings. Finally, as three respondent companies were testing the Beta model at the end of this study, and with a further

two companies waiting to test the model, findings should be compared to prior R&D practises to validate this model. Importantly data coming out of this final aspect may well shed further light on the applicability of this model, and the use of a phenomenological paradigm for R&D model construction.



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## Appendix A – Letter Sent To Prospective Interviewees

Page 1

19/08/2012

Dear Sir/Madam,

You are regarded as an industrial expert in the research, development and commercialisation of non-*in vivo* antiviral disinfectant products. I would like to ask for your support in research I am carrying out for a Doctorate in Business Administration (DBA) in Edinburgh Business School at Heriot-Watt University. The title of this research is: '*An Antiviral Disinfectant Research and Development Process Model for Small to Medium Enterprises Based within the United Kingdom*'. This research is focused towards the pre-commercialisation aspects of antiviral development, and I would like to carry out in depth interviews with you, at your convenience. All interviews will be confidential and anonymised, with no link to you or your organisation. If you are in agreement with either yourself or members of your organisation taking part in this study, please sign this document on your letterhead and e-mail it to me at [andrewdean@spartannano.co.uk](mailto:andrewdean@spartannano.co.uk).

Organisation:

Address:

I/We hereby agree to support this research in the form of an in depth interview to support the production of a DBA on the following subject: '*An Antiviral Disinfectant Research and Development Process Model for Small to Medium Enterprises Based within the United Kingdom*'.

Name:

Signature:

Position in organisation:

Date:

Once this document is signed, please e-mail it to: [andrewdean@spartannano.co.uk](mailto:andrewdean@spartannano.co.uk)

## Appendix B – Excerpt from Transcript with an R&D Manager

In this appendix, part of Question 2 from the main study is examined with one of the R&D managers as an example of an excerpt from the interviews.

Question 2: *‘How is management segmented?’* If the answer was perceived as limited, the following question gave guidance: *‘Do factors such as your academic/work background/experience play a role in this?’*

**Respondent:** *“Hmmm, well management is segmented by need in many ways, with several err, company drivers meaning there is a need, so we have a manager.”*

**Interviewer:** *“Could you tell me more?”*

**Respondent:** *“Ok, so for what we do in R&D, I’m the guy in charge on, if...as the R&D manager. I’m in charge of R&D, as the R&D manager. But...I have a boss, someone senior, you know, a business guy, someone who knows little about science, profit obsessed. Ok, I’m being cliché...but you get what I mean?”*

**Interviewer:** *“I think I understand...So you are in charge of R&D? And you have a senior manager overseeing R&D? Could you say more about this?”*

**Respondent:** *“Sure, I make all of the nitty gritty R&D decisions, what to pass, what to fail, and...I...also know, when, you know...when to call the senior management...usually when there’s a big problem...the kind that screws things up...I don’t want that responsibility. So he steps in, sorts it out, you know...makes erm, a decision, continue or stop R&D. Suits me fine. But in every other way I run the daily stuff, I have to, I know the science, business managers don’t!”*

**Interviewer:** *“You feel that business managers don’t know the science?”*

**Respondent:** *“Not at all, they get very confused, and this, this...well it just hampers communication and R&D in general. Its not easy trying to communicate complex sci...science ideas to a manager who doesn’t understand.”*

**Interviewer:** *“This leads me back to part of my original question about how you feel that academic and work experience relates to how management is segmented. Do you think you would be able to say a bit more about this?”*

**Respondent:** *“It is pretty simple...I’m a scientist and I run R&D. Senior management are business guys...and they run the company”*



Interviewer: *“Could you go a bit more in depth with how this works?”*

**Respondent:** *“Ok...So I have a background in science, did a degree...and MSc in Science...erm...its what you do to be a scientist...and...hmmm...then I worked in various science companies, doing different stuff! Lots of R&D! Lots of different positions in R&D...I feel qualified to manage R&D. But you know, senior management they study business! They don't understand science...but feel they do...and get confused about what we do. Can't understand what we say, erm, half the time. It complicates everything! We live in different worlds”.*

**Interviewer:** *“Is there any cross over of knowledge between science...and business orientated managers?”*

**Respondent:** *“At the moment...if there is, it is unintended and coincidental, and no we don't have any mechanisms to transfer what we say, what we mean. For instance...in R&D...we...we often don't, I mean, we often have little idea what the product is needed to do. It is an over simplification to say it just kills viruses. No communication to us about this. We need to know!*

**Interviewer:** *“Ah yes, I can see how this could be challenging, and thank you, we will definitely pick up on some more of these aspects, and go more in depth, later in the interview”.*