Critical Appraisal of Product Development Expertise in Irish SMEs

This thesis is submitted to Dublin City University as the fulfilment of the requirement for the award of the degree of

Doctor of Philosophy

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy is entirely my own work and has not been taken from the work of others save to the extent that such work has been cited and acknowledged within the text of my work.

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Abstract

The focus of this research was on the product development expertise of Irish SMEs. In particular, SMEs developing physical products (a physical product is defined as an electronic, medical device, plastic or general engineering product). A survey of Irish SMEs was conducted across industry sectors developing physical products with the objective of understanding how indigenous SMEs and therefore Ireland is progressing towards becoming a knowledge economy. SME characteristics (customers and markets, organisational structures, systems, processes and procedures, human and financial resources, culture and behaviour) were researched and used to understand the issues SMEs have with product development (PD research is mostly considered from the perspective of large companies). In relation to product development: strategy, innovation and learning, strategic techniques, organisational structure, product development process design, types of product development processes, tools and methodologies, technology, intellectual property, change management, marketing and branding and performance measurement were all examined. Survey items (variables) were identified from the literature review and used to create a survey designed based on 'best practice' PD and SME characteristics. This survey was conducted based on identified survey best practice in order to increase response rate and went through two pre-tests and a pilot before the final study. Descriptive analysis, reliability/consistency analysis and regression analysis were conducted on the constructs of product development. Specific relationships identified in the literature review were examined. The results of this analysis revealed that Irish SMEs are operating in a 'Knowledge Based Development' or learning environment. They carry out many of the techniques associated with various tools and methodologies but reported no use of these T&M which could aid their approach. There is a high use of technology, especially CAD and technology is mostly developed within the product development process. There was a high use of Cross Functional Teams and in general strategy and fuzzy front end/voice of the customer usage was carried out well. There were no issues with change management and in relation to intellectual property the use of an IP policy,

strategy and portfolios was low. Generally, Irish SMEs are ready to reach the next stage of company evolution by linking 'organisational (innovation) processes'.

Table of Contents

Chapter 1 1
Thesis Objective 1
1.0 Introduction 1
1.1 Background 1
1.1.1 Building Ireland's Knowledge Economy 3
1.1.2 Enterprise Strategy Group Report – Ahead of the curve 6
1.2 Review of the SME Sector in Ireland 9
1.2.1 Sales, Marketing and Innovation Capabilities of SMEs 11
1.2.1.1 Sales and Marketing 12
1.2.1.2 Innovation 14
1.3 Irish Product Development Survey Research 17
1.3.1 Ledwith 17
1.3.1.1 Approach 18
1.3.1.2 Findings 19
1.3.2 Hurst 19
1.3.2.1 Approach 19
1.3.2.2 Findings 20
1.3.3 Cormican and O'Sullivan 20
1.3.3.1 Approach 20
1.3.3.2 Finding 21
1.4 Is there a Gap in indigenous SMEs PD Approaches? 21
1.4.1 The Gap in Irish product development survey research 22
1.4.2 Further Justification for PD indigenous SME Survey Research 22
1.4.3 Statement of Research Gap 23
1.5 Objectives of the Thesis 24
1.6 Literature Review Structure 25
1.7 Conclusion 26
Chapter 2 27
Literature Review & Identification of SME and PDP Characteristics 27

2.1 Introduction 27
2.2 SME Characteristics (SMEC) 30
2.3 Strategy, Innovation and Learning 33
2.3.1 Fuzzy Front End (FFE) 33
2.3.1.1 FFE Models 34
2.3.1.2 SME Company Innovation and the Market/Learning Orientation 34
2.3.2 Types of Strategies 36
2.3.2.1 Open or Closed Strategy in PD 36
2.3.2.2 Strategic Planning – High and Low Technology Company's 37
2.3.2.3 Barriers to Implementing Strategy 37
2.3.2.4 Porter - Competitive Strategy 38
2.3.2.5 Miles and Snow Typology 38
2.3.2.6 The Resource-based View (RBV) and Dynamic Capabilities 40
2.3.2.7 Technology Development Strategy (Flexibility and TTM) 42
2.3.2.8 SME Applicable Strategy 44
2.3.3 PDP Strategic Areas and Strategic Techniques 45
2.4 Product Development Process Characteristics 47
2.4.1 SME Product Development Characteristics 48
2.4.1.1 Millard and Lewis, and Moultrie *et al* findings 48
2.4.1.2 SME export management capabilities 48
2.4.1.3 Innovation Implementation in SMEs 49
2.4.1.4 Resource-based View (RBV) Findings 49
2.4.1.5 Methods for modelling SME innovation processes 50
2.4.1.6 Dynamic Capabilities 51
2.5 Strategic Techniques 56
2.5.1 Strategic Planning 57
2.5.1.1 Applied Strategic Planning Model 58
2.5.2 New Product Strategy (NPS) 60
2.5.2.1 The Strategy Development Process for an NPS 61
2.5.2.2 Disadvantage of an absent NPS 64
2.5.2.3 SME Strategic Structure 64
2.5.3 Portfolio Management 65
2.5.4 Product Platforms and Families 66
2.5.4.1 Platform Common Building Blocks 66

2.5.4.2 Product Families 66
2.5.4.3 Product Platforms in SMEs 67
2.5.5 Technology Development Planning (Roadmapping) 68
2.5.5.1 Common Roadmap Framework 68
2.5.5.2 Types of Roadmaps 68
2.5.5.3 Roadmaps for Portfolio Management and Product Platforms 70
2.5.6 Conclusion 70
2.6 PD Organisational Structure 70
2.6.1 Organisational Development 71
2.6.2 Organisational Structure Theory 72
2.6.2.1 Organisational Design Decisions 73
2.6.2.2 Organisational theory conclusion 73
2.6.3 Common Forms of Organisational Structures 73
2.6.4 Contemporary Organisational Designs 74
2.6.4.1 Virtual Organisation 74
2.6.4.2 Boundary-less Organisation 74
2.6.4.3 Learning Organisations 74
2.6.5 Product Development Teams or Cross Functional Teams 76
2.6.5.1 Team Collocation 76
2.6.6 Conclusion 77
2.7 PD Tools and Methodologies (T&M) 77
2.7.1 Background journal articles 77
2.7.2 Design for Six Sigma (DFSS) 80
2.7.2.1 Plan/Prerequisites Phase 80
2.7.2.2 Identify Phase 81
2.7.2.3 Design Phase 81
2.7.2.5 Validate Phase 81
2.7.3 Design for Six Sigma Tools 82
2.7.3.1 Quality Function Deployment (QFD) 82
2.7.3.2 Failure Modes and Effects Analysis (FMEA) 84
2.7.3.3 Systematic Exploration 84
2.7.3.4 TRIZ (Theory of Inventive Problem Solving) 84
2.7.3.5 Design for Manufacture/Assembly 87
2.7.3.6 Robust Design 88

2.7.4 Conclusion 92
2.8 Technology 93
2.8.1 Computer-Aided Design (CAD) 95
2.8.1.3 CAD Assembly Modelling 96
2.8.2 CAM/CAPP/NC 96
2.8.2.1 NC Programming 97
2.8.2.2 Computer-Aided Process Planning (CAPP) 98
2.8.2.3 CAD/CAM Integration 98
2.8.2.4 Feature Recognition 99
2.8.3 Computer Aided Engineering (CAE) 100
2.8.3.1 Advantages of CAE and its place in the PD Cycle 100
2.8.3.2 Finite Element Analysis (FEA) 101
2.8.3.3 Computational Fluid Dynamics (CFD) 101
2.8.3.4 Kinematic and Dynamic Analysis 101
2.8.4 Collaborative Technology Tools 101
2.8.4.1 CAD Collaboration 102
2.8.4.2 Web-Hosted Meetings 102
2.8.4.3 Web-Enabled Product Development 102
2.8.5 Rapid Prototyping (RP) 103
2.8.6 Rapid Tooling (RT) 104
2.8.7 Rapid Manufacturing (RM) 104
2.8.8 Reverse Engineering 104
2.8.9 Conclusion 105
2.9 Intellectual Property 106
2.9.1.1 Patents 106
2.9.2 Methods of IPP and SME IPP issues 107
2.9.3 Company Policy/Budget 107
2.9.4 IP Strategy 108
2.9.5 Conclusion 109
2.10 Change Management 110
2.10.1 Why use a Change Management Process? 110
2.10.2 Whole -Scale Change 112
2.10.3 Conclusion 112
2.11 Marketing (Backend) 113

2.11.1 Role and Relevance Model ... 114
2.11.1.1 Marketing-Led Organisation (MLO) ... 115
2.11.1.2 Marketing Dominated Organisation (MDO) ... 115
2.11.1.3 Marketing Weak Organisation (MWO) ... 115
2.11.1.4 Marketing Independent Organisation (MIO) ... 116
2.11.1.5 Role and Relevance Strategies ... 116
2.11.2 Marketing Planning Process ... 116
2.11.3 Networking ... 117
2.11.4 Conclusion ... 118
2.12 Product Development Processes ... 118
2.12.1 Sequential Product Development Process ... 119
2.12.2 The Stage Gate Process ... 119
2.12.3 Evolutionary Prototyping Process ... 120
2.12.4 Design to Schedule/Budget Process ... 120
2.12.5 Knowledge Based Development (KBD) ... 121
2.12.5.1 Trade-off curves and Subsystem targets (Performance Targets) ... 122
2.12.5.2 Set-Based CE v Point-Based CE (Narrow and Combine) ... 123
2.12.5.3 Responsibility Based Planning and Control (Key Integrating Events) ... 125
2.12.6 Systems Engineering (SE) ... 125
2.12.7 Concurrent Engineering ... 126
2.12.8 Conclusion ... 126
2.13 Performance Measurement ... 127
2.13.1 Selection of Measures for Product Development ... 133
2.13.2 Conclusion ... 133
Chapter 3 ... 134
Research Approach ... 134
3.1 Introduction ... 134
3.2 Research Approach ... 134
3.2.1 Quantitative Research Approach ... 136
3.2.1.1 Theory ... 136
3.2.1.2 Hypothesis ... 137
3.2.1.3 Operationalisation of Concepts ... 137
3.2.1.4 Selection of Respondents or Participants ... 139

3.2.1.5 Setting up a Research Design ... 143
3.2.1.6 Collect Data ... 144
3.2.1.7 Analyze Data ... 144
3.2.2 Conceptualisation and Instrument Design ... 144
3.2.2.1 Reliability and Validity ... 144
3.3 Conclusion ... 146
Chapter 4 ... 148
Pre-Test, Pilot Analysis and Final Questionnaire Methodology ... 148
4.1 Introduction ... 148
4.2 Online Surveys ... 148
4.2.1 Non-response ... 149
4.3 Non-expert and Pre-test 1 and 2 ... 152
4.4 Pilot Study ... 155
4.4.1 Non-Analytical Findings ... 156
4.4.2 Analytical Findings ... 156
4.4.2.1 Descriptive Statistics ... 157
4.4.2.2 Exploration of Normality ... 166
4.4.2.3 Reliability/Consistency Analysis ... 169
4.4.2.4 Correlation and Regression Analysis ... 173
4.5 Final Questionnaire Methodology ... 176
4.6 Conclusion ... 178
Chapter 5 ... 179
Final Questionnaire Data Analysis ... 179
5.1 Introduction ... 179
5.2 Descriptive Statistics ... 179
5.2.1 Descriptive Statistics Conclusion ... 191
5.3 Exploration of Normality ... 192
5.4 Reliability/Consistency Analysis ... 205
5.4.1 PCA for Q1.0 items: ... 206
5.4.2 PCA for Q7.0 items: ... 208
5.4.3 PCA for Q8.0 items: ... 210
5.4.4 PCA for Q11.0 items: ... 211
5.5 Conclusion ... 214
Chapter 6 ... 215

Regression Analysis/Hypothesis Testing 215
6.1 Introduction 215
6.2 Regression Assumptions 215
6.3 Sub-Hypothesis Testing 217
6.3.1 Sub-Hypothesis No.1 218
6.3.2 Sub-Hypothesis No.2 219
6.3.3 Sub-Hypothesis No.3 221
6.3.4 Sub-Hypothesis No.4 223
6.3.5 Sub-Hypothesis No.5 224
6.6.6 Sub-Hypothesis No.6 225
6.3.7 Sub-Hypothesis No.7 226
6.3.8 Sub-Hypothesis No.8 227
6.3.9 Sub-Hypothesis No.9 229
6.3.10 Sub-Hypothesis No.10 232
6.3.11 Sub-Hypothesis No.11 232
6.3.12 Sub-Hypothesis No.12 233
6.3.13 Sub-Hypothesis No.13 235
6.3.14 Sub-Hypothesis No.14 236
6.3.15 Sub-Hypothesis No.15 237
6.3.16 Sub-Hypothesis No.16 239
6.3.17 Sub-Hypothesis No.17 240
6.3.18 Sub-Hypothesis No.18 241
6.3.19 Sub-Hypothesis No.19 241
6.3.20 Sub-Hypothesis No.20 242
6.3.21 Sub-Hypothesis No.21 245
6.2.22 Sub-Hypothesis No.22 245
6.3.23 Sub-Hypothesis No.23 246
6.3.24 Sub-Hypothesis No.24 247
6.3.25 Sub-Hypothesis No.25 247
6.3.26 Sub-Hypothesis No.26 248
6.3.27 Sub-Hypothesis No.27 249
6.3.28 Sub-Hypothesis No.28 250
6.3.29 Sub-Hypothesis No.29 251
6.4 Sub-Hypothesis Conclusion 253

6.4.1 Strategy Usage/Understanding 254
6.4.2 Organisational Structure / PDP Environment 256
6.4.3 T&M usage/understanding 256
6.4.4 Technology and Technology Development 258
6.4.5 IP Strategy and Portfolio Usage 259
6.4.6 Issues with Change Management 259
6.4.7 Marketing Usage (Front and Backend) 260
6.4.8 PDP Usage (Stage Gate, CE and KBD) 260
6.4.9 Performance 261
6.5 Conclusion 262
Chapter 7 263
Conclusion and Recommendations 263
7.1 Conclusion 263
7.1.1 Strategy usage/understanding 263
7.1.2 Organisational Structure/PDP Environment/Culture 264
7.1.3 T&M usage/understanding 264
7.1.4 Technology and Technology Development 264
7.1.5 IP Strategy and Portfolio Usage 265
7.1.6 Issues with Change Management 265
7.1.7 Marketing Usage (Front and Backend) 265
7.1.8 PDP Usage (Stage Gate, CE and KBD) 265
7.1.9 Performance 266
7.2 Recommendation 266
References 268
Appendix A Elements and Questions 288
Appendix B Checklist for any given Questionnaire Item 333
Appendix C.1 Pre-test Instructions 335
Instructions: 335
Appendix C.2 Pilot and Final Questionnaire 337
Appendix C.3 Pilot 2008 - with Variables 349
Appendix C.4 Final Analysis 355
Appendix C.5 Cold Calling Strategy 365
Appendix C.6 – Final Questionnaire Email 366
Final Questionnaire Email Style One: 366

Final Questionnaire Email Style Two: 367
Appendix C.7 – Final Questionnaire Reminders 370
Reminder One Style One: 370
Reminder One Style Two: 370
Final Reminder Style One: 371
Final Reminder Style Two: 371

Glossary

Acronym	**Explanation**
A	
AGV	Automated Guided Vehicle
B	
BMT	Business Modelling Technique
BOM	Bill of Materials
BSC	Balanced Score Card
C	
CE	Concurrent Engineering
CI	Continuous Improvement
CAD	Computer Aided Design
CAE	Computer Aided Engineering
CAM	Computer Aided Manufacture
CFD	Computational Fluid Dynamics
CFT	Cross Functional Team
CIM	Computer Integrated Manufacturing
CNC	Computer Numerical Control
CRM	Customer Relationship Management
CSI	Critical Success Indicator
CQI	Continuous Quality Improvement
CAPP	Computer Aided Process Planning
CIMRU	Computer Integrated Manufacturing Research Unit (at NUIG)
D	
DMADV	Define, Measure, Analyze, Design, Verify
DMAIC	Define, Measure, Analyze, Improve, Control
E	
ECO	Engineering Change Order
EDM	Electrode Discharge Machining

Acronym	**Explanation**
F	
FEA	Finite Element Analysis
FEI	Front End of Innovation
FFE	Fuzzy Front End
G	
GPP	Generative Process Planning
H	
HR	Human Resources
HP	Hewlett Packard
I	
IC	PD element: Innovation Characteristics
IDP	Innovation Development Process
IMI	Irish Management Institute
IP	Intellectual Property
IPC	Innovation Process Characteristics
IPO	Irish Patent Office
IPP	Intellectual Property Protection
IPR	Intellectual Property Right
IRR	Internal Rate of Return
ISO	International Standards Organisation
K	
KBD	Knowledge Based Development
KM	Knowledge Management
L	
LOB	Line Of Business
LPD	Lean Product Development
M	
MNC	Multi-National Companies
MDO	Marketing Dominated Organisation
MIO	Marketing Independent Organisation
MLO	Marketing-Led Organisation
MWO	Marketing Weak Organisation

Acronym	Explanation
MRP	Materials Requirements Planning
N	
NC	Numerical Control
NCD	New Concept Development
NPD	New Product Development
NCMS	National Center or Manufacturing Sciences
NITM	National Institute of Technology Management
NPPD	New Product and Process Development
NPS	New Product Strategy
NPV	Net Present Value
O	
O/M	Owner Manager or Manager
P	
PD	Product Development
PM	Performance Measurement
PCA	Principal Component Analysis
PDP	Product Development Process
PDM	Product Data Management
PIM	Product Innovation Management
PLC	Product Life Cycle
PLM	Product Lifecycle Management
PMS	Performance Measurement System
PART	Planning for Activities Resources and Technology
PDCA	Plan Do Check Act
PDMA	Product Development Management Association
Q	
QFD	Quality Function Deployment
R	
R&D	Research & Development
RP	Rapid Prototyping
RT	Rapid Tooling
RM	Rapid Manufacturing

Acronym	**Explanation**
RBV	Resource Based View
ROI	Return on Investment
S	
SE	Systems Engineering
SBF	Small Business Forum
SD	Standard Deviation
SME	Small or Medium sized Enterprise
SMEC	SME Characteristic
SPM	Special Purpose Machines
STEP	Standard for the Exchange of Product Model Data
SWOT	Strength Weakness Opportunity and Threat
T	
T&M	Tools and Methodologies
TM	Total Quality Management
TRIZ (Russian)	Theory of Inventive Problem Solving (TIPS)
TTM	Time To Market
V	
VPP	Variant Process Planning
VOC	Voice Of Customer
W	
WCM	World Class Manufacturing

List of Figures

Figure	Page	Title
1.0	1	Chapter 1 layout
1.1	1	Thesis Chapter layout
1.2	4	Gross Expenditure on R&D as %GDP / GNP, 2001
1.3	5	Distribution of Indigenous Firms R&D by Sector, 2001
1.4	7	Expertise/Knowledge Profile in Ireland
1.5	8	Identified Competitive Advantages
1.6	10	Criteria and Thresholds
1.7	11	Distribution of Irish Labour Force, 2005
1.8	12	Companies Surveyed by Number of Employees
1.9	13	Sales and Marketing Skills Base Comparison
1.10	13	Responsiveness to Customer Feedback
1.11	14	Firms carrying out Market Research
1.12	15	Structure of Innovation at stages of the PDP
1.13	15	Cross Sectoral Analysis of Innovation Management at stages of PDP
1.14	16	Sources of Innovation for Companies
1.15	17	Level of Innovation Capability
1.16	26	Literature Review Structure
2.0	28	Relationships of SMEC and Appendix Tables
2.1	29	Process Based Model of Product Development
2.2	44	OECD SME Strategies
2.3	65	SME Strategic Structure
2.4	85	TRIZ Problem Analysis Flow Chart
2.5	94	Implementation Framework for CIM in SMEs
2.6	97	The Improving methods of STEP CAD/CAM integration
2.7	122	Knowledge Based Development PDP
2.8	123	Point-Based CE v Set-Based Concurrent Engineering
2.9	124	Number of Alternatives/Cost v Time

2.10	124	Resources/Cost v Time
3.0	135	Research Approach Flow Charts
3.1	136	Quantitative Research Approach Model
3.2	140	Framework for Research Policy in Ireland
3.3	141	Enterprise Ireland Strategy Overview
4.0	156	Pilot Study Analysis
4.1	159	No. of Patents Held by Industry Sector
4.2	160	Mean sales from Export by Mean Patents held
4.3	160	Mean Dependent Variables by Industry Sector
4.4	161	Dependent Variable (Mean) by Number of Employees
4.5	162	Dependent Variable (Mean) by Industry Sector
4.6	162	Dependent Variable (Mean) by Number of Employees
4.7	164	Type of Product Developed by Industry Sector
4.8	165	Type of Product Developed by No. of Employees in SME
4.9	175	Scatter plot of Q1PC1 and item 5.4 Utknowledge
5.0	182	No. of Patents Held by Industry Sector
5.1	183	Mean Sales from Export and Mean Patents Held by Industry Sector
5.2	184	Mean Dependent Variables by Industry Sector
5.3	185	Dependent Variable (Mean) by Industry Sector
5.4	186	Dependent Variables (Mean) by Number of Employees
5.6	188	5.6 Type of Product Developed by Industry Sector
5.7	189	Type of Product Developed by SME size
5.8	189	Simulation Software Usage by Number of Persons in SME and Industry Sector
5.9	199	Step 214 usage by Industry Sector
5.10	201	Rapid Prototyping by Industry Sector
5.11	202	Patent Usage Frequencies
5.12	202	Patent Usage by Industry Sector
5.13	203	NDA’s by Industry Sector
5.14	207	Scree Plot of Variance for Q1.0
5.15	208	Scree Plot of Variance for Q7.0
5.16	210	Scree Plot of Variance for Q8
5.17	212	Scree Plot of Variance for Q11

6.0	218	Principal Component Q1PC1
6.1	220	Coefficients for Q1PC1 and Q16 items
6.2	221	Principal Component for Q24PCce
6.3	222	Coefficients for Q24PCce and Q1.0 items
6.4	223	Principal Component Q24PCkbd
6.5	224	Coefficients for Q24PCkbd and Q1 items
6.6	225	Histogram of Q2.0
6.7	227	Histogram of Q14.0
6.8	228	Coefficients for Q5.2 and Q5 items and Q6
6.9	230	Principal Components for Q12PCbackend
6.10	230	Coefficients for Q12PCbackend and Q5.0 items and Q6.0
6.11	234	Principal Component Q5Q6PCstrategy
6.12	234	Coefficients for Q5Q6PCstrategy and Q7.2
6.13	235	Coefficients for Q5Q6PCstrategy and Q7.4
6.14	236	Coefficients for Q5.5 and Q7.3
6.15	237	Q10.0 Strategy Types by Industry Sector
6.16	238	Q10.0 Strategy Types by No. of Employees
6.17	240	Histogram of Q13.0
6.18	246	Coefficients for Q19.1 and Q16.0/18.0
6.19	249	Q35, Q36 and Q37 Histograms
6.20	250	Secrecy by Number of Persons in SME
6.21	250	Q353637PC
6.22	252	Coefficients for Q37.0 and Q24.0 CE items
6.23	253	Coefficients for Q37.0 and Q1.0 items

List of Tables

Table	Page	Title
1.0	8	Competitive Advantage Characteristics
2.0	27	Literature Review Appendix Table Construction
2.1	30	SME Characteristics (SMEC)
2.2	34	FFE v NPD
2.3	39	Miles and Snow Typology
2.4	46	PDP Strategic Areas and required Strategic Technique
2.5	50	SME Specific Problems
2.6	53	Traditional View and New View of Dynamic Capabilities
2.7	54	Market Dynamic Comparisons
2.8	69	Product-Technology Roadmap
2.9	71	Organisational Practices during Evolution (Five Phases of Growth)
2.10	130	Comparison of Performance Measures
3.0	143	Sample Frame
4.0	155	Pre-Test and Pilot Call Breakdown
4.1	157	SME Locations by response count
4.2	157	SME industry sector by response count
4.3	158	SME size by response count
4.4	158	Total Number of Patents Held
4.5	163	Quality Culture
4.6	163	Product Development Environment
4.7	164	Q34 Percentages of Products Sold as Part of Others Products
4.8	166	Questionnaire Exceptions to Normality
4.9	169	Cronbach's Alpha for Scaled Items
4.10	170	PCA of Q1.0 items
4.11	171	Q1PC1 and Q1PC2
4.12	171	PCA for Q8.0 items
4.13	172	Q8PC1 and Q8PC2

4.14	172	PCA for Q11.0 items
4.15	173	Q11PC1, Q11PC2 and Q11PC3
4.16	173	PCA factors from Q1, Q8 and Q11
4.17	175	Model Summary and Parameter Estimates
4.18	177	Final Survey Call Breakdown
5.0	179	SME Locations by response count
5.1	180	SME industry sector by response count
5.2	181	SME size by response count
5.3	182	Total Number of Patents Held
5.4	187	Quality Culture
5.5	187	Product Development Environment
5.6	188	Percentages of Products Sold as Part of Others Products
5.7	190	Technology is Developed Offline
5.8	190	Technology is developed within the PDP
5.9	190	Ideation using Tools and Methodologies
5.10	193	Exploration of Normality (Final Study compared to Pilot)
5.11	196	Comparison of Q16.0 to Q17.0
5.12	197	Comparison of Q17.0 to Q16.0 and Q18.0 Frequencies
5.13	200	Q19 Item Frequencies
5.14	203	IPP Policy Item Frequencies
5.15	204	IP Portfolio and Strategy Item Frequencies
5.16	204	Q24 PDP Item Frequencies
5.17	205	Q35 Frequency
5.18	206	Cronbach's Alpha for Scaled Items (Final Study compared to Pilot)
5.19	206	PCA of items Q1.0
5.20	207	Q1PC1 and Q1PC2
5.21	208	PCA for Q7.1, Q7.2 and Q7.3
5.22	209	Q7PC1
5.23	209	Q7PC1 and Q7PC2
5.24	210	PCA for Q8.0
5.25	210	Q8PC1
5.26	211	Q8PC1 and Q8PC2
5.27	211	PCA for Q11.0

5.28	2.12	Q11PC1 and Q11PC2
5.29	213	Q11PC1, Q11PC2 and Q11PC3
5.30	214	Principal Components
6.0	216	Type of Variables
6.1	218	Regression Results for Q1PC1 and Q5.4
6.2	219	Regression Results for Q1PC1 and Q16.0 items
6.3	222	Regression Results for Q24PCce and Q1.0 items
6.4	223	Regression Results for Q24PCkbd and Q1 items
6.5	224	Regression Results for Q24PCkbd and Q1 items
6.6	226	Regression Results for Q4.0 and Q3.0 items
6.7	226	Frequency Analysis of Q3.0 and Q4.0 (N95)
6.8	228	Regression Results for Q5.2 and Q5.0 items and Q6.0
6.9	229	Frequency Analysis of Q5.2, Q5.0 items and Q6.0 (N83)
6.10	230	Regression Results for Q12PCbackend and Q5.0 items and Q6.0
6.11	231	Frequency Analysis of Q12.0 (N95)
6.12	232	Regression Model Significance Values for Performance v Strategy
6.13	233	Regression Results for Q10.1 and Q7.0 items
6.14	233	Frequency responses to Q7.0 (N83)
6.15	234	Regression Results for Q5Q6PCstrategy and Q7.2
6.16	235	Regression Results for Q5Q6PCstrategy and Q7.4
6.17	236	Regression Results for Q5.5 and Q7.3
6.18	239	Frequency Analysis for Q11 (N92)
6.19	241	Frequency Analysis for Q16.1, Q18.4 and Q18.6 (N95)
6.20	242	QFD Comparison
6.21	243	KBD (N94)
6.22	244	CE (N94)
6.23	245	Regression Results for Q9.1 and Q16.0/Q18.0
6.24	247	Regression Results for Q20.1 and Q1.0 items
6.25	247	Regression Results for Q20.2 and Q1.0 items
6.26	248	Regression Results for Q20.1 and Q5.0 items
6.27	248	Regression Results for Q20.2 and Q5.0 items
6.28	248	Frequency responses for Q21.0
6.29	251	Regression Model Significance

6.30	251	Regression Model Significance
6.31	251	Regression Results for Q37.0 and Q24.0 items
6.32	252	Regression Results for Q37 and Q1.0 items

Chapter 1

Thesis Objective

1.0 Introduction

This chapter will cover the changing background of the Irish economy and what this means to both indigenous and foreign enterprises, especially those engaged in product development. As the chapter progresses it builds on findings, leading to the research gap and the objective of the thesis. It explains why the focus of this research is on the product development expertise of Irish SMEs. In particular, 'technology based' SMEs developing physical products (a physical product is defined as an electronic, medical device, plastic or general engineering product). Figure 1.0 shows the layout of this chapter while Figure 1.1 shows the overall thesis chapter layout.

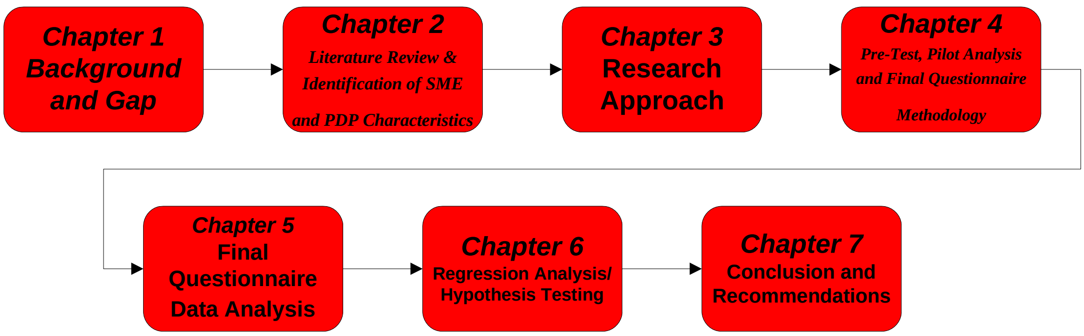

Figure 1.0 Chapter one layout

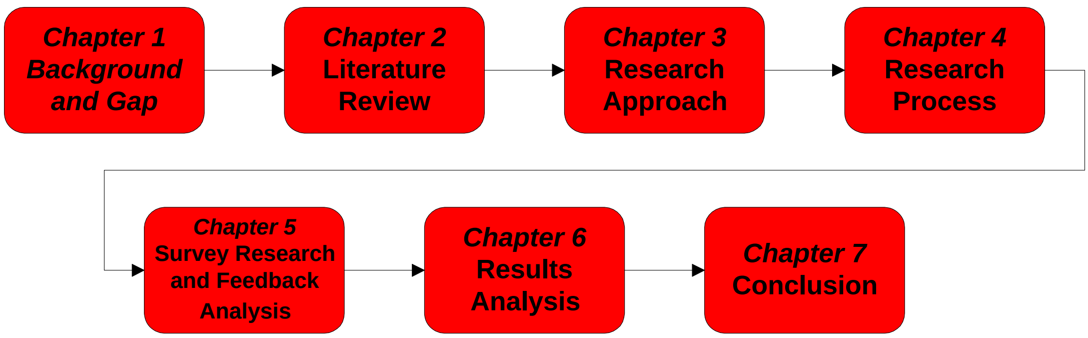

Figure 1.1 Thesis chapter layout

1.1 Background

The European Union (EU) has a major influence on how people live their lives in Ireland, both socially and economically [1]. In the late eighties and early nineties, the

EU and its member states started paying more attention to Science and Technology (S&T) in Europe. At the same time (1989) structural funding for research was granted to Ireland along with the investment from the EU's own Framework Programmes for Research, Technological Development and Demonstration (RTD&D), therefore like the other member states Ireland started examining the national status of S&T:

- In 1992 and 1993 the National Economic and Social Council (NESC) [2, 3] produced two economic reports: "The Irish Economy in a Comparative Institutional Perspective" and the Council's "Strategy for Competitiveness, Growth and Employment".
- Forfás produced the 1995 report "Making Knowledge Work for Us" (TIERNEY Report) – the first indigenous review of science policy in Ireland which concluded the need for greater awareness of S&T in Ireland [2].
- In 1996, a Science, Technology and Innovation "White Paper" was produced - it sought to trigger a more open discussion involving the wider public (at the time S&T was more about science itself than about its economic and social role) [2]. The Irish S&T environment was known to comprise of foreign companies, who although creating jobs and exports, were hiding the weakness of our indigenous small to medium sized (SMEs) sector. The government assumed that Ireland could just purchase innovation from others and not develop our own expertise [2].
- The EU Heads of State met in Lisbon (2000) (prompted by a decade of slow growth and slipping competitiveness) – A new target for Europe was to "become the most competitive, knowledge-based economy in the world by 2010" [4].
- The EU commission's April 2003 publication "More Research for Europe" [5] set two targets: A target for Europe of achieving Gross Expenditure on R&D (GERD) as a percentage of GDP of 3% by 2010; with two-thirds (i.e. 2%) to come from the private sector.
- Based on these EU targets a high level national steering group was set up [6] with the goal of developing the Irish Research and Development Action Plan [6], entitled "Building Ireland's Knowledge Economy – The Irish Action Plan for Increasing Research and Development to 2010" [7].

- This ‘Action Plan’ considered the EU’s “More Research for Europe” report and complemented the July 2004 Enterprise Strategy Group report, “Enterprise Strategy Group Report – Ahead of the curve” [6, 8]. The ‘Action plan’ and ‘Ahead of the Curve’ will both be discussed next.

1.1.1 Building Ireland’s Knowledge Economy

The “Action Plan” [7] describes Ireland’s 2001 research and innovation performance, defines a vision for building a knowledge economy, and describes how to implement it. The vision is a follows:

“Ireland by 2010 will be internationally renowned for the excellence of its research and will be at the forefront in generating and using new knowledge for economic and social progress, within an innovation driven culture”[5] [7]

Figure 1.2 below compares Ireland’s 2001 gross expenditure on R&D as a percentage of GDP/GNP to that of Europe as a whole, the European nation countries, OECD, China, Singapore, USA, Japan and Korea. In relation to the EU we were about two thirds of the EU average i.e. 1.4% GNP (Gross National Product). The GNP value is used for Ireland as it is the national income unlike the national output GDP value which includes the repatriation of profits and royalty payments from multinational corporations (MNCs); GNP is therefore a more realistic measure.

[5] The current vision (2007) as quoted in the Strategy for Science, Technology and Innovation report has changed the year to 2013 9. Department of Enterprise and Trade and Employment [online]. *Strategy for Science, Technology and Innovation 2006-2013*. 2007. [cited 16 February 2007]; Available from: http://www.entemp.ie/publications/science/2006/sciencestrategy.pdf .

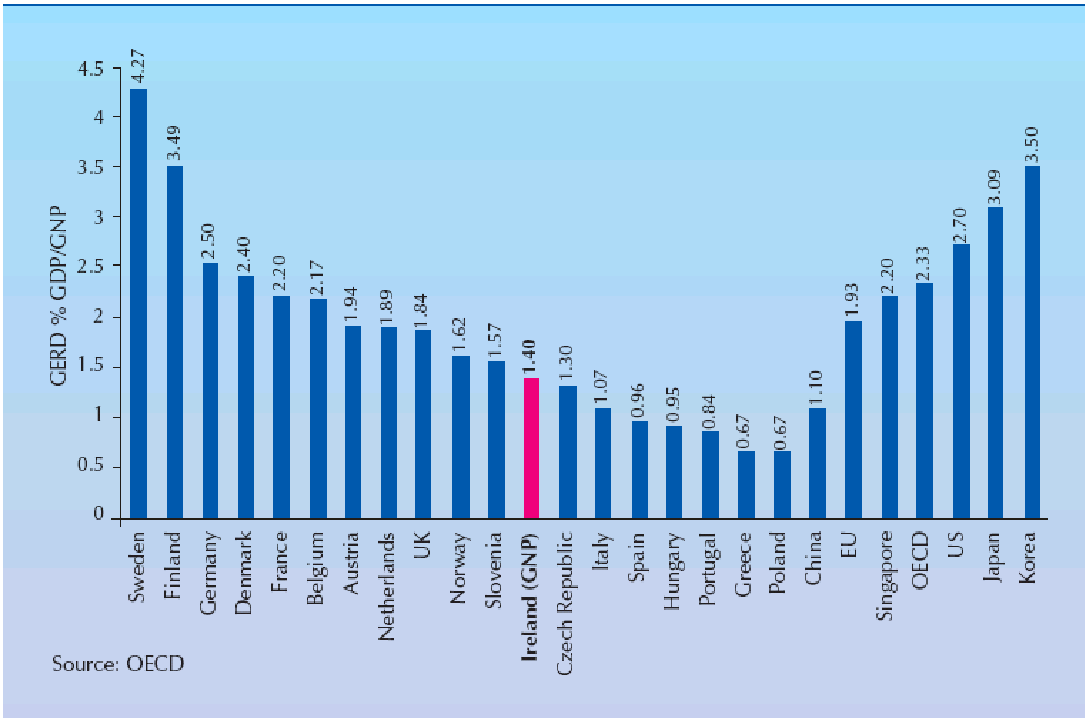

Figure1.2 Gross Expenditure on R&D as %GDP / GNP, 2001 [7]

As can be seen, Sweden at 4.27% and Finland at 3.29% were already over the EU goal of 3%. During the 1990's, in Ireland, R&D on business, higher education and public research institutions increased by a factor of three. The 2001 values and the 2010 values (per annum) i.e. the target values required in order to reach the vision are below along with some general information [7] (from [10], an enterprise is "any entity engaged in an economic activity, irrespective of its legal form"):

- Overall, business investment in R&D should increase from €917 million in 2001 (0.9% GNP) to €2.5 billion in 2010 (1.7% GNP)[6].
- Indigenous Enterprises.
  - Only 1000 indigenous enterprises (representing one third) spend on R&D, and of these 85% spend less than €500,000.
  - 525 with minimum scale R&D (greater than €100,000) in 2001 should reach 1050, double, in 2010.
  - 26 of the 1000 enterprises spend more than €2 million (significant R&D), this should be 100 in 2010.
- Foreign Enterprises.

[6] The current vision (2007) as quoted in the Strategy for Science, Technology and Innovation report has changed the year to 2013 9. Ibid. [cited..

- o 300 enterprises (one third) are active in R&D and account for two thirds of all business R&D.
  - o 150 spend less than €500,000 per annum.
  - o 239 enterprises have minimum scale R&D (greater than €100,000), this should increase to 520 in 2010.
  - o 47 enterprises have significant scale R&D (greater than €2 million), this should increase to 150 in 2010.
  - o 19 spend more than €5 million (representing two thirds of all R&D).
- Higher Education and public research sector spending reached €422 million in 2001 (0.4% GNP), this should increase to 1.1 billion in 2010 (0.8% GNP).

The overall increase in R&D performance from the business, higher education and public sector should result in gross expenditure of 2.5% of GNP in 2010. As a result of this it is predicted that the number of researchers should increase from the 2001 value of 5.1 per 1000 employed to 9.3 per 1000 employed in 2010.

As can be seen from Figure 1.3 below, Ireland's indigenous R&D strengths lie in the sectors of information communication technologies (ICT) and food and drink (this research is concerned with physical products), although a lot of academic research is ongoing in biotechnology.

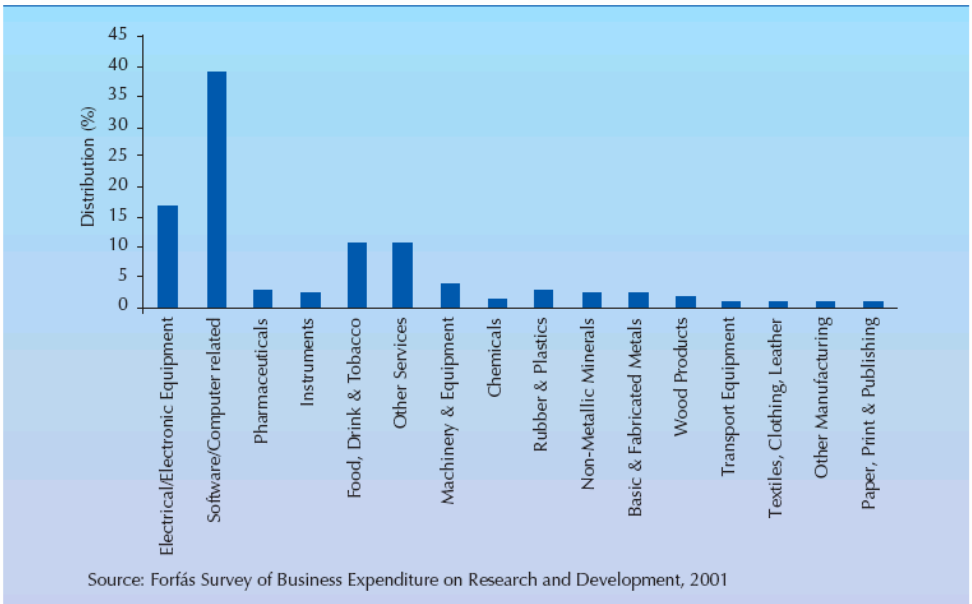

Figure 1.3 Distribution of Indigenous Firms R&D by Sector, 2001 [7]

Based on these ‘Vision’ goals various state bodies have developed their own strategies in order to assist business, both indigenous and foreign, and educational institutions, to achieve the desired levels of R&D. The key findings of the action plan were to develop a pro-innovation culture, change the direction of the enterprise support budget towards R&D while making the R&D support process less bureaucratic, develop a national plan to improve research in the higher education sector while building an international reputation, make Ireland a highly attractive place for researchers and research careers, and finally to turn the knowledge arising from all research into products and services [7].

1.1.2 Enterprise Strategy Group Report – Ahead of the curve

This group specifically looked at the move to a knowledge economy from the perspective of the enterprise sector. Their report “Ahead of the Curve” stated the challenges facing enterprise in the Irish economy:

- The scale of globalisation – Countries like India and China, with a combined population of two billion people offer lower costs and skilled labour and are directly competing with Ireland.
- An increase in the Irish Cost base.
- Ireland’s low rate of tax (12.5%) is being copied by competitors.
- Overall, Ireland’s indigenous industry sector has not been strong in exports over the last decade.
- Since 2006 the EU have changed state aid limits thus restricting state aid for enterprise.

While bearing the above points in mind, it also has to be noted that the nature of global trade is also changing. Ireland’s future economic development will be strongly influenced by:

- A shift toward services as a major driver of Gross Domestic Product (GDP).
- Knowledge as a driver of economic development and an influencer of new products.

Due to these facts the enterprise strategy group set out a new strategic direction for enterprise in Ireland which was based around Ireland's current strengths. Figure 1.4 shows a profile of expertise in Ireland in 2004 and the required profile in 2015 across what is basically a top level product development process.

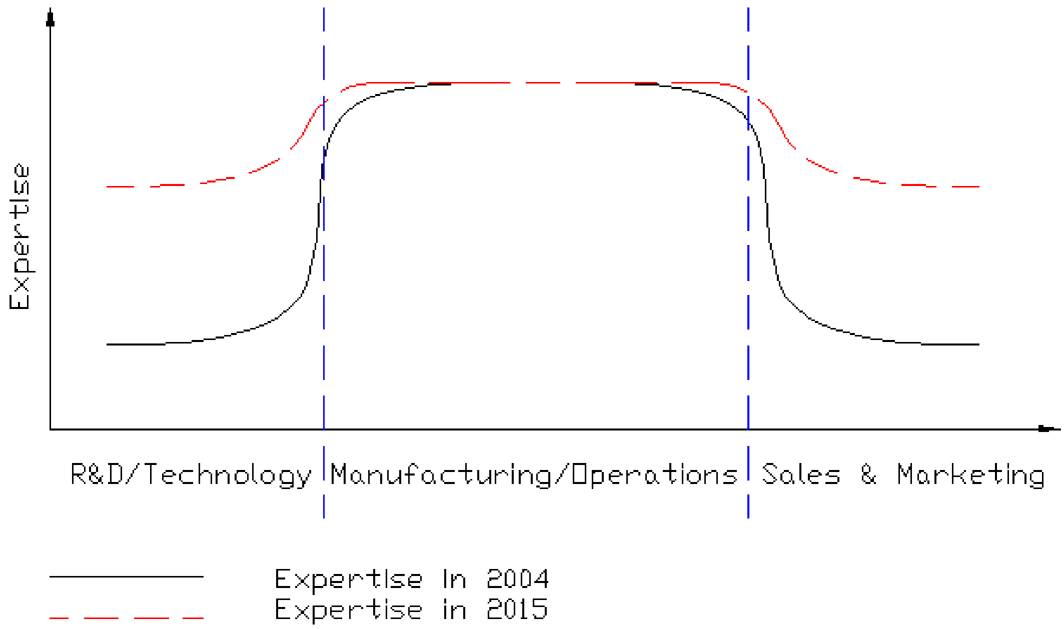

Figure 1.4 Expertise/Knowledge Profile in Ireland [8]

As can be seen from this graph, Ireland's enterprise strengths currently are in the operational aspects of manufacturing and services. By 2015 these need to be in the product development and marketing areas i.e. where knowledge drives economic development. The reason for this current state is that Ireland's expertise is mostly gained from foreign enterprises that generally do all the early development and marketing of their products in their own countries and manufacture them in Ireland for export. The Enterprise Strategy Group identified five sources of competitive advantage with which Ireland can reach the 2015 graph. Figure 1.5 shows the essential conditions and the competitive advantages required for sustainable Irish enterprises.

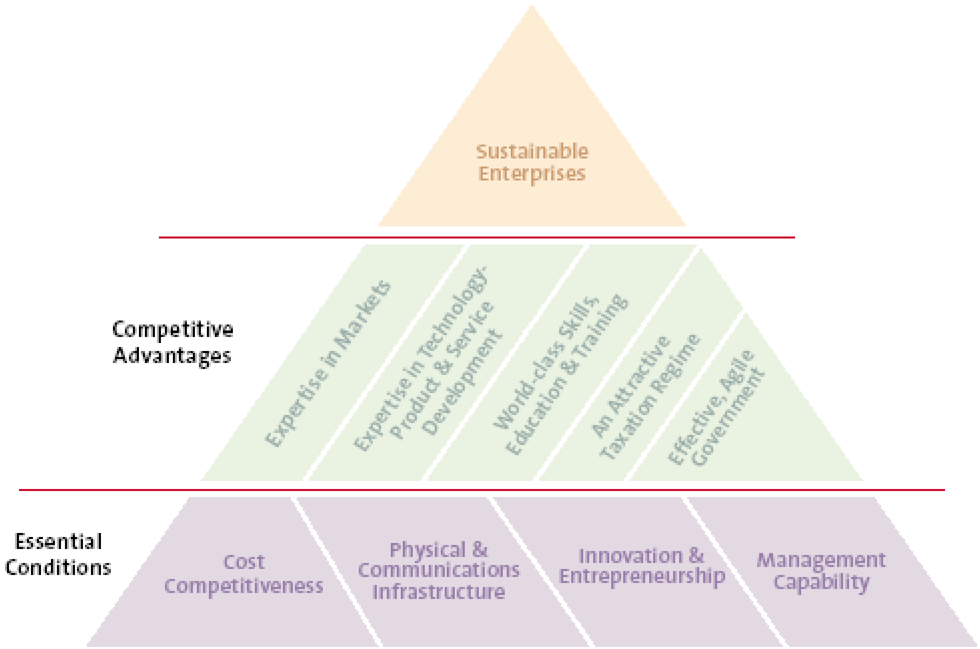

Figure 1.5 Identified Competitive Advantages [8]

The competitive advantages and their associated characteristics are shown in the Table 1.0 below:

Table 1.0 Competitive Advantage Characteristics [8]

Competitive Advantage	Characteristics
Expertise in Markets	Development of international marketing and sales expertise to bring enterprise in Ireland closer to customer needs.
Expertise in Technology-Product and Service Development	Development of world-class capability in focused areas of technology and in innovative techniques, to drive the development of sophisticated, high-value products and services.
World-class Skills, Education and Training	Building on Ireland's historic commitment to education with a renewed focus on excellence and responsiveness to deliver skills appropriate to the needs of enterprise.
Attractive Taxation Regime	An ongoing commitment to our competitive tax regime, promoting enterprise and driving business growth.
Effective, Agile Government	A single-minded national consensus on the enterprise agenda, driven from the highest level and across all of Government, together with governance systems which enable swift decision-making and execution.

It is commonly accepted that Ireland is currently strong in three of these nationally, and must continue to remain so, but must seriously develop the expertise in sales and marketing, and product and service development [8].

As can be understood from the above discussion, the EU, the Irish Government, its State Bodies and the enterprise sector are all driving the Irish economy from a manufacturing based economy to a knowledge based economy built on basic and applied research and product development. To quote the Communication from the EU commission, “More Research for Europe – Towards 3% of GDP”;

“The place for R&D in the overall business strategy of companies as well as the effectiveness and efficiency of their R&D activities are important factors to consider” [5]

Against this background, it was decided to carry out further research into the indigenous SME sector in Ireland i.e. it was emerging as the area to focus on due to: low spending on R&D, the requirement to have knowledge as a driver (Figure 1.4 above), the requirement to develop expertise in product development, low physical product R&D strengths and weak exports over the last decade. The following two sections examine the SME Sector in Ireland and in particular the sales, marketing and innovation capabilities of SMEs. This will give a better understanding of product development within the indigenous SME sector.

1.2 Review of the SME Sector in Ireland

Figure 1.6 shows the SME definition of micro, small and medium sized companies in terms of three criteria and their thresholds; staff headcount, annual turnover, and annual balance sheet [10].

Enterprise category	Headcount: Annual Work Unit (AWU)	Annual turnover	or	Annual balance sheet total
Medium-sized	< 250	≤ €50 million (in 1996 € 40 million)	or	≤ €43 million (in 1996 € 27 million)
Small	< 50	≤ €10 million (in 1996 € 7 million)	or	≤ €10 million (in 1996 €5 million)
Micro	< 10	≤ €2 million (previously not defined)	or	≤ €2 million (previously not defined)

Figure 1.6 Criteria and Thresholds [10]

According to the small business forum (SBF), [11], over 97% of businesses operating in Ireland are 'small'. This is approximately 250,000 businesses employing 777,000 people. Reference [11] states that "the performance of the small business is thus an important contributor to the overall quality of life and standard of living in the country…and…as the Irish economy becomes increasingly knowledge-based, and as low value-added activities migrate to lower cost economies, a greater proportion of the country's wealth will have to be generated by indigenous companies". Figure 1.7 shows the distribution of the Irish labour force in 2005.

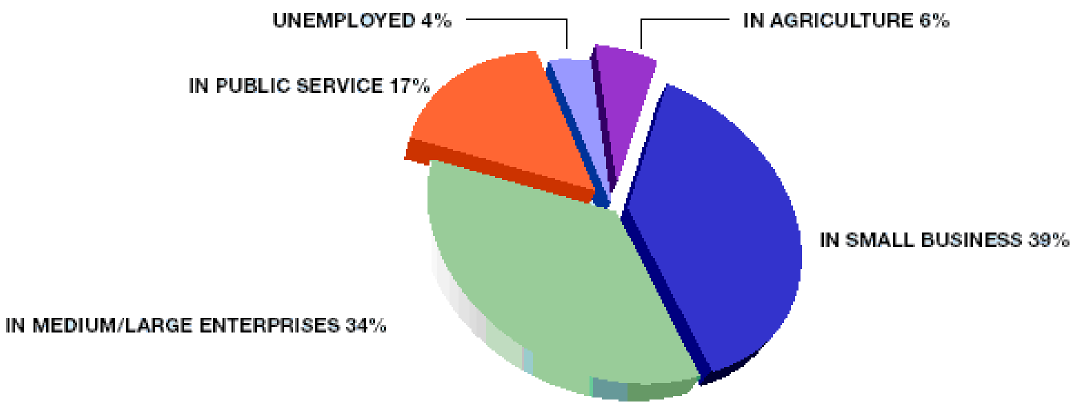

Figure 1.7 Distribution of Irish Labour Force, 2005 [11]

The current National Development Plan (2007-2013) [12] outlines the planned government investment for indigenous SMEs. The combined enterprise development investment is 3.3 billion Euro (indigenous SME and foreign direct investment (FDI)). Of this sum, 1.7 billion Euro will be available to indigenous enterprise via Enterprise Ireland (supported at regional level by the County Enterprise Boards) during the Plan period. This investment will focus on:

- High-potential start up companies and 'scaling growth' orientated companies.
- Increasing competitiveness and productivity of existing companies.
- Developing management standards.
- Access to equity and finance/loans.
- Support for entrepreneurs and micro-enterprises [12, 13].

In general one of the main purposes of this investment is the financial implementation of the current Strategy for Science, Technology and Innovation strategy [9] and the 'Ahead of the Curve' report [8, 12].

1.2.1 Sales, Marketing and Innovation Capabilities of SMEs

Reference [14] discusses sales, marketing and innovation capabilities of Irish exporting SMEs. The findings in this report were based on a survey of 63 Irish exporting SMEs (15 in engineering/electronics, 10 in healthcare/pharmaceuticals/diagnostics, 14 in international traded services/software and 24 in food) and 30 overseas SMEs carried out in 2003 - . The breakdown of firms surveyed by number of employees is shown in Figure 1.8 (only 5% with more than 250 employees).

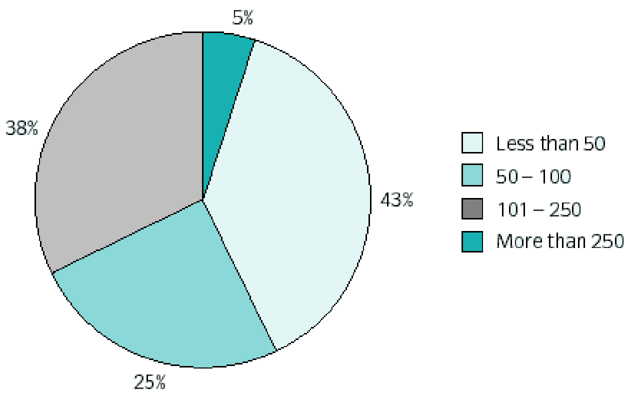

Figure 1.8 Companies Surveyed by Number of Employees [14]

Seven areas of capability were addressed by the survey:

- Marketing and selling strategy processes.
- Skills base.
- Customer focus.
- Marketing information systems.
- Innovation.
- Branding and promotion.
- Use of Information and Communication Technologies.

1.2.1.1 Sales and Marketing

Reference [14] found that SMEs' priority is always sales rather than marketing. Due to restraints on time and resources associated with detailed planning, SMEs do not prepare detailed plans as they are more concerned with responding quickly to changing market circumstances and therefore adapt their strategy and focus as needed. Also, they consider their time is better served dealing with customer issues. When asked, Irish SMEs considered sales management to be a key area for improvement (63%) with marketing planning and NPD both next at 46%. Whereas only 26% of overseas considered NPD an issue, Figure 1.9 below[7].

[7] IP is low on Figure 1.9 because internationally traded services and food companies do not have IP as a major concern when compared to high-technology companies.

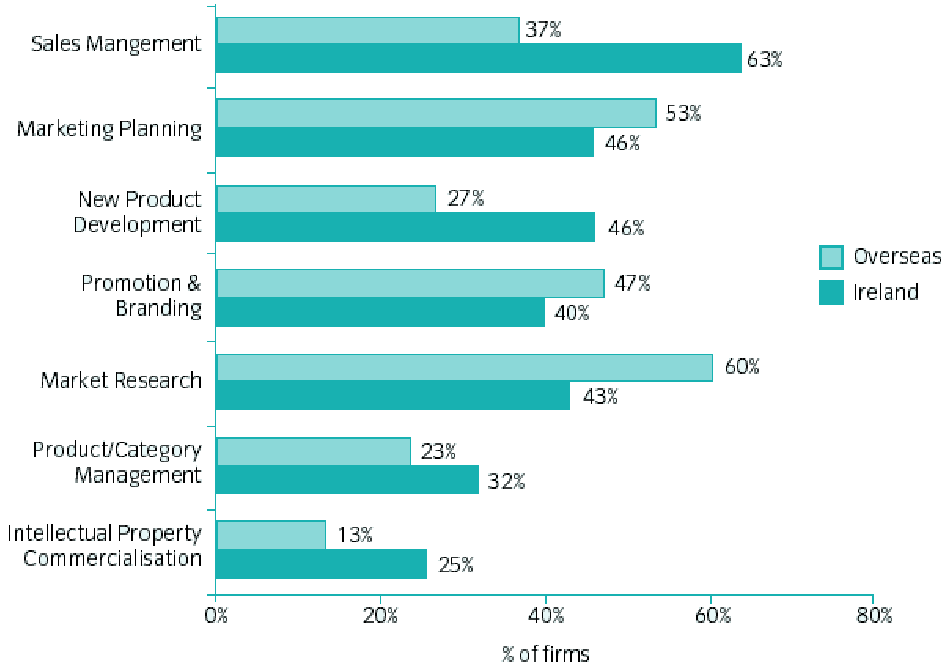

Figure 1.9 Sales and Marketing Skills Base Comparison [14]

This is addressed by some companies by appointing a 'Chief Selling Officer' who can be the CEO/CFO to take lead sales responsibility.

In terms of the customer, Irish SMEs are very focused on customer needs, with 73% carrying out customer surveys, see Figure 1.10.

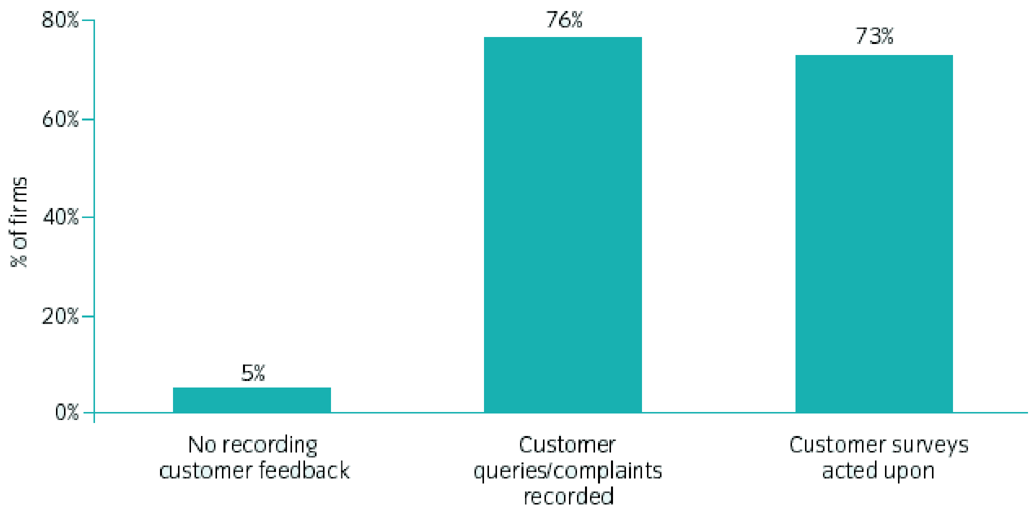

Figure 1.10 Responsiveness to Customer Feedback [14]

These SMEs also carry out customer base segmentation by trade buyers/end users, customer, and profitability. Another finding of this report was the weakness in market research, Figure 1.11.

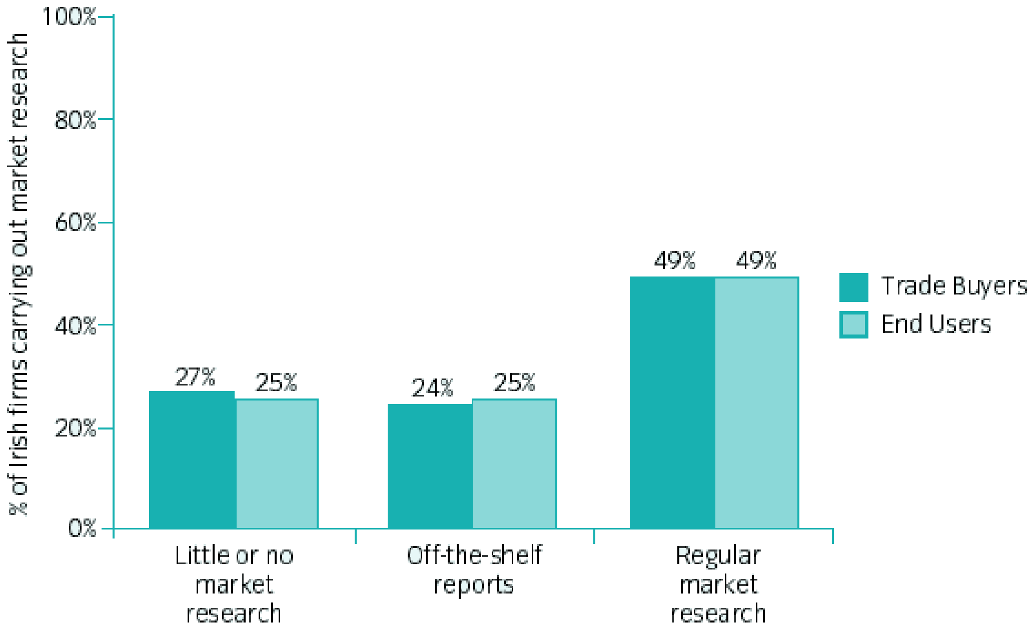

Figure 1.11 Firms carrying out Market Research [14]

Because many SMEs have a niche market focus they do not have to carry out full market research like the MNCs. This is because they can stay close to their key customers and gain feedback as described above and in some sectors off-the-shelf reports and information services are adequate [14]. However, it is questionable if this is sufficient to remain in touch with developments in technology. This will be dealt with in Section 2.5 on Strategy Techniques.

1.2.1.2 Innovation

As discussed in reference [14], the environment in which SMEs operate needs to be suitable for nurturing innovation. This is decided by government policy and outside of the scope of this thesis.

On the innovation front (Section 2.3) the survey found that 83% of Irish SMEs recognised continuous innovation as key to their strategy. Also, while most companies were targeting product and technology innovation, half the companies were focusing on 'breakthrough' rather than 'incremental' innovation but less than half were happy with their idea generation and idea screening processes. Figure 1.12 shows this as the structure of innovation across general stages of the front end PDP. There was a lack of understanding of these processes and the tools and methodologies used in the early phase of innovation (idea generation and screening of best ideas).

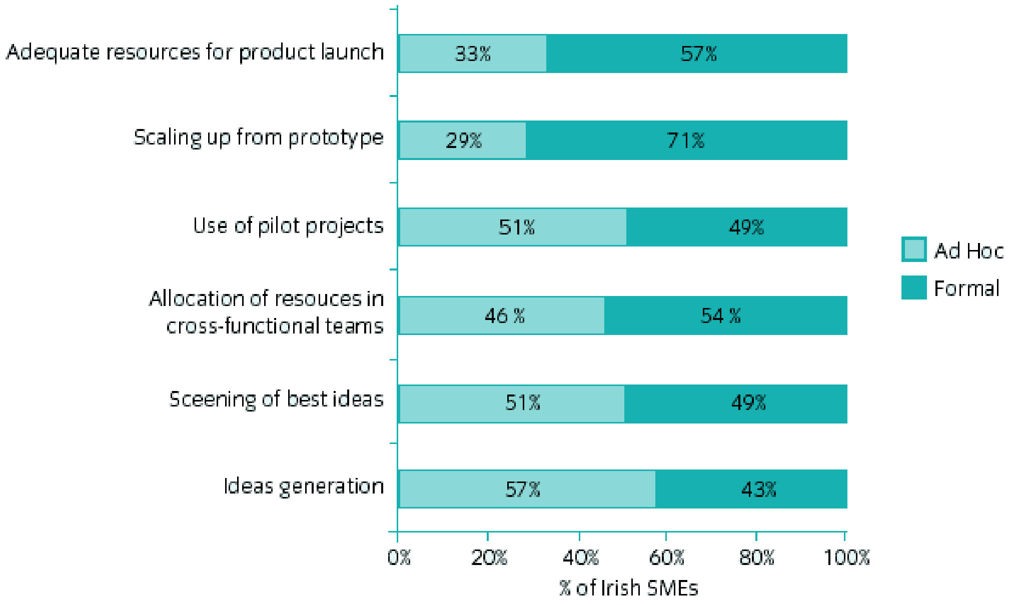

Figure 1.12 Structure of Innovation at stages of the PDP [14]

Figure 1.13 shows how far along the structure of innovation cycle companies are by sector:

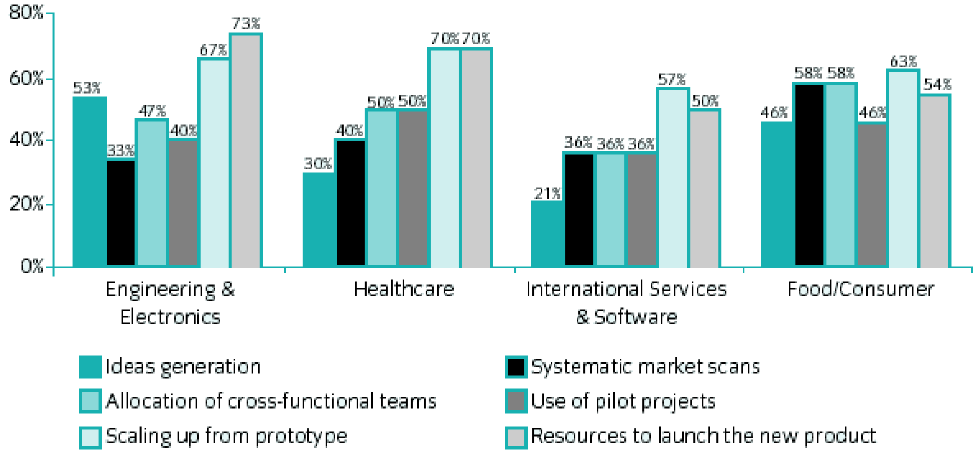

Figure 1.13 Cross Sectoral Analysis of Innovation Management at stages of PDP [14]

As can be seen international services and software is the overall weaker sector. All sectors are better at allocating resources to product launch than the initial ideas generation stage. Overall the Engineering and Electronics sector is better at ideas generation.

Figure 1.14 shows the ‘sources of innovation’ for Irish SMEs companies in comparison to the surveyed overseas companies:

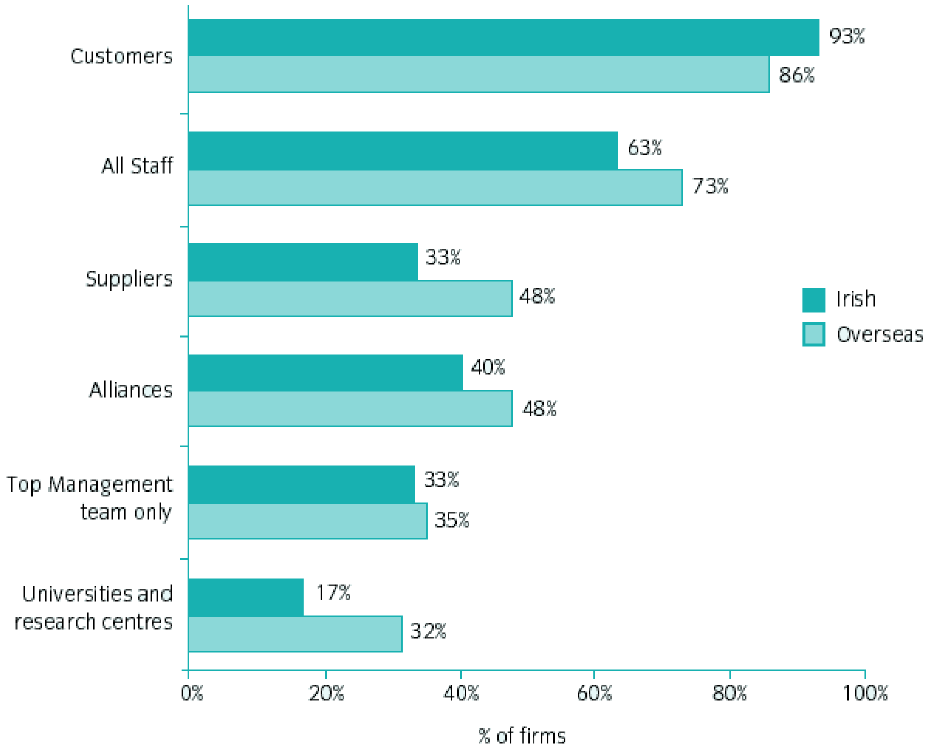

Figure 1.14 Sources of Innovation for Companies [14]

This again shows the importance of the link to the customer placed by Irish SMEs with 93% of new ideas generated via the customer by literally listening rather than using tools and methodologies. In addition, 33% of ideas arise from suppliers and 63% include all their staff. It is also clear that Irish SMEs are not using universities and research centres sufficiently, although according to Forfás this could be linked to the difficulty of commercialising academic research.

Figure 1.15 shows the level of innovation capability as rated by Irish SMEs.

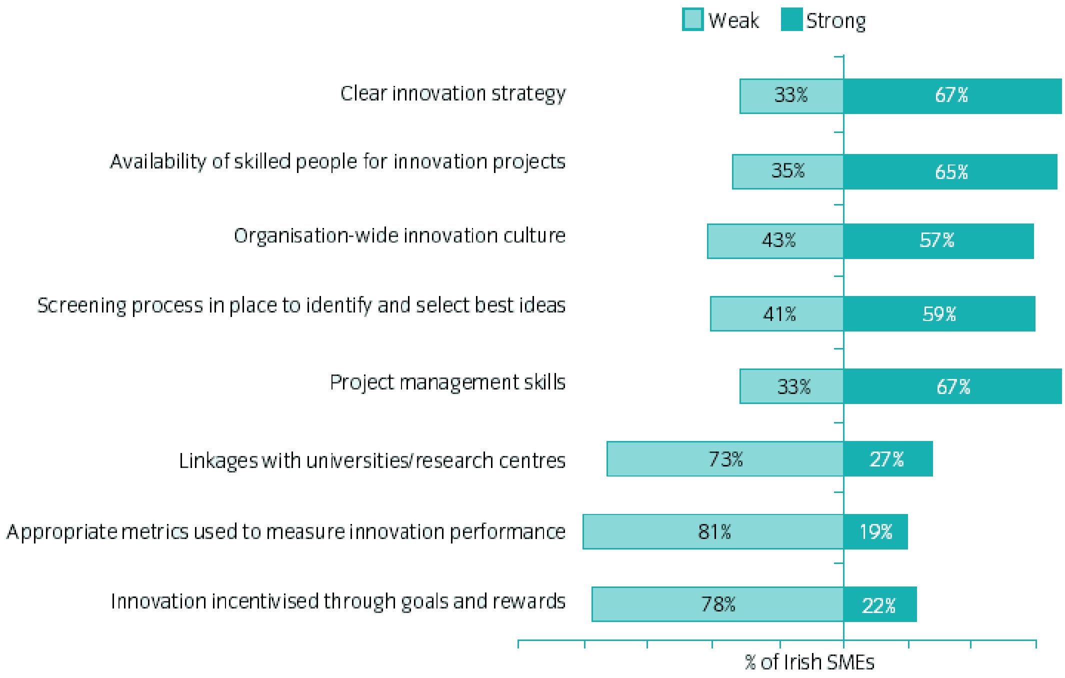

Figure 1.15 Level of Innovation Capability [14]

Both company wide innovation culture and screening processes should be improved. There is also a high lack of metrics to measure innovation performance (See Section 2.13).

This examination of the SME sector showed there are improvements to be made in the way indigenous SMEs do business – in particular product development. It was therefore decided to ascertain the academic research conducted on indigenous SMEs. Specifically any indigenous SME product development based surveys in order to discover if there was justification for surveying indigenous SMEs in Ireland.

1.3 Irish Product Development Survey Research

In total 696 Irish reports were found in relation to PD. Two of these are directly relevant in terms of a survey, one PhD study by Ledwith [15, 16] and another PhD study by Hurst [17]. Also found relevant was the work of Cormican and O'Sullivan [18].

1.3.1 Ledwith

Ledwith's PhD [15] was on the research of management of NPD in small electronic firms (at the time of that study the SME definition was less than 100 employees). She examined strategic and market factors, development process factors and organisational factors. Much of her literature review was based on large companies as she stated that information on SMEs was minimal.

1.3.1.1 Approach

The following bullet points highlight the approach of Ledwith's work:

- The research method involved collecting information at both corporate and project level.
- Used a research tool which was used previously as part of a USA study in order to compare findings i.e. this research was part of a larger project called INTERPROD.
- There were seven questionnaires – Three at company level and four at project level.
- Respondents varied for each type of questionnaire – Managing director, technical manager/director, marketing manager and R&D Engineers.
- Companies chosen from the 1997 Kompass database with 888 companies identified.
- 56 Developing Electronic (Hardware) products from idea generation to manufacturing and marketing start-up and after sales service.
- 36 companies interviewed – 14 Large and 22 Small. This interview was the survey. Each company was brought through the survey in person via an interview [16].
- All companies discussed two projects, one successful one failure. Although not all could distinguish failures from successes (this method was used as it crosses boundaries between small and large companies).
- Used a Likert-type scale as a success/failure approach was deemed to be the most practical way to address the research questions [16].
- Spearman correlation coefficients were used to measure the association between two variables when only ordinal data were available. For reference [15] this was the level of project success (ordinal scale) compared to the degree of application of management practices (ordinal scale).
- Not all Irish owned but had Irish management [15].

1.3.1.2 Findings

Ledwith [15] found that at the company level SMEs had fewer patents i.e. they were not protecting their technology findings. Also, they tend to work with external organisations less than the MNCs, and in particular customers and suppliers. Yet, understanding user requirements is a key success factor for SMEs but not for large firms. SMEs had more success with product developments that were a close fit to their existing markets whereas MNCs could target rapidly growing markets. In terms of organisational structures, companies with 15 to 20 employees had excellent communications due to their size; however, SMEs with 50 and greater employees must add mechanisms for communications and knowledge management. Top management involvement was also found to be critical in SMEs and there was concern that the SMEs' outlook was short term i.e. they only concentrate on individual products and do not consider platforms.

1.3.2 Hurst

Hurst [17] looked at changing relationships between buyers and suppliers, models of concurrent engineering and success factors of product development; this was carried out in 1996. He saw the challenge of his PhD as threefold:

1. How to conduct a survey.
2. The development of an alternative and suitable model of the concurrent engineering methodology that would be relevant in the context of the typical SME in Ireland.
3. The difficulties of assessing PD performance in industry (practical based environment) while still researching the PhD to the required level of academic rigour. This contradiction manifests itself in the item questions.

1.3.2.1 Approach

It involved a survey of 208 SMEs (indigenous and foreign owned) in Ireland and had a response rate of 40.1% (83). This thesis had two elements, the understanding of the then current PD status in Ireland and the prediction of future PD based on the then best practice of concurrent engineering. The difference between what was considered current and future was the difference between past methods of carrying out PD based on process, organisation, strategy and performance and what Hurst considered the future of PD. The future was concurrent engineering as described in Section 2.12 of this thesis. The second of Hurst's surveys therefore had the use of teamwork, integrated Computer Aided Design (CAD) (See Section 2.8) systems and design tools such as Quality Function Deployment (QFD) (See Section 2.7) and Robust Design (Taguchi Method) (See Section 2.7). In total there were 170 items on the questionnaire, estimated to take 30 minutes. The questions were of two types, type one required the response to have factual information and type two was based on a scoring system. The response rate was improved by issuing a press release to the business and technology press and general newspaper editors in Ireland explaining what the research was and asking for cooperation.

1.3.2.2 Findings

This survey concluded that there was a low level of understanding of the methods and tools used in support of PD and therefore few companies looking to implement best practice PD methods [17].

1.3.3 Cormican and O'Sullivan

Cormican and O'Sullivan [18] developed a product innovation management (PIM) model and based on this a product innovation scorecard. This was used to measure companies' performance in terms of product innovation management.

1.3.3.1 Approach

The following bullet points highlight the approach of the Cormican and O'Sullivan paper [18], whose origins will be discussed in Section 2.3.1.2 under the 'fuzzy front end':

- Studied eight technology based organisations whose main activity was Product Design and Development; they were all multinational corporations.
- Interviewed members of the senior management team.
- Goal of the interviews:
    - Identify the strengths and weaknesses of each organisation's product innovation process.
    - Identify factors that facilitate innovation in industry.
    - Discuss how companies must improve in order to maintain long term competitive advantage.

- They used case study analysis as Lewis [18] states that researchers should use field based research methods (case study analysis) in order to allow for the rapid changes in technology and managerial methods.
- Case research especially for the product innovation process.
- Sample chosen was selective – Based on organisations known for best practice in product innovation.
- Industrial sectors were – Healthcare, computing, pharmaceuticals, telecommunications and electronics.
- PIM scorecard had 50 criteria or traits.
- Score 1 to 5 depending on agree or disagree with statements – circled the statement most applicable.

1.3.3.2 Finding

They concluded that the PIM was a best practice model which facilitates product innovation management in a dynamic environment. They found that the eight organisations had:

- A focused vision.
- Strong leadership and customer orientation.
- High level of idea exploitation and problem solving.
- Cross functional teams with all levels of the organisation involved.
- Effective project planning and selection needed more thought.
- Communication between teams (and within teams), customers, and suppliers was critical and needed more infrastructure [18].

1.4 Is there a Gap in indigenous SMEs PD Approaches?

This section will examine the justification for researching the product development approaches of indigenous SMEs. It will draw conclusions on the Irish product development survey research in Section 1.3 and the research carried out by the Organisation for Economic Co-operation and Development (OECD). A specific look at Ireland by the Small Business Forum (SBF), Expert Group on Future Skills Needs, Forfás and the National Competitiveness Council (Ireland’s competitiveness challenge) will be examined. Based on this a gap in the research will be identified.

1.4.1 The Gap in Irish product development survey research

Based on the review of the Irish product development survey research the following shows the potential to research SMEs further:

- The PhD research carried out by Hurst [17] was conducted in 1996 (12 years ago) and as such does not cover the current thought. At the time he concluded that there was a low level of understanding around product development in Irish SMEs.
- Cormican and O'Sullivan's research was conducted on MNCs only and did not cover SMEs. It also only surveyed 8 companies [18].
- Ledwith's research [15, 16] surveyed 22 SMEs in 1999 that were in one sector, electronic.

1.4.2 Further Justification for PD indigenous SME Survey Research

According to the first report from the Small Business Forum (SBF) [11] there is very little statistical information on small business (<50 employees) in Ireland. For their report, they stated that statistical information used was either inconsistent or incomplete. OECD [19] supports this by stressing the lack of information on SMEs for policy making. They state that 'many issues relating to SMEs can only be addressed with sets of micro-level data that allow for tracing individual firms or establishments over time' [19].

Reference [15] stated that small companies are concerned about operational issues such as controlling costs, improving quality, reducing failures rather than future opportunities i.e. new product ideas, new markets, and improved time to market. However, this is something that is going to have to change due to the global threat to SMEs. According to the Forfás report Innovate-Market-Sell [14], overseas manufacturers are advancing from simple contract manufacturers to developing, manufacturing and selling their own products and therefore increasing competition on Irish SMEs. This is during a time when Irish political and economic objectives have largely been designed to attract foreign owned industry [20] and when 33%-41% of small companies fail within the first five years [14]. References [14, 15] also state that there is a need to develop product development processes tailored to SME needs as most literature on PD is for and therefore based on multinational research [14]. In addition [14] also states that SMEs do not have resources or time to follow very structured or written processes. This would also suggest the need to understand product development approaches/expertise in SMEs.

Ireland has a very small market and therefore Irish SMEs must gain the skills to become exporters relatively sooner than other countries [14, 20, 21]. Most SMEs focus on specific market niches and must look beyond exporting to the UK [14, 20]. In relation to skills, the work of Expert Group on Future Skills Needs [22] found that SME training courses are too theoretical and not tailored to SME specific needs. There is a lack of detailed understanding of the following issues:

- Product and process development.
- Strategic management – The ability to develop a long term strategy for the company and provide a shared vision for the future.
- Innovative thinking – The ability to develop innovative approaches to High Performance Management (HPM) and to recognise innovative solutions presented by others.

'High performance management' is a phrase which refers to the evolution of organisational practices involving high levels of employee involvement and organised improvement processes [22]. The strategic management issue was supported by a survey of 20 organisations by [20] all of which cited the requirements to learn how to do robust strategy design (Section 2.7) and strategic thinking (Section 2.3/2.5). This is supported by a reference [14] survey, which found that market planning and NPD were key areas for improvement for SMEs with both at 46% (See Figure 1.9 above). This is also in line with the findings of reference [23] which stated that there are low levels of R&D, and limited sales and marketing capabilities within SMEs.

1.4.3 Statement of Research Gap

The finding of this chapter show that both the EU and the Irish Government (and state bodies) efforts are all focused on creating indigenous SME engineering companies built on R&D. It also shows the current gap in academic research on indigenous SMEs and therefore these indigenous companies should be the ones surveyed. By surveying indigenous SMEs an improved and more detailed understanding of where Ireland is along Figure 1.4 (the current versus the future profile of expertise/knowledge in Ireland) will be gained.

Therefore, the definitive gap in information in the public domain lies in the approaches (level of expertise) with which indigenous SMEs are conducting their product development and this is the gap the survey will try to ascertain.

As can be seen in Section 3.2.1.1 this gap is used to form the general theory or hypothesis that 'indigenous SMEs do not follow 'best practice' approaches to product development' i.e. if SMEs are using 'best practice' than Ireland will have a high level of expertise. This is tested by breaking the hypothesis into sub-hypotheses (Section 3.2.1.2).

1.5 Objectives of the Thesis

The first objective of the research is to carry out a literature review of product development approaches with a view to best practice in the SME and MNC sector from:

1. An international perspective – Journals/databases, books and the internet.
2. A national perspective – Journals/databases, books and the internet.

Based on the results of this literature review a process questionnaire and a performance questionnaire will be designed encompassing best practice and focussed on SMEs. These will be used to survey indigenous SMEs in Ireland. These SME's will be 'technology based' companies producing physical products. According to the OECD [24], SMEs fall into three groups:

1. 'High-tech' SMEs or technology developers (have R&D capacity).
2. Lead technology users (Some have R&D capacity some do not).
3. Technology followers with potential for innovative activity.

Technology developers and some lead technology users benefit from R&D support because their focus is on developing leading edge technologies. All the indigenous SME companies in the sample frame (See Section 3.2.1.4.1) used for the survey received development grants and are or based on their application should be, technology developers or lead technology users with R&D activities [24].

Software development is not considered within the scope of this research. A physical product is defined as an electronic, medical device, plastic or general engineering product. It does not include pharmaceutical or food companies as their product development processes are ‘process’ based i.e. chemical based and recipe based as distinct from mechanical and are therefore developed differently.

Thus, the research will:

1. Add to the worldwide level of understanding of SME Product Development.
2. Add to the level of understanding of SME Product Development expertise in indigenous Irish SMEs.

It is hoped that this research will:

- Give an understanding of the level of expertise within indigenous SMEs developing physical products.
- Be used or adapted to survey other industries by Forfás or Enterprise Ireland.
- Aid Enterprise Ireland in implementing their action to “Develop innovation management processes tailored to SME needs” [14].
- Be used to inform government policy.
- Be used by SMEs engaged in product development to improve their business (as a measure of best practice).
- Be used as a basis for further ‘best practice’ studies into other development areas e.g. software development.

1.6 Literature Review Structure

Chapter 2 details the literature review. It is broken down into 13 sections, see Figure 1.16 below:

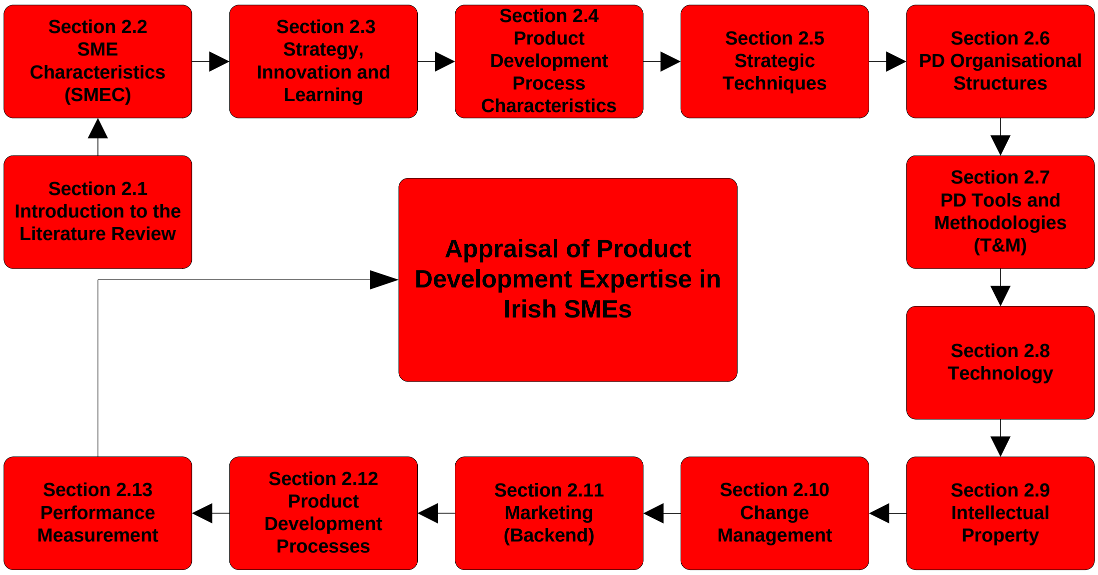

Figure 1.16 Literature Review Structure

Chapter 3 covers the top-level research approach, explaining the rationale behind the selection of a quantitative research approach. The quantitative research approach uses a survey research method for data collection, which is discussed, along with the sampling frame and the company selection process - this is followed by the questionnaire design. Chapter 4 covers the Pre-Test, Pilot Analysis and Final Questionnaire Methodology. Chapter 5 examines the final questionnaire data – descriptive statistics, exploration of normality and reliability/consistency analysis. Chapter 6 carries out regression analysis/hypothesis testing and finally Chapter 7 concludes the research with recommendations for further study/research (Figure 1.1 above).

1.7 Conclusion

The research gap and the objective of the thesis were detailed in this chapter. The overall layout of the thesis and details of the structure of chapter 2 were also outlined. The next chapter covers the literature review.

Chapter 2
Literature Review & Identification of SME and PDP Characteristics

2.1 Introduction

This chapter covers the literature review as shown in Figure 1.16 of Chapter 1. Chapter 1 examined the current research of PD in Ireland, specifically, indigenous SME product development based surveys. This chapter will start with an examination of international journal articles on SME product development. Management aspects of SMEs are not as well researched as those of large companies. This includes the PDP. It is thought that large company product development approaches can not be ‘scaled down’ and used by SMEs [25-28]. In order to understand product development in SMEs an understanding of specific SME Characteristics (SMEC) (Section 2.2) and SME Product Development Process (PDP) Characteristics (Section 2.4) are required. The SME PDP characteristics in Section 2.4 are used to explain how all sections of the literature review can be used as part of an SME PDP. Table 2.0 below shows the appendix tables related to the product development process elements (A.1 to A.14) and the corresponding thesis sections they are created from. Appendix A.15 to A.28 will be the final tables from which the questionnaire is created (an existing questionnaire could not be used as none could be found that covered all the areas of PDP specific to SMEs – they are not well known).

Table 2.0 Literature Review Appendix Table Construction

Appendix Tables – PDP Elements	Corresponding Thesis Sections	Questionnaire Tables
A.1 – Strategy	Section 2.3 and 2.5	A.15 - Strategy
A.2 - Learning	Section 2.3 and 2.4	A.16 - Learning
A.3 - Innovation	Section 2.3 and 2.4	A.17 - Innovation
A.4 - Tools and Methodologies	Section 2.4 and 2.7	A.18 - Tools and Methodologies
A.5 – PDP Processes	Section 2.4 and 2.12	A.19 - PDP Processes
A.6 - Product Design	Section 2.4, 2.7 and 2.8	A.20 - Product Design
A.7 - Organisational Structure	Section 2.4 and 2.6	A.21 - Organisational Structure
A.8 - Technology	Section 2.4 and 2.8	A.22 - Technology

Appendix Tables – PDP Elements	Corresponding Thesis Sections	Questionnaire Tables
A.9 - Leadership	Section 2.4	A.23 - Leadership
A.10 - Change Management	Section 2.4 and 2.10	A.24 - Change Management
A.11 - Culture	Section 2.4	A.25 - Culture
A.12 - Marketing and Branding	Section 2.4 and 2.11	A.26 - Marketing and Branding
A.13 - Intellectual Property	Section 2.9	A.27 - Intellectual Property
A.14 - Performance Measurement	Section 2.13	A.28 - Performance Measurement

Figure 2.0 below explains the relationship further.

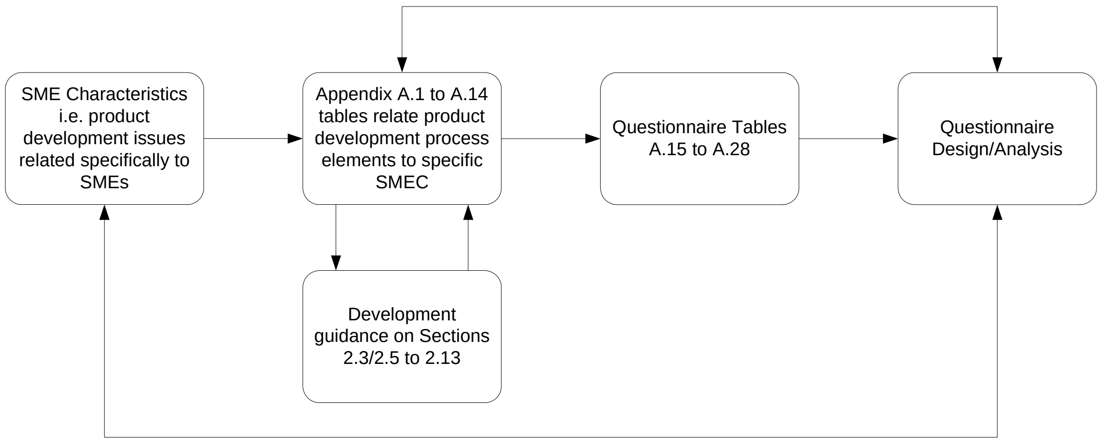

Figure 2.0 Relationships of SMEC and Appendix Tables

Within each PDP Element table are PDP characteristics, each of which relate to an SME Characteristic (the origin of these is explained in Section 2.2). As each thesis section is covered, PDP characteristics will be added to Appendix A.1 to A.14 as shown in Table 2.0 (they appear in the Appendix tables in the order they are created from the literature review). Due to the integrated nature of product development, certain characteristics could appear in other element tables – however, in all decisions it is attempted to place the characteristic in the element table with the highest relevance. In addition, some characteristics are used to guide the development of sections 2.3/2.5 to 2.13. In order for guidance to appear in the form of a characteristic it must have a corresponding SME Characteristic i.e. all PDP characteristics must have associated SMEC. When a characteristic is added to the text the format A.8.4 (for example) will be used – where 'A' refers to the appendix, '8' refers to the PDP element (in this case technology) and '4' refers to the characteristic number. These characteristics are associated to Appendix A.15 to A.27

– the rough format of the final questions. Appendix A.15 to A.27 are also created as the literature review is developed. In the case where an A.1 to A.14 characteristic is a question in itself it is transferred to A.15 to A.27 and placed at the bottom of the table i.e. a check of A.1 to A.14 was done at the end of the A.15 to A.27 table creation to ensure no potential questions were missed.

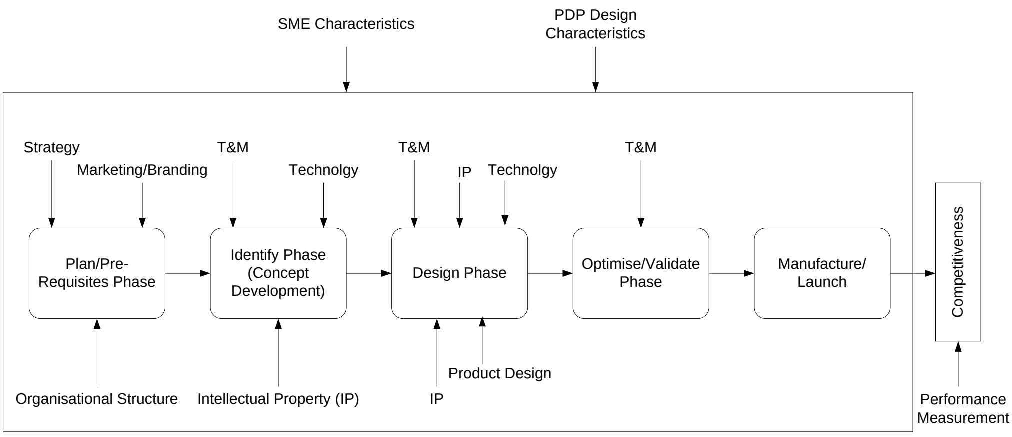

Figure 2.1 Process Based Model of Product Development

Figure 2.1 above shows the 'Process Based Model of Product Development' which has an output of competitiveness measured in terms of overall product performance measurement. The effectiveness of individual processes (inputs) is also measured.

This is similar to an approach taken by Chiesa *et al* [29] who developed a technical innovation (management) audit. The audit had two dimensions: a process audit, which assessed if the processes necessary for innovation were in place and the level to which best practice was used and the performance audit, which assessed the outcome of each process and the overall process of innovation in terms of its effect on competitiveness. Therefore, Chiesa *et al* audit was used not only to identify performance measurement issues (needs and problems) but also to identify process issues (how to solve those problems). This is in line with the conclusion of dynamic capabilities (Section 2.4.1.6). As discussed in references [26, 30] some SMEs do not have a PDP and therefore must add this requirement as part of their strategy i.e. SMEs should follow a formal product development process (A.1.1). Based on this an examination of strategy (product and technology) is conducted first, resulting in Section 2.3 on Strategy, Innovation and Learning. The outcome of this section is a table of strategic techniques, which are examined further in Section 2.5.

2.2 SME Characteristics (SMEC)

The references shown in Table 2.1 below all discuss SME characteristics (SMEC) in relation to their particular research area. These include characteristics identified from the indigenous SME product development based surveys discussed in Chapter 1. They all stress the need for a better understanding of SME product development as the role of SMEs in economic development is crucial. These research areas include; knowledge management [25], innovation implementation [27], new product development in British SMEs [26], a learning framework for the small business environment [28], market and learning and innovation capabilities [31], generic strategies [32], understanding new-to-market product development [33], methods for modelling and supporting innovation processes [34] and barriers to successful NPD [35]. The SME characteristics shown in this table are sub-divided into specific categories: Customer and markets, Organisational structure, Systems processes and procedures, Human and financial resources and Culture and behaviour. Reference [25] was used as the basis for Table 2.1 as they used these categories of SME Characteristics to understand Knowledge Management in SMEs. The references in Table 2.1 where then examined in order to validate this table, strengthen it by adding appropriate PD characteristics and find further explanation for each characteristic specifically in relation to product development. The term owner/manager (O/M) is used to describe an owner of the business who manages or a manager of the business that is not necessarily an owner. Whether the manager is an owner or not should not affect how they approach product development (See A.9.7). Because of this the characteristics under the reference [25] 'Ownership and Management' category are now distributed under the five headings in Table 2.1.

Table 2.1 SME Characteristics (SMEC)

1	SMEC - Customers and Markets	References
a	Generally dependent on a small customer base (Niche)	[15, 24, 25]
b	Mostly local and regional markets - only a few international. Rarely have industry power.	[25, 28]
c	Management highly visible and close to point of delivery. Generally, frequent/closer contact with customers – can enable a rapid detection and response to technical and market shift. As close to customer - tend to avoid high PD risks (new ideas and trials based on short run and immediate customer response)	[15, 25, 34, 36, 37]
d	Many know customers personally and socially	[25, 28]
e	May have difficulty building credibility with a potential partner – partner may have more knowledge to lose than gain	[33]

2	**SMEC - Organisational Structure**	
a	Simple structure	[25, 28]
b	Flat structure - few layers of management	[25]
c	Flexible structure and information flows – easier to implement cross -functional teams. Good internal communication. (Ref [15] stated communication mechanisms required >100 employees)	[15, 24, 25, 28, 33, 34, 36, 38]
d	Multi tasked owner/managers	[25]
e	Division of activities limited and unclear	[25]
f	Low degree of specialisation - more generalist	[25]
3	**SMEC - Systems, Processes and Procedures**	
a	Simple planning and control system	[25]
b	Informal evaluation and control system/process – quicker decision making and therefore higher potential for innovation. Also, can be centrality of decision making - few decision makers.	[25, 36]
c	Flexible and adaptable processes/ SMEs can adapt and change quickly	[25, 27, 34]
d	Operational rather than strategic process focus. No long-range planning. Naïve about strategic planning i.e. inward looking, ignore change, rely on efficiency-based measures as a plan, and think they are immune to external influences.	[25, 31, 34, 37, 39, 40]
e	Innovation capability gap – some are innovative, some are not. Need to develop a culture of innovation.	[24, 34, 36]
f	Fewer formal rules and procedures for activities/operations – lack of process control/innovation processes are weak	[15, 17, 25, 34, 36]
g	Generally not protecting their Intellectual Property – IP increases as size decreases (measure of knowledge creation)	[15, 24]
h	Work with external organisations (e.g. universities) less	[15, 24]
i	Develop products in less time	[15, 17, 24, 38]
j	Low degree of standardisation and formalisation	[25]
k	Mostly people orientated	[25]
l	Learning is a critical function rarely supported in SMEs - SMEs knowledge is often tacit.	[31, 34, 41]
m	Product design is crucial for the performance of companies and economies – it is badly performed by SMEs	[35, 42]
4	**SMEC - Human and Financial Resources**	
a	Lack of financial resources (low tech). More financial resources (High-tech [40]). High external investment for new technologies can be avoided (rely on internal expertise).	[17, 24, 28, 34, 37, 38, 40, 43]
b	Few human resources.	[17, 24, 25, 27, 28, 30, 36, 38, 43]
c	Time as a scarce resource (management and employee)	[17, 24, 28, 38, 39, 43]
d	Modest know how with less expert professionals - Modest management skills and competency	[25, 28, 34, 37, 39]
e	Manager and Employee's average technical ability can be higher (High-tech) – Key people with long experience of products.	[34, 37, 40]
g	Employees are more versatile	[25]
h	Staff training and development is likely to be ad hoc, small scale, individualistic – learning through workplace action or about learning in the individual through education (training and seminars). Learning	[25, 28, 31]

	can also be externally influenced e.g. by suppliers or customers.	
i	Closer and informal working relationship	[25]
j	Low amounts of unionisation	[25]
k	Low degree of resistance to change	[25]
5	**SMEC - Culture and Behaviour**	
a	Unified culture – organisation has one culture – Less bureaucratic	[24, 25, 27]
b	Organic and fluid culture	[25]
c	Creativity issues. Motivation and blame culture – can depend on owner/manager (O/M) skills and capabilities	[34, 41]
d	Departmental/functional mindset less prevalent - corporate mindset	[25]
e	Very few interest groups	[25]
f	Mostly started, owned, and dominated by entrepreneurs. O/M influences operations and behaviour of employees – company builds on O/M values and beliefs (these could be restrictive/non-innovative or entrepreneurial/innovative). R&D support critical.	[15, 25, 28, 32, 34, 36]
g	O/M has erroneous perception of their company and business environment (strategy is controlled by the owner manager) – difficultly matching company activities with environment i.e. affects strategic planning, market fit to resources and competitive position.	[32, 34, 37]
h	O/M perceives company as doing better than actual (can result in unwillingness to change). Connected to 5g i.e. strategic planning	[26]
i	O/M ‘special social characters’ who strive for autonomy and independence, thus have autocratic, egocentric, impulsive and unpredictable management styles	[35]
j	Directive (dictatorial) and paternal management style more prevalent. Can be family run – higher employee motivation or family conflicts	[25, 36]
k	O/M are results orientated. Adaptive learning based on cost and operational efficiency. Can learn on earlier PD efforts. Can be short term thinkers.	[15, 25, 31, 37]

Some of these SME characteristics contain contradictions. Thus, they can be disadvantages or advantages depending on how they are viewed and/or applied to the PDP. The SMEC are cross-referenced to product development elements (Section 2.4) as explained above. For example, SMEC 1a,1b,1c and 3e,3f,3L are three ‘customer and market’ SME characteristics and three ‘Systems, Processes and Procedures’ SME characteristic that relate to A.2.3 i.e. characteristic 3 of Learning. The format SMEC 1a,b,c and 5c can also be found in the main text. In these cases, these SME Characteristics are used to support that text. Another point to note is that all SMEs journals researched considered SMEs internally homogenous i.e. all the characteristics apply to all the SMEs in this study.

2.3 Strategy, Innovation and Learning

According to Keskin [31] “Innovation is the name of the game in the twenty-first century. Increased competition, ceaseless turbulence, change and uncertainty have forced organisations to embrace innovation as an integral part of their corporate strategy” (A.1.2). Innovation comes from the Latin word “novus” meaning new or as stated in the Mirriam-Webster online dictionary [44] it is the introduction of something new or a new idea, method or device. However, a more accurate definition comes from reference [45] and is as follows:

“People using new knowledge and understanding, to experiment with new possibilities, in order to implement new concepts that create new value”

This definition contains all the elements required for innovation i.e. ‘People’ not tools innovate, the generation and capture of ‘Knowledge’ which is ‘New’, and the fact that ‘Experimentation’ is required to test new ideals against reality and ‘Create New Value’ for the organisation and its customers (internal and external) [45]. The innovator can be seen to be positioned thus:

Dreamer – Artist – Inventor – Innovator – Entrepreneur – Trader – Mandarin

This shows that the innovator must have both technical (inventor) and marketing (entrepreneur) skills [46]. This positioning of the innovator is supported by the fact that one of the key areas of innovation is the Fuzzy Front End (FFE) which has technical and marketing elements. The FFE happens before the product development stage and is explained below.
Note: there are various types of innovation. This research is concerned with: service innovation, innovation through the design of a product, and process innovation i.e. improving the PDP [47].

2.3.1 Fuzzy Front End (FFE)

The FFE is the area of PD which lies between when work on a new idea can start and when it actually starts. Typically, it is a long process, poorly understood, and open for a lot of improvement, hence fuzzy [48]. The differences between the unstructured FFE and the relatively structured NPD process are shown in Table 2.2.

Table 2.2 FFE v NPD [49]

	FFE	NPD
Work	Experimental	Disciplined
Commercialisation Date	Unpredictable	Highly certain
Funding	Depends	Budgeted
Revenue Expectation	Great Deal of Speculation	Believable
Activity	Individual or Team	Multi-function
Measure of Progress	Strengthened Concept	Milestone Achievement

2.3.1.1 FFE Models

Two methods of managing the FFE are the 'New Concept Development' or 'Front End of Innovation (FEI)' model [49, 50] and the 'Product Innovation Manager (PIM)' model [51-54]. Both models contain strategic planning, identification of markets and technologies, idea generation and selection and concept definition (detailing of form and function). The FEI also comprises leadership and culture whereas the PIM covers knowledge management and performance and measurement. Both the FEI and PIM were based on large companies whereas the following sections will discuss the relevance of the FEI and PIM sections for SMEs in terms of overall strategy. The link between innovation strategy and market/learning orientation is examined next.

2.3.1.2 SME Company Innovation and the Market/Learning Orientation

Drucker, as cited by Senge [41], states that innovation is a discipline; the meaning of the word discipline is 'to learn'. Whichever type of innovation an organisation or company is trying to create value with, in order to be innovative, it must become a learning organisation. Therefore, in order to innovate, people must want to learn and gain knowledge (A.2.1). Reference [41] states that "today's working culture goes against innovation" – an employee is seen in a negative light if an error is made, to be an innovator mistakes must be made to gain knowledge and create new value

(A.3.1). Clemmer [55] quotes from Senge's book (The Fifth Discipline: The Art and Practice of The Learning Organisation) (A.10.1):

"It is no longer sufficient to have one person learning for the organisation, a Ford or a Sloan or a Watson. It is just not possible any longer to 'figure it out' from the top, and have everyone else following the orders of the 'grand strategist.' The organisations that will truly excel in the future will be the organisations that will truly tap people's commitment and capacity to learn at all levels in an organisation"

Therefore, the first step to becoming an innovative organisation is becoming a learning organisation as this will act as the means to becoming innovative (A.2.2). Learning organisation, innovation and market orientation can be combined to create new services, products and processes. Keskin [31] researched the interactions of market and learning orientation, innovation and firm performance based on a survey of 300 SMEs (response was 157 SMEs). This research was furthering research conducted by Caltanone *et al* (187 companies) [56] on learning orientation, firm innovation capability and firm performance by adding the marketing orientation dimension. From reference [31] market orientation is:

- Gathering and using customer information.
- Developing a strategic plan based on this information.
- Implementing this plan in order to respond to the needs of customer's.

Marketing orientated companies ignore emerging markets, technologies and competitors. Therefore, they require a learning orientation to build on their current marketing orientation by using the information on emerging markets, technologies and competitors (current and potential) to develop breakthrough products and technologies and operate in new markets. Company innovativeness is the cultural openness to new ideas and experimentation (A.3.2) [31]. The link between marketing and learning orientations and company innovativeness is well established in large companies [31, 56]. Keskin [31] found that in SMEs "learning orientation translates marketing attitudes (orientation) into effective behaviour to facilitate SME innovation". The other findings from this research are related to the PDP (A.5.1), Learning (A.2.3) and the SMECs shown in Table 2.1 above. Generally, SMEs become more competitive with these orientations. The different strategic approaches to understanding marketing orientation are examined next.

2.3.2 Types of Strategies

A company's strategy[8] can be analysed by looking at the decisions that make up the strategy. Many companies do not have strategic plans but do have realised strategies (based on targeting customers, making investments, designing products etc.) [57]. Many SMEs have emergent strategies rather than planned strategies. According to Hurst [17] "It is impossible to deal with all the possible strategic options available to such a complex group of companies as exists within the SME area as the world of the SME along with the markets in which they operate differ greatly". However, having a clear strategy is a key success factor to product success i.e. Irish SMEs need to think strategically to create a competitive advantage and develop a culture of innovation [14, 17, 20, 24] (A.1.3). According to Teece *et al.* [58] strategic management is about how companies achieve and sustain competitive advantage and according to O'Regan and Ghobadian [32] SMEs are focusing on strategy as a mechanism for achieving competitive advantage. Therefore, this section will examine the difference between low technology and high technology strategic planning, the SME barriers to implementing a strategy and then the types of strategies available to SMEs. As outlined by reference [59] there are four types of strategic approaches: prescriptive (long term planning), emergent (or learning), competitive positioning and resource/core competency based. Competitive position is Porter's Competitive Strategy. Resource-based View (RBV) along with an expanded view called Dynamic Capabilities are discussed below along with technology strategy. In addition, the Miles and Snow typology is discussed as an alternative to competitive positioning. Firstly, Lindman's [37] research will be examined.

2.3.2.1 Open or Closed Strategy in PD

Lindman [37] researched whether an open (seeking cooperation and flexibility by utilizing knowledge from external resources) or closed (knowledge is generated from internal resources only) innovation strategy works best for five SME case companies via in-depth interviews. The SMEs were manufacturers of industrial machinery and

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[8] The word strategy comes from the Greek "Strategos" which means the art of the general 57. Bourgeois III, L.J., *Strategic Management: From Concept to Implementation*. 1997., Fort Worth, Texas: Drydan Press. ..

equipment. These in-depth interviews were followed by a 100 line NPD statement questionnaire (based on Lindman's literature review) in order to validate the interview data. A table of the key strategic characteristics for PD strategy and process were compiled based on these findings. Overall, an open strategy is best for company's developing new products with new technology. The finding of Lindman's research include SMEC 1c,3d,4a,4e,5g – Table 2.1 above and A.4.1 to A.4.3.

2.3.2.2 Strategic Planning – High and Low Technology Company's

O'Regan and Ghobadian [40] carried out an empirical comparison of high and low technology strategic planning approaches from the perspective of the key strategy drivers of leadership and culture. This involved 1000 SMEs (194 responses, 89 high and 105 low) in the electronic and engineering sectors in the UK. These sectors represented mature products (low tech) and short life cycles (high tech) respectively. The first finding of this survey revealed that due to leadership and culture low tech company's fear competitors in emerging markets. Secondly, leaders in high-tech companies have transformational (caring, passionate, interested) and human resource styles. They correlate with all the characteristics of strategic planning except 'internal orientation'. Thirdly, the leadership styles and cultural styles also correlate with all the performance indicators (except short term performance). Fourthly, the culture styles indicate significant correlations with strategic planning characteristics. Therefore, high-tech companies have an externally orientated strategic view, leadership style and culture leading to greater performance (A.1.6). However, this study did not consider the owner/manager characteristics as shown in Table 2.1 above.

2.3.2.3 Barriers to Implementing Strategy

Reference [39] carried out an empirical study of formal and non-formal planning in SMEs (independently owned and subsidiary). The research goal was to discover the extent of strategic planning in SMEs, the process of strategic planning and identify the barriers (eight were identified) to strategic planning. O'Regan and Ghobadian [39] cited Hewlett "a strategic plan and the strategic planning process itself offers a competitive edge and enables a company to measure achievements against expectations". This study involved 1000 SMEs (194 responses) in the electronic and engineering (products with short life cycles and changing technology) sectors in the

UK. Companies with a formal planning process were able to overcome the barriers better than those without a process. The characteristics of a strategic planning process were analyzed and for every characteristic companies with a formal process were found to be statistically higher. This was statistically significant for external orientation (competitive position emphasised), availability of relevant information, emphasis of analytical techniques (instead of gut feeling) (See Table 2.3 below), generating new ideas and strategy as a control mechanism (monitoring actions, revising strategy) [39]. This study further shows that formal strategic planning is of benefit to SMEs (A.1.3).

2.3.2.4 Porter - Competitive Strategy

There are five forces effecting business or competitive strategy. They are: the threat of entry by new competitors, the intensity of the rivalry between existing competitors, pressure from substitute products, the bargaining power of buyers and the bargaining power of suppliers. There is an inverse relationship between returns (profit margins) and intensity of competition i.e. as intensity increases, returns decrease [60, 61]. Porter also recommends three generic competitive strategies which could be used to compete and therefore help a company remain in an industry with intense competition [60]; cost leadership, differentiation, and focus. The Focus strategy has two alternatives, low cost and differentiation. They are called generic strategies because they are not company or industry dependent [61, 62, 63, 64].

According to Teece *et al.* [58] the company entry strategy approach follows three steps:

1. Chose an industry based on its ‘structural attractiveness’.
2. Pick an entry strategy based on assumptions about competitors’ rational strategies.
3. If not already owned obtain the required assets (see section 2.3.2.6 below) in order to compete in the market.

2.3.2.5 Miles and Snow Typology

Both reference [32] and [65] discuss Miles and Snow typology (or as it is also known the four business strategy types). According to O'Regan and Ghobadian [32], Miles and Snow maintain that every company has a dominant trait which is based on the main decision maker’s understanding of the operating environment. Strategic orientation deals with the direction and thrust of the company and is based on the traits that guide the strategy formulation and deployment process. Table 2.3 [32, 65] shows how these are combined. This typology can be used to compare a company's strategy with its external operating environment [32, 65], thus helping to decide which type of product developer/business type to be [65].

Table 2.3 Miles and Snow Typology [32, 65]

Strategic Orientation	Main Focus	Traits
Prospector	An industry innovator who takes risks. They monitor and act quickly to emerging or new opportunities and generally are first to market with their new products.	External orientation, environment scanning, maximising new opportunities. Innovative to meet market needs. Flexibility and freedom from constraining company rules and regulations. Welcome changes and sees the environment as "uncertain'.
Defender	Tries to find and sustain a position in a niche product or market area and keep it by offering higher quality, better service or lower prices. Unless an industry change affects them directly they ignore it.	Narrow range of products/services. Internal orientation based on efficiency measures and avoiding unnecessary risk. Centralised control and a functional structure are common.
Analyzer	Fast follower, they are generally not first to market. They follow the prospectors' lead but produce cost efficient and at times superior products comprising better features and benefits.	Operates well in both stable and dynamic markets. Uses efficiency and increased production in stable markets and innovates in dynamic markets.
Reactor	Does not maintain its products and markets as well as its competition. Unless there are strong external or market pressures they do not respond.	Short term planning, reacts to others actions. Change presents difficulties.

These strategic orientation/business strategy types: prospectors, analysers, defenders and reactors, are based on the speed a company reacts to changing markets and external conditions by changing their own products and markets. O'Regan and Ghobadian [32] carried out a survey on 1000 SMEs (194 respondents) in the electronic and engineering sector in the UK. These four strategic orientations were analysed in relation to constructs under the areas of strategy, leadership, culture and the operating environment. The overall conclusion was that the Miles and Snow typology is applicable to manufacturing SMEs (with short life cycles and changing technology (hi-tech SMEs)) i.e. strategic orientation must be considered during strategy formulation and deployment stage (A.1.7). Prospectors and defenders were dominant with the number of prospectors decreasing as company size increased.

O'Regan and Ghobadian [32] state the literature suggests that Porter's competitive strategy is not suitable to SMEs. As referenced in [32], Rugman and Verbeke state that Miles and Snow typology is particularly relevant to SMEs. Also, Mosey [33] stated that one of the main flaws of Porter's 'position within the market' was that once a new product was launched it changed the competitive position (markets) assumed before launch and therefore failed to consider the change in power after a 'new-to-market' product [33].

2.3.2.6 The Resource-based View (RBV) and Dynamic Capabilities

According to Hadjimanolis [36], technological innovation is required for competitive advantage and the strategic management of technological innovation is based on the purchase and development of the relevant resources and capabilities. Therefore, the RBV "focuses a company's resources and capabilities to understand business strategy and to provide direction to strategy formulation"[36]. Hadjimanolis also states that the Resource-based View (RBV) of strategy is particularly suited to small companies due to their lack of resources (SMEC 4a,4b,4c). Resources are defined as "those tangible and intangible assets that are tied semi-permanently to the company" [36]. Assets are physical (e.g. specialised equipment, geographic location), human (e.g. expertise in nanotechnology), technological (while there is a need for 'know-how'), complementary (e.g. past experience of NPD), marketing (e.g. skills or product position) or reputation (e.g. external company reputation)" [36, 58, 66]. Competitive advantage is gained through the 'clustering' of complementary resource assets e.g. marketing skills with technology 'know-how' and their uniqueness (company specific). These assets must be inimitable such that a competitor cannot copy/obtain them, thus eliminating the competitive advantage. The principles of RBV are [36]:

- Resource uniqueness.
- Ability of resources to complement each other.
- Inimitability.
- Interaction of resource clusters.

- Path dependency (See section 2.4.1.6 on Dynamic Capabilities below).
- Learning aspect (See section 2.4.1.6 on Dynamic Capabilities below).

As discussed in reference [58] the company entry strategy approach follows three steps:

- Identify the company's unique resources (assets).
- Decide which market the resources gain the required financial return.
- Decide if the financial return on these assets is effectively utilised based on integrating into related markets, selling the output to related companies or selling the assets themselves to a company in a related business.

However, RBV only considers strategy from the perspective of the internal organisation and does not consider the external environment. Reference [33], from the perspective of product development, points out that if resources are unique and inimitable how can they be developed or acquired. Also, identification of core competences can only be done post hoc and can therefore not be used to decide which competences to develop. Reference [66] detailed how the RBV breaks down in high velocity markets. Reference [36] quotes McGrath *et al*. as stating that the RBV lacks practical strategic management guidance. All of these points led to the expansion of RBV into Dynamic Capabilities. See section 2.4.1.6 for a definition of dynamic capability. Mosey [33] examined how SMEs can build dynamic capabilities for NPD by conducting a longitudinal case study on five SMEs over a period of five years. This work built on the research of Teece *et al.* [58] and Eisenhardt and Martin [66] from the perspective of the SME and specifically the organisational process of product development. By virtue of examining SMEs from the view of dynamic capabilities this research took a dynamic view rather than examining one specific capability e.g. dynamic owner manager, multifunctional development teams or research partnerships and 'best practice' (management processes, organisational structures). Therefore, processes, positions and paths were examined. These and the finding related to the PDP are discussed in Section 2.4.1.6. Of relevance to this section are the processes chosen i.e. opportunity identification process (identification of NPD market opportunities), market intelligence process (market boundaries, business model and competitive situation), product strategy process (NPD vision and communication of the vision) and NPD management (product specification and balancing resources between new opportunities).

2.3.2.7 Technology Development Strategy (Flexibility and TTM)

According to the references in SMEC 2c,3i, SMEs have an edge in flexibility and adaptability and are better at adapting to new situations and market conditions than multinational companies; they develop products in less time. The effectiveness of a particular method of reducing time to market (TTM) is dependent on the type of product being developed i.e. its complexity, newness [15]. As explained in Section 1.5 the SMEs are developing technology based products. According to Ledwith [15] the SME development process is faster by developing incremental new products yet in reference [14] Irish SMEs are focusing on 'breakthrough' products and technologies. Reference [15] states that both large and small companies struggle with disruptive technologies and SMEs should avoid radical new products (breakthrough) and high levels of differentiation i.e. they should adapt one core technology and practice cost leadership or focus strategies [15]. On the other hand patenting is a measure of new technology knowledge and it tends to increase as company size decreases [24] and according to reference [38] SMEs can be leaders in applying new technologies. This points to SMEs as technology developers producing breakthrough and disruptive technologies. According to the survey conducted by reference [14] continuous innovation is key to the SME strategy and most companies are targeting product and technology innovation with half the companies focusing on 'breakthrough' rather than 'incremental' innovation [14].

However, Christensen [67] states that "the evidence is quite strong that companies whose strategy is to extend the performance of conventional technologies through consistent incremental improvements do about as well as companies whose strategy it is to take big, industry-leading technological leaps". This is supported by [24] i.e. many technology breakthroughs are based on small incremental advances which large organisations are not as interested in because sales are small (1 million Euro a year is a lot for a SME but not an MNC). Reference [14] also states that for SMEs 'breakthrough' technology can change an industry, however, the risks are greater and the time to market is longer than incremental innovation [14]. Therefore, considering that speed is one of the main advantages of an SME this is counter productive. So what is the best approach for the SME? Before this can be understood it is necessary to understand the different types of technology development i.e. disruptive and sustaining. According to Christensen [67] disruptive technologies result in worse product performance, at least in the near term. They generally under-perform established products in mainstream markets, however they are cheaper, simpler, smaller, and frequently more convenient to use (new and fringe customers value this) whereas sustaining technologies are new technologies that foster improved product performance. They can be ‘breakthrough’ (radical) or incremental in nature. However, they all improve the performance of established products along the dimensions of performance that mainstream customers in major markets value [67]. In reference [68], breakthrough (radical) innovations require new processes and have new core products while incremental innovations are enhancements, hybrids and cost reduced versions. Therefore, sustaining technologies (whether breakthrough or not) are those that established companies’ main customers want whereas they do not want disruptive technologies. As stated in reference [69] the ideal is to develop a product so that it always follows the market trajectory because it is the customers and not the technologies who decide when the shift in technology occurs. Reference [69] states that 90% of the innovations of companies worldwide are required to meet customer needs and are technology sustaining (incremental and non-radical). Therefore, as discussed in Section 2.11, this thesis material is based on a marketing pull process and not a technology push/driven process. However, ‘needs’ creating and disruptive innovations are predominantly technologically radical product innovations i.e. disruptive technologies are at the bottom of the ‘S’ curve [69]. Although, there are advantages and disadvantages to both – pulled products may not be as innovative as pushed products but are more aligned to customers needs. Pushed products can be too complicated or not what the customer requires and therefore hard to sell while pulled products can be too simplistic an improvement on existing products to be competitive [70]. However, ideation using tools and methodologies such as TRIZ (See Section 2.7) can lead to new breakthrough ideas and these technologies can then be developed incrementally (A.8.1, A.22.25). This approach also allows SMEs to take advantage of their inherent flexibility and speed when it comes to technology development and to reduce risk. Reference [27] also stated that the process of innovation in SMEs should incorporate incremental change with bursts of radical change and reference [24] states that the balance between marketing push and technology pull is critical – if either dominates then the customer is not satisfied.

2.3.2.8 SME Applicable Strategy

As A.1.3 suggests a formal strategy process must be implemented. However, this process must consider SMEC 4a,4b,4c. According to the reference [14] survey, global competition and changing technologies (SMEs are at a disadvantage for scale economies and R&D [20, 24]) are constant threats to SMEs so developing a marketing plan (strategic plan and new product strategy) helps retain current customers, develop new customers and create new opportunities. Also, SMEs can be new companies with little knowledge of their market. According to Moultrie *et al.* [42] all of the PD and design processes researched placed a major emphasis on pre-development activities (FFE – Section 2.3.1) – See A.1.4. The development of these plans also aids in measuring performance (Section 2.13) [14] (A.1.8). Figure 2.2 shows a model of SME strategies taken from the OECD (1993) by Hurst [17]:

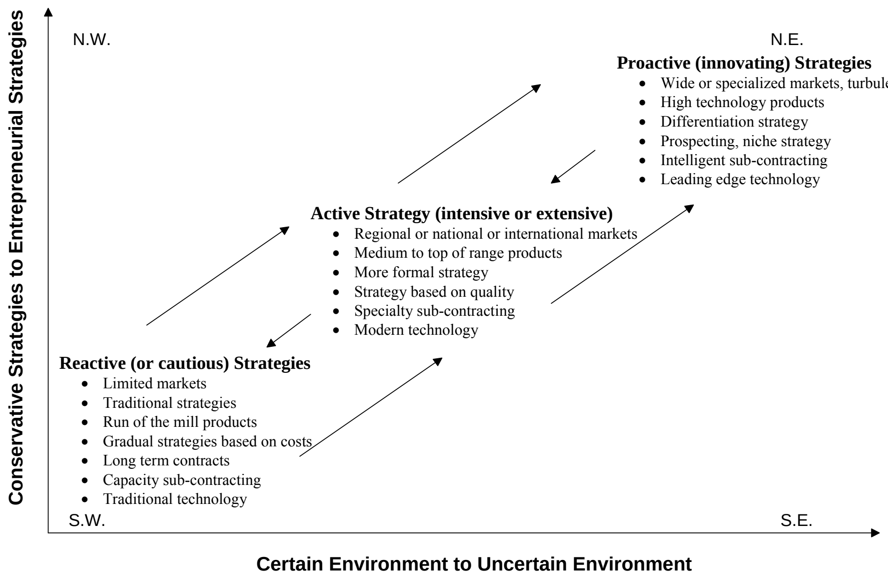

Figure 2.2 OECD SME Strategies [17]

The proactive (innovating) strategy is in line with the innovating strategies discussed by the latest OECD report [24] and SMEC 1a. Irish SMEs also have a niche market focus and stay close to their customers (SMEC 1a,b,c) although do not keep track of emerging technology because they do not carry out full market research (Figure 1.9) – See A.1.9 [24]. In some sectors, off-the-shelf reports and information services are considered sufficient [14]. This strategy results in a lack of focus on international competition as a company irrespective of its size is faced with industry competition

[17]. The innovation strategy discussed by the OECD [24] requires investing in knowledge through R&D using human capital and a skilled labour force with top engineers and scientists. In this way SMEs act as an agent of change, experimenting, generating new ideas and pursuing innovative activity [24].

2.3.3 PDP Strategic Areas and Strategic Techniques

The above sections discussed the FFE, high and low technology strategy differences, barriers to strategy implementation, Porter's Competitive Strategy, Resource-based View (RBV), Dynamic Capabilities and the Miles and Snow Typology. The FFE models identified [49, 51] strategic planning, identification of markets and technologies, idea generation and selection and concept definition (detailing of form and function) as important. Reference [39] found that the barriers to implementing a strategy were reduced by having a formal strategy process. As stated above Miles and Snow typology can be used to determine a company's business type and give direction. The RBV is superseded by dynamic capabilities [33] with the opportunities identification process (identification of NPD market opportunities), market intelligence process (market boundaries, business model and competitive situation), product strategy process (NPD vision and communication of the vision) and NPD management (product specification and balancing resources between new opportunities) used. Reference [20] (Irish Management Institute (IMI)) stated that Irish SMEs strategy development should contain: a vision and business definition for the company, long term goals and short term performance targets (and an understanding of how to deliver these and the resources allocated), an understanding of the forces shaping the company's industry, an ability to identify and build competitive advantage which can create customer value and a look towards the future [20]. Reference [39, 40] list the following SME strategic characteristics: external orientation (competitive position, technology trends, economic/business conditions), internal orientation (managerial ability, financial strengths/weaknesses, HR strength/weakness), departmental co-operation, resources for strategy, systems capabilities/creativity, strategy as a control mechanism and analytical techniques (ability to use techniques e.g. SWOT). These are in line with the strategic plan and new product strategy requirements recommended by the other references. In addition, reference [71] states that for strategic decisions there is not a systematic difference between medium-sized and small companies.

Table 2.4 below shows the above determined PDP strategic areas, corresponding process characteristics and the required strategic techniques.

Table 2.4 PDP Strategic Areas and required Strategic Technique

PDP Strategic Areas		PD Process Characteristic	Strategic Technique	Reference
1	Product Development Process	Requirement for a Product Development Process	Use a formal product development process – See section 2.4	A.1.1
2	Marketing Plan/Niche Strategy - Product specialisation, geographic Diversification.	SME requirement for a Formal Strategic Plan (A.1.3)	Strategic Planning and New Product Strategy	Table 2.1, [14],[42], [24],[39],[33]
3	Exporting Strategy (comprising of areas 7, 11 and 13 of this table) – See section 2.4.1.2	Requirement for an exporting strategy	Strategic Planning and New Product Strategy	[24],[72],[17]
4	Conduct Technology Development	Requirement for a Technology Strategy	Incremental and Radical	Section 2.3.2.7 [24],[27]
5	A vision and business definition for the company	Mission Formulation	Applied Strategic Planning - Mission formulation	[20]
6	Competitive position - Determine Industry to be in and understand the competition	External Orientation of Strategic Plan	Applied Strategic Planning - Environment Monitoring	[20, 33],[39] [40]
7	Identify Market trends/opportunities		Strategic Planning and New Product Strategy	[33, 39, 40, 50, 51, 72]
8	Understand/Identify technology trends		Applied Strategic Planning - Environment Monitoring	[33, 39, 40, 50, 51]
9	Plan considers the Future		Strategic Planning - Applied Strategic Planning (Strategic Business modelling with 'Futuring' and Gap Analysis)	[20]
10	How to Gain Feedback from Customers/Understand their needs		Please see Section 2.5	[24]
11	Long term goals and short term performance targets.	Performance Targets	Applied Strategic Planning - Strategic Business Modelling	[20, 72]

PDP Strategic Areas		PD Process Characteristic	Strategic Technique	Reference
12	Develop and Sustain Competitive Advantages	Internal/External SWOT	Applied Strategic Planning - Performance Audit (Internal and External) SWOT and Competitive Analysis	[20, 39, 40, 72]
13	Relationships and Networks	Strategic Links	Form Strategic Links	[72]
14	Idea Generation and Selection, Concept Definition	Ideation (FEE)	Please see Section 2.7	[24], [50, 51]

Section 2.5 discusses the strategic techniques' found in Table 2.4 above. These are actual techniques an SME can use to gain competitive advantage as part of their product development process. Section 2.4 explains why a PDP is required in SMEs. The PDP design characteristics identified in section 2.4 are used to explain how sections of the literature review can be used as part of an SME PDP.

2.4 Product Development Process Characteristics

A company's NPD process should be applicable to that company's requirements i.e. there is no 'best' process. However, a formal NPD process is necessary to manage NPD projects (A.1.1). This is also supported by [68] as they state that it is generally accepted that success is increased if a structured process is followed. R&D undertaken by small companies is mostly informal and therefore not as effective as larger companies who are following an NPD process [15]. This suggests that the NPD process should exist within the SME although Ledwith's finding were that PDP formality is not sufficiently linked with NPD success [15]. However, this goes against the findings of A.1.1 and its corresponding SMEC. Reference [35] found a lack of understanding of the design and development process in SMEs suggesting that a better understood process would result in more success. The key is to have a process that is not laden down with paperwork and is therefore suited to the SME (A.5.2). The PDP can and should be a competitive advantage [17]; therefore, the SME must have, and be able to manage, the development process. In order to understand product development in indigenous SMEs an understanding of specific SME Product Development characteristics is required.

2.4.1 SME Product Development Characteristics

This section details journal articles based on a tool to evaluate design performance in SMEs, management practices associated with SME export capabilities, evaluation of innovation implementation in SMEs, methods of modelling SME innovation processes and RBV/dynamic capabilities.

2.4.1.1 Millard and Lewis, and Moultrie *et al* findings

Millward and Lewis [35] carried out three detailed longitudinal case studies on small (10 to 50 employees) manufacturing companies where fabrication was the core business and a desire to develop new products was shown. Three generic managerial issues which imposed on the PD process emerged: the influence of the O/M, O/M focus on time and cost ahead of PDP and the lack of understanding of product design importance.

Moultrie *et al* [42] developed a tool to evaluate design performance in SMEs. The tool was based on extensive literature and case exploratory work. 47 success factors were studied for the PD process (process audit) along with eight well established design processes (product audit). The characteristics taken from Millward and Lewis and from Moultrie *et al* are in the areas of strategy, tools and methodology (T&M), PDP, product design, organisational structures, technology/technology development and leadership:

- Moultrie – A.1.11, A.5.7, A.6.1, A.6.5, A.6.6, A.8.2 (A.22.26, A.22.28)
- Millward and Lewis –A.1.1, A.1.3, A.1.10, A.5.2 to A.5.6, A.5.9, A.6.2, A.7.1, A.9.1 to A.9.3
- Moultrie and 'Millward and Lewis' – A.4.3, A.5.8

2.4.1.2 SME export management capabilities

Doole *et al* [72] researched the management practices, processes and activities that are most closely associated with high levels of export capability in 250 SMEs in the UK using an instrument developed over five years (Export Marketing Profiling System (EMPS)). Based on reference [72] research the export capabilities associated with performance are the three categories of company characteristics (size and management), company competencies (domestic market performance, product uniqueness, production capacity, labour skills and type of industry, market planning, quality of export staff, foreign market connections and financial management skills) and export-marketing strategy (product design, quality and uniqueness, communication and relationships). The final instrument comprised of 17 indicators used to find the important elements of these three categories. They found the key activities most closely related to export capability were the elements of the export marketing strategy [72] as shown in Table 2.4 i.e. PDP Strategic Areas 7, 11 and 13. The sharing of this information and knowledge were seen as critical. In addition, A.6.4 and A.12.1 were found.

2.4.1.3 Innovation Implementation in SMEs

Humphreys *et al* [27] explored (quantitatively and qualitatively) the application of a process of innovation within an SME case study (50 employees) over a six year time frame. This research used the CENTRIM G2 innovation audit model. This research considered people, process and product dimensions. Process based approaches to change implementation can be used in SMEs as well as MNC (A.10.2). However, the process of innovation requires ongoing attention as it is easier to lose than it is to obtain. The organisational structure (some cases the O/M) must be designed to support innovation (A.7.2). As referenced in [27], Tidd *et al* states that the most innovative companies are those that develop the best fit between structure, operating contingencies and flexibility. In order to develop an innovative process the SME manager's PDP design must have certain characteristics i.e. A.5.10. The implementation of the process of innovation in SMEs is affected by three themes: innovation culture, innovation technology, and innovation and leadership. The findings from Humphreys *et al* research were in the elements of Strategy, Learning, Innovation, PDP, Organisational Structure, Technology, Leadership and Culture and are A.1.5, A.2.4, A.2.5, A.3.3 to A.3.10, A.5.11, A.5.12, A.7.3 to A.7.10, A.8.3 (A.22.29), A.8.4 (A.22.30), A.8.5 to A.8.7, A.9.2 to A.9.6 and A.11.1 to A.11.12. Overall, companies must consider people and cultural issues along with technology innovation in order to be successful at implementing innovative product development practices. Innovation is not a quick fix as it requires longitudinal implementation [27].

2.4.1.4 Resource-based View (RBV) Findings

In relation to strategy, the RBV and the principles of RBV were explained in Section 2.3.2.6 [36]. Hadjimanolis [36] examined these principles in relation to RBV innovation predictors or as they are shown in Table 2.1, the SME Characteristics - 1b,2c,3b,3e,3f,4b,5f and 5j. The aim of the Hadjimanolis research was to identify the internal SME characteristics/innovative predictors that resulted in high performance in technological innovation in small companies based on RVB. This research was conducted on 25 case study companies with less than 100 employees. Generally, the case focus was on innovation resources, capabilities, strategy and the role and tasks of the owner/manager. The research findings are Learning (A.2.5) and Innovation (A.3.11).

2.4.1.5 Methods for modelling SME innovation processes

Scozzi and Garavelli [34] researched which business modelling techniques (BMTs or techniques for process modelling and analysis) to use in order to support and improve innovation processes within SMEs. BMTs were considered unsuitable for processes such as PD as PD is highly unstructured with unpredictable activities which are reciprocal rather than sequential. The SMEs lack of specialised resources to manage 'Innovation Development Processes' (IDP) make it difficult to identify and adapt them. An IDP is defined as a set of tasks aimed at the creation of a new product/process. Innovation processes from PD were analysed from seven perspectives resulting in the identification of the main problems. These problems were then translated into SME specific problems as shown in Table 2.5.

Table 2.5 SME Specific Problems

PD Process Perspective	Main Problems	SME Specific Problems
Sequence of Tasks	Task definition; management and control; role assignment; management of the part-whole relationship	Procedure neglect; responsibility avoidance; lack of process control; management deficiencies (A.5.13)
Decisions that evolve over time	Problem framing and problem solving; storing/retrieval decisions associated to past projects and their rationale	Problem framing and problem solving; lack of a structured organisational memory (A.4.4)
Strategic process	Strategy development and communication	Lack of a strategic vision (short-term vision) (A.1.3)
Political process	Management of attention; creation of a good currency; change management; conflict management	Change management; conflict management (A.10.3)

Interpretative process	Communication among departments due to the development of different thought world	Communication among departments due to the development of different thought world (A.7.11)
Creative process	Creativity and motivation; blame culture	Blame culture (A.11.5)
Communication and information flow	Lack of structured communication (internal and external to the company); loss of architectural knowledge; selection of supporting technologies	Lack of structured communication (internal and external to the company) – use of ICT to capture PDP knowledge and learning. (A.5.11, A.7.15, A.7.11)

A field study was carried out on 19 Italian SMEs (with an average of 46 employees and €7m annual turnover) which consisted of an hour long interview during which the O/M or person responsible for the IDP was brought through a questionnaire based on the main problems of Table 2.5. This research proved the 'SME specific problems' did exist as identified. The relevant SMEC and Element characteristics are shown in Table 2.1 and Table 2.5. According to Scozzi and Garavelli [34] – *Recent studies have shown that structured techniques can be used to build and support innovation by following well defined procedures and practice* (this supports Section 2.4.1.6 below i.e. Table 2.6 No. 1 and 2). By doing this they can become aware of innovation issues and characteristics. The PD process was considered as a model consisting of three phases: planning, development and learning. It was stated that planning and learning although crucial are not carried out by most SMEs (See SMEC Table 2.1). The other findings of this research relate to the advantages of using tools and methodologies (A.4.1, A.4.5 to A.4.14), Learning (A.2.6), PDP (A.5.8), Organisational Structures (A.7.11), Leadership (A.9.2), Change Management (A.10.3) and Culture (A.11.4, A.11.5).

2.4.1.6 Dynamic Capabilities

This section describes how an SME PDP can be developed based on best practice. As detailed in Section 2.3.2.6 the RBV was expanded into the area of dynamic capabilities. According to Boccardelli and Magnusson [73] dynamic capabilities "has received increasing attention in the field of strategic management research". Teece *et al.* [58] state that dynamic capabilities are suitable for companies that operate in environments of innovation-based competition, price/performance rivalry, increasing returns and 'creative destruction' of existing competencies i.e. high technology industries (the subject of the thesis research/survey). Dynamic capabilities integrates and uses research in areas such as the management of R&D, product and process development, technology transfer, intellectual property, manufacturing, human resources and organisational learning. It is therefore an integrative approach to understanding newer sources of competition [58, 66]. The strategy of gathering valuable technology assets and protecting them with intellectual property is not considered enough for competitive advantage i.e. a company could have a lot of technology and no capabilities [58]. 'Dynamic' refers to the ability to renew competences in order to achieve synergy with the changing business environment. 'Capabilities' refers to the important role of strategic management in adapting, integrating, and reconfiguring internal/external organisational skills, resources and functional competences to match a changing environment [58]. Therefore, both competences and capabilities adapt to changing environments. In order to be strategic a capability must be in line with a user need (generating revenue), unique (product price is competitive) and hard to replicate (longer retention of profits) [58]. Accordingly, Teece *et al.* state a company's capability must be understood in terms of the company's organisational structures and managerial processes rather than its balance sheet items. Balance sheet items can be assigned a cost and therefore are not distinctive competences as they can be bought and sold. In order to understand distinctive competences and capabilities Teece *et al*. formed three categories:

- Processes – This refers to organisational and managerial processes. An organisational process has three roles: coordination/integration (static concept), learning (dynamic concept) and reconfiguration (transformational concept) [58]. Examples of processes are: opportunity identification, market intelligence gathering, NPD management and product strategy planning [33].
- Positions – The strategic position of a company is also determined by its assets (Section 2.3.2.6 above).
- Evolutionary paths – A company's future is based on its current and therefore past decisions e.g. fixed costs like previously purchased equipment. Its routines can also restrain its behaviour. The future path of a company is directly tied to its technological opportunities. Past research will impact a company's options in relation to the amount and level of R&D it can do [58]. Other examples of paths are: evolution of product technology, evolution of organisational structure, evolution of ownership, evolution of market position and evolution of financial performance [33].

Thus, a company's competence and dynamic capabilities are in the company's organisational processes. These processes are formed by the company's assets (positions) and its evolutionary path [58]. A definition of dynamic capabilities is given by [66]:

"The company's processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match and even create market change. Dynamic capabilities thus are the organisational and strategic routines by which companies achieve new resource configurations as markets emerge, collide, split, evolve, and die"

Eisenhardt *et al.* [66] expanded on Teece *et al.* research by examining (using organisational theory and empirical research) dynamic capabilities from the perspective of sustained competitive advantage in dynamic markets where dynamic markets are seen as moderately dynamic or hi-velocity markets i.e. dynamism varies (Table 2.7). For their research they considered dynamic capabilities to consist of strategic processes such as product development and strategic planning i.e. processes that create value for companies in dynamic markets by managing resources into new value areas. These capabilities or processes are not unknown as they have extensive empirical research leading to 'best practice'. This means the PD process has greater equifinality, homogeneity, and substitutability across companies. Table 2.6 summarises these finding.

Table 2.6 Traditional View and New View of Dynamic Capabilities [66]

		Traditional View of Dynamic Capabilities	New View of Dynamic Capabilities
1	**Definition**	Routines to learn routines	Specific organisational and strategic processes (e.g. product development, strategic decision making) by which managers alter their resource base
2	**Heterogeneity**	Idiosyncratic (i.e. company specific)	Commonalities (i.e. best practice) with some idiosyncratic details
3	**Pattern**	Detailed, analytic routines	Depending on market dynamism, ranging from detailed, analytic routines to simple, experimental ones (Table 2.7 below).
4	**Outcome**	Predictable	Depending on market dynamism, predictable or unpredictable
5	**Competitive Advantage**	Sustained competitive advantage from principles of RBV as applied to dynamic capabilities	Competitive advantage from valuable, somewhat rare, equifinal, substitutable, and fungible dynamic capabilities

6	**Evolution**	Unique path	Unique path shaped by learning mechanisms such as practice, codification, mistakes, and pacing

Table 2.7 shows the differences between moderately dynamic and high-velocity markets.

Table 2.7 Market Dynamic Comparisons [66]

	Moderately Dynamic Markets	**High-velocity Markets**
Market Definition	Stable industry structure, defined boundaries, clear business models, identifiable players, linear and predictable change	Ambiguous industry structure, blurred boundaries, fluid business models, ambiguous and shifting players, nonlinear and unpredictable change
Pattern	Detailed, analytic routines that rely extensively on existing knowledge	Simple, experiential routines that rely on newly created knowledge specific to the situation
Execution	Linear	Iterative
Stable	Yes	No
Outcomes	Predictable	Unpredictable
Key to effective evolution	Frequent, nearby variation	Carefully managed selection

Based on Table 2.6 and 2.7 dynamic capabilities are processes such as product development. These processes have 'best practice' across companies and vary with market dynamism from robust routines to semi-structured routines. These processes evolve via well understood learning mechanisms. Competitive advantage can be reached by multiple paths to the same dynamic capability (e.g. knowledge creation). Mosey [33] was discussed in Section 2.3.2.6 in relation to strategy. The origins of this research and the nature of the study were also discussed re Eisenhardt *et al.* This research developed an integrative framework of new-to-market product development within the SME. The framework also had a theoretical representation of company capabilities responsible for NPD (these findings can be found in sections 2.2/2.3 – SMECs and analysis of strategy). As cited in Mosey, O'Shea and McBrain state that SMEs should have fixed development processes focused on prototyping and experimentation with customers rather than no process at all (A.5.14). Hadjimanolis [36] proposed the RBV as discussed in section 2.3.2.6 and 2.4.1.4. As cited in Mosey, Simon states that only companies with long-term strategies and long-term ambition and focus on PD can sustain PD performance (A.1.12). Mosey's research examines integrating all of these together by using the three categories of Teece *et al.*

(processes, positions and paths) [58]. Mosey concludes that PD processes which achieve competitive advantage come from various paths based on Eisenhardt and Martin's concept of equifinality i.e. dynamic capabilities are developed slowly based on organisational learning within the context of market dynamics (Table 2.7). Therefore, Mosey proposed that a company should develop a PD process using the following steps:

1. Single product development project
2. This is followed by probing the future
3. Each PD should then have linked routines from one development to the next.

These steps would introduce processes to improve company management of PD (individual projects). As the PD process matured to a steady stream of products the company would 'probe the future' therefore predicting and exploiting new opportunities (market and technological trends) by building partnerships with lead users. Finally, the company would introduce processes to facilitate learning between consecutive and concurrent PD projects. A Cross Functional Team would manage any conflicts with support of the O/M. The O/M would analyze performance and change resources and the PD process to meet the needs of new opportunities. However, the 'positions' of an SME could influence the capability to develop new-to-market products. A case study of five companies was conducted over five years to check this sequence of steps in terms of dynamic capabilities and paths, processes and positions. The findings from this research can be found in Organisational Structures (A.7.12 to A.7.15), Leadership (2.9.7), Culture (A.11.13), PDP (A.5.15), Technology Development (A.8.8, A.22.27) and Learning (A.2.7). Overall, consideration of processes, positions and paths is necessary for dynamic capability creation. Each company must discover a way into potential markets as working with new partners is context specific. Experience and credibility is gained by transferring products into new areas and experimentation with sourcing new technologies to meet emerging needs. This learning requires mechanisms so managers routinely reflect upon the PD process. This flexibility and capability to learn and adapt offers a major competitive advantage over larger competitors (A.2.8)[33]. Dynamic Capabilities therefore allow the following conclusions in relation to developing an SME PDP:

- Dynamic capabilities are processes such as product development which have 'best practice'.

- The use of *generic development 'processes'* (e.g. opportunity identification, market intelligence gathering, NPD management and product strategy planning) can be used to support NPD. This is in line with the finding of Scozzi and Garavelli in Section 2.4.1.5 and Table 2.6 point 1.
- 'Best practice' generic development processes can be used to develop an SME PDP. Table 2.6 point 2.
- Based on Sequential PDP 3 steps capability development these best practices can be introduced to develop a PDP for an SME.
- Learning systems can be used to aid transfer from one development to the next (3 steps) allowing the selection of the appropriate processes for each development type. The SME PDP can be developed in a systematic and prolific manner.

The remaining sections of this literature review examine 'Best practice' generic development processes. If an SME follows these 'processes' (shown in Figure 1.16) they will have an SME PDP. Therefore, a survey based on these processes or thesis sections **can determine the status of SME PDP in indigenous SMEs**. At this point of the research eleven tables of process characteristics are created. These will be developed as detailed in Section 2.1. The strategic techniques (based on table 2.4) are examined next.

2.5 Strategic Techniques

Based on findings shown in Table 2.4 and the characteristics A.1.2, A.1.3, A.1.4, A.1.6, A.1.8, A.1.10, A.1.11, A.4.1, A.4.5, A.5.6 and A.5.7 this section will discuss Strategic Planning and developing a New Product Strategy. As the sections of Section 2.5 are discussed, strategic characteristics will be added to Appendix A.1 and Appendix A.15 and subsequently used to form questionnaire items for the survey (Chapter 3).

2.5.1 Strategic Planning

According to reference [74], "Strategic planning[9] is a disciplined effort to produce fundamental decisions and actions that shape and guide what an organisation is, what it does and why it does it".

Strategic planning is carried out when (A.15.1):

- An organisation is in start up mode.
- The company is starting a new venture such as developing a new product, department, or division.
- To prepare for a new fiscal year.
- In order to update action plans [75].

The complexity of the environment, organisational leadership, organisational culture, organisational size, and the experience of the planners all determine how a plan is developed. An organisation can choose from various different planning models and if required use elements of each to determine their process. The following are types of planning models [75]:

- Basic strategic planning – Steps are; create mission statement, select goals to achieve the mission statement, employ strategies to implement goals, devise action plans to implement strategies and monitor the success of goals.
- Goal Based (or Issue based) – This is a more detailed approach than the basic one above.
- Alignment – Used to fine tune or correct faulty strategies.
- Scenario – Used with other models to ensure strategic thinking.
- Organic – Unlike the above mechanistic processes this is a self-organising process [75].
- Applied Strategic Planning – Similar to the Basic and Goal based processes only it helps the organisation to envision the future and therefore create its

[9] Strategic planning and long-range planning were an interchangeable term in the fifties and early sixties when the economic environment was considered stable and somewhat predictable. During this time the strategic plan would look out approximately seven years whereas now they are separate terms with strategic planning looking out over the period of a year or so 75. McNamara, C.o. *Strategic Planning (in nonprofit or for-profit organizations).* 2007. [cited 15 January 2005]; Available from: http://www.managementhelp.org/plan_dec/str_plan/str_plan.htm#anchor4293716937..

future (A.1.13, A.15.2). This is in line with an SME strategically looking to the future as recommended by reference [20] (A.1.12) in Table 2.4. See below for the steps [76].

2.5.1.1 Applied Strategic Planning Model

The key steps of the process are explained.

2.5.1.1.1 Planning to Plan

This step checks for who is involved in the planning process, how long it will take, what information is needed and ensures the right level of commitment. This step also aligns the plan with the budget as the strategic plan is at the core of the organisation's budget.

2.5.1.1.2 Environmental Monitoring

The environments monitored are the macro environment, industry environment, competitive environment, and the internal organisation environment [76, 77].

2.5.1.1.3 Mission Formulation

A.15.3 shows the questions asked to formulate a mission statement [76, 77].

2.5.1.1.4 Strategic Business Modelling

This process consists of identifying the major lines of business (LOB), the critical success indicators (CSI) and future planning (A.15.4) [76, 77].

2.5.1.1.5 Performance Audit

This is carried out in order to understand the company's strengths, weaknesses, opportunities and threats (SWOT) [77] (A.15.5). Internally, the audit examines corporate performance indices such as growth, production, quality, service, profit, ROI, and cash flow. It also examines any other data that help to understand the present capabilities e.g. the life cycles of products, employee productivity, scrap rate, inventory turnover, facilities, and management capability. Externally, competitive analysis is carried out on companies in the same business or targeting the same clients [77]. The following tasks are completed:

- Map the company value chain i.e. identify the competitor companies and assess their futures (how are they changing - who is gaining and who is losing) [65].
- Gathering competitor intelligence - Information can be found from products, trade shows, suppliers, company's sales representatives, patent searches, purchasing, market research, and the internet (especially if the competitors are stock market (public) listed companies) [65, 78].
- Identify industry drivers and any shifts in them i.e. what factors make the competitors profitable and successful (cost of materials, low cost production) – What solutions for the company customers to these factors?
- Carry out a market and industry trend analysis
- Carry out a competitive strategy analysis using the Miles and Snow Typology (Section 2.3.2.5).
- Establish who makes the money in the company's industry or market.
- Identify opportunities and threats.
- Use this assessment along with customer VOC and feedback from lead users.

[65]

2.5.1.1.6 Gap Analysis

This looks at the gap between the future strategic state and the current strategic state in terms of the results of the audit (A.15.6) [77].

2.5.1.1.7 Integrating Action Plans and Implementation

This is the development of the action plans by the SME or its functional units now that the gap analysis is complete. Using teams, the functional level action plans are implemented. Therefore implementation is the "handover" of the strategic plan to the functional managers (A.15.7) [76, 77].

2.5.1.10 Benefits of Strategic Planning for SMEs

- The modelling process leaves a clearly defined purpose (mission statement) and results in achievable goals within a realistic timeframe.
- Helps to identify and solve problems that otherwise could be missed.
- Communication of the goals and objectives throughout the organisation.
- Develop a sense of ownership of the plan.

- Organisation’s resources are focused on key priorities.
- Provide a base from which progress can be measured and establish a mechanism for informed change when needed.
- Helps build a bridge between the O/M, staff, and operators, resulting in strong focused teams.
- Increases productivity from increased efficiency and effectiveness [75].

2.5.2 New Product Strategy (NPS)

The new product strategy can also be referred to as the Product Innovation and Technology Strategy (PITS) [65] or the Product Innovation Charter [68]. According to Kepner-Tregoe [79], Kuczmarski [80], Wheelwright [68], Cooper [65] and Moore [81] the link between the business strategy and the new product strategy is of critical importance (A.15.9). As discussed in reference [65], the NPS can be seen as a part of the business unit strategy or functional strategy. It is the master plan for a company’s NPD business, providing the bridge between the NPD and the company’s business strategy. It contains/explains the following:

1. The business goals for the NPD effort.
2. The role of new products in the overall company business.
3. The arenas or areas of strategic focus and priorities e.g. what types of markets or market segments (e.g. Market arena X,Y and Z), applications, types of technologies (e.g. Technology arena A and B) and technology platforms, and the product types, product lines or product categories. Expanding this further results in Portfolio Management (See section 2.5.3).
4. The spending priorities or deployment decisions e.g. assuming the marketing arenas are part of the strategic focus, how much will be spent on the strategic focus marketing arenas X, Y and Z (prioritising X,Y and Z).
5. Arena Entry Strategy – How to attack each strategic arena.

One and two are roles and goals, whereas three, four and five are based on strategic arenas. As discussed in Section 2.3.2.5 a company can also base its business on four strategy types. The next section describes the process used for developing a NPS [65].

2.5.2.1 The Strategy Development Process for an NPS

This section will go through the strategy development process (A.15.8). Firstly, goal setting will be examined in more detail, target arenas are then defined (arena identification), strategic analysis is carried out (SWOT), and finally a new product attack plan is worked out for each arena. This entails the business strategy types (Section 2.3.2.5) along with the five different strategy types, A to E, discussed below [65].

2.5.2.1.1 Goal Setting

The definition of goals for an NPS is a crucial process that first starts with strategic planning for the entire business, see Section 2.5.1 above for more details. From this strategic business planning model the business' growth and goals are decided, along with the areas of the strategic thrust (the direction of the product development effort). Using gap analysis these goals are then converted into new product goals which describe the role of new products (e.g. strategic roles such as exploiting a new technology, defending a market share) and the expected performance (e.g. in three years time, 40% of business sales will come from new products) of the NPD effort.

Based on Section 2.3.2.5 prospectors and defenders are the dominant business type used by SMEs (A.15.10) [65].

2.5.2.1.2 Definition of Target Arenas

Arena definition is carried out by doing a strategic analysis, then opportunity identification and then by assessing the identified opportunities. Strategic analysis is basically SWOT as outlined in the Strategic Planning Section 2.5.1. It leads to a company knowing its potentially hottest strategic arenas e.g. market arenas, technologies arenas and/or product arenas (A.15.11). Once this is known a company knows its core competencies or strengths which can be then leveraged to their advantage [65].

2.5.2.1.2.1 Mapping Arena Opportunity against Business Strength

Arena opportunity and Business Strength can be mapped against each other (A.15.12) resulting in SMEs pursuing the best opportunities [65].

2.5.2.1.3 Developing Attack Plans

The NPS process is now at the stage where an attack plan needs to be developed for the previously identified arenas. Although it is normally industry and company specific, attack plans can be based on the business types (as explained in Section 2.3.2.5) and the four strategic thrusts. SMEs can also consider product platforms (See Section 2.5.4) and must consider spending splits and resource splits [65].

2.5.2.1.3.1 Four Strategic Thrusts

The following Four Strategic Thrusts impact the business performance and should be considered when developing an NPS:

1. Technologically sophisticated strategies
    - Advanced development technologies resulting in advanced products
    - Strongly R&D inclined
    - Proactively acquire new technology
    - High level of ideation
    - Develop high risk products based on the company's offensive innovation business strategy
2. Market-orientated and marketing driven strategies
    - NPD process is very marketing orientated
    - Proactive in market need identification
    - Products are market needs driven
    - Products are sensitive to the changes of the market
3. A focused new product effort
    - Develop new products that are closely related to each other
    - Aimed at closely related markets
    - Use similar technologies and manufacturing methods
4. An offensive orientation
    - Outperforms a defensive strategy
    - Aggressive business, aimed at growth and gaining market share
    - Proactive towards market need identification
    - Active new product idea search [65]

2.5.2.1.3.2 Five Different Strategy Types

Also, a company can choose between Five Different Strategy Types for the NPS, they are:

A. The differentiated strategy

- This is the strategy with the best results
- Contains 1, 2 and 3 of the four strategic thrusts
- Attacks high growth and high potential markets with weak competition
- High priced products with strong differentiation and competitive advantage
- High quality products with better focus on customers needs than the competition and unique product features

B. The low-budget conservative strategy
   - Undifferentiated "me-too" new products
   - Low R&D spending
   - Company takes very little risk, new products are developed in line with their core business and markets
   - Have low failure rates and positive results, although make no major impact on the business

C. The technology push strategy
   - Innovative technology driven approach
   - No fit between the products developed and the markets targeted
   - Markets that are targeted are unattractive
   - High amount of product cancellations and failures
   - Less profitable then A and B.

D. The "not in the game" strategy
   - "me-too" products with low technology and low risk
   - Bad fit with current company technology and manufacturing capabilities
   - High rate of commercial product failure

E. The high-budget diverse strategy
   - High levels of unfocused R&D spending
   - Attack new markets and new technologies unsuccessfully
   - Like 'D', NPD results in a high rate of commercial failure [65]

Unlike strategy type B,C,D and E, type A has an excellent balance between technological sophistication with aggressiveness and a strong market orientation

(A.8.4). According to a survey carried out by Cooper [65] this strategy type A is better than the others from the point of view of new product success, business unit sales (47% v 35%), and meeting the businesses stated new product aims. This strategy is universal i.e. it can apply to various businesses and industries. Type B strategy only works well in businesses with strengths in marketing (strong sales forces, channel system, advertising and marketing research skills), and slower growth industries (technologically mature). Therefore, if Hi-Tech SMEs compare their NPS to Type A, it will yield information on their companies strategic strengths and weaknesses (A.15.13).

2.5.2.1.4 Defining Spending and Resource Splits

Spending and resource splits can be done by splitting across the type of projects, by project newness, by technologies or technology platforms (See Section 2.5.4) and by the phase of development e.g. split across FFE (Fuzzy Front End, see Section 2.3.1) and say the development phase.

2.5.2.2 Disadvantage of an absent NPS

- No direction – goals and roles.
- Poor new product results.
- Business decisions are made independently of each other.
- In companies with a strategy, it is often a result of evolution based on some internal decisions and external factors coming together. These companies have no analytical planning i.e. it is haphazard and not carried out in an official manner.
- Strategy and performance are not closely linked [65].

2.5.2.3 SME Strategic Structure

Figure 2.3 below shows an SME's strategic structure. This shows the link between Strategic Planning, New Product Strategy, the Product Portfolio, Platform Strategy and Technology Roadmaps [82]. The Typical PD processes are dealt with in Section 2.12 below.

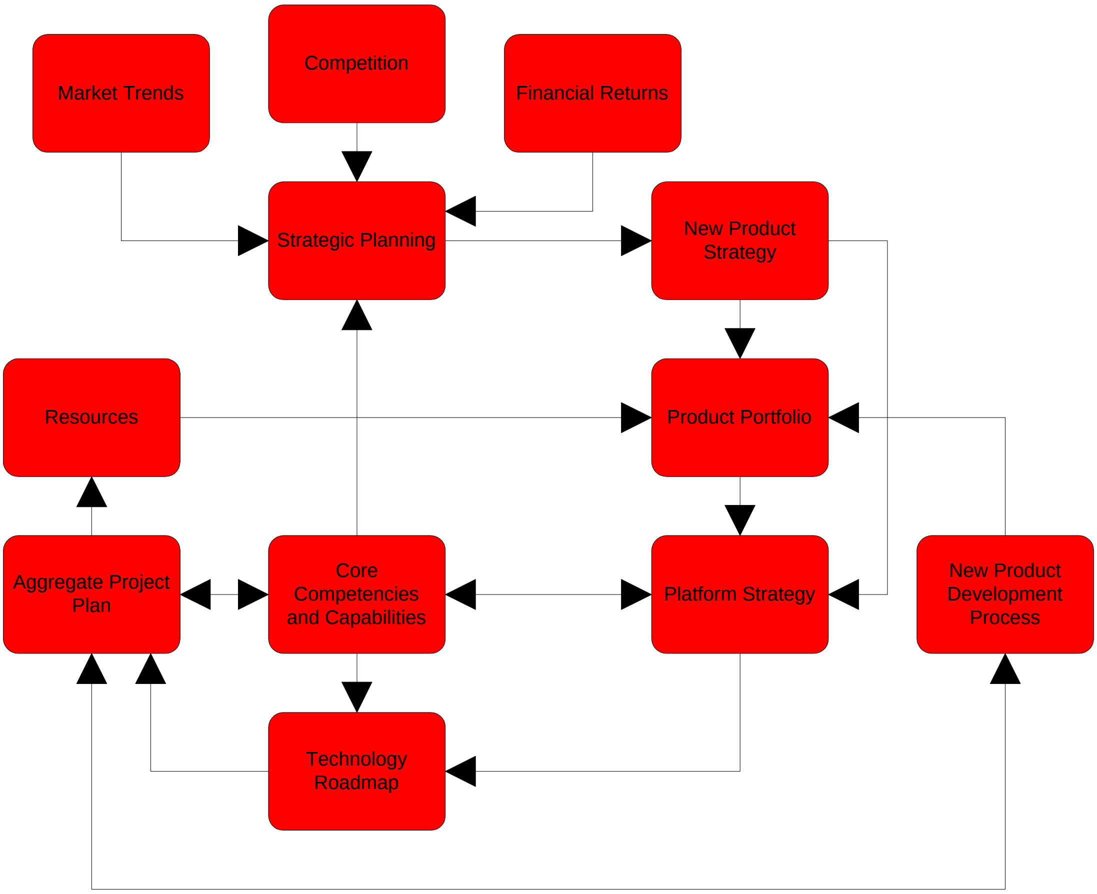

Figure 2.3 SME Strategic Structure [82]

Instead of the Four Business Types or the Five Strategy Types the attack plan could be based on product platforms (A.15.14). After identifying the strategic marketing arenas, product platforms could be developed to target the arenas, See Section 2.5.4 below on product platforms [65]. In addition, strategic thrust 3 could be aided by the use of product platforms. A.4.3 cites the advantages of product platforms from the perspective of T&M. A.1.10 and A.1.11 cite the use of a product portfolio and relate it to SMEC (A.15.15).

2.5.3 Portfolio Management

This section is taken from the work of Dr. Robert G. Cooper, Scott J. Edgett and E.J. Kleinschmidt [65, 83-85]. It has been shown that companies that have a systematic portfolio management process out-perform those that do not (A.1.14). PM is the expression of the business strategy, an indication of how and where the company needs to invest in the future [83]. Traditional portfolio models were very mathematically based and require a lot of data, modern portfolios do not. A definition of portfolio management is given in reference (A.15.16) [65]. Surveys carried out by reference [83] have found four main interrelated issues in the traditional project/portfolio management of products. They lead to the four goals in portfolio management:

1. Maximising the value of the portfolio (A.15.17).
2. Balancing the portfolio (A.15.18).
3. Strategically Aligning the Portfolio (A.15.19).
4. Picking the Right Number of Projects (A.15.20).

It is required to ensure the four goals are based on accurate data before integrating portfolio management into NPD (A.15.21) [65, 84, 85].

2.5.4 Product Platforms and Families

Once an SME successfully manages an individual product development project and then introduces and successfully manages a portfolio management approach, the next step is to progress to product platforms (A.15.22) [86] (See Section 2.4.1.6 – this is an example of an evolutionary path which could be developed based on the 3 steps). Although the term is 'product platform' a platform can be based on a process, customer, or brand. Also, component standardisation, and product architecture (combination of its subsystems and interfaces) can be part of the platform along with global platforms and product families [87]. The definition of a product platform, as defined by McGrath of PRTM [87], is as follows:

"A set of subsystems and interfaces that form a common structure from which a stream of related products can be efficiently developed and produced"

2.5.4.1 Platform Common Building Blocks

Marc H. Meyer and Alvin P. Lehnerd [88] discuss the common building blocks for platform development. The "common building blocks" are the influence behind the "product platforms" and therefore the products brought to market (A.15.23) [88].

2.5.4.2 Product Families

Product families are based on product platforms and are defined by Meyer and Utterback as [87]:

"A set of products that share a common platform but have specific features and functionality required by different sets of customers/market applications"
Next generation product families can be built on either a new product platform or extensions of the current product platform [87, 88].

2.5.4.3 Product Platforms in SMEs

Because of the common building blocks in reference [88] the use of product platforms may be limited in SMEs. In addition:

- Cost of setting up a product platform is high due to the higher amount of investment and time required than when developing a single product. This also effects the time on ROI.
- Platforms can cause over-designing in the product families lower-end products in order to keep to the platform strategy.
- If the product platform is weak, not only will one product be affected but all the products.
- Product platforms may hamper innovation and renewal of products due to the modular approach.
- They may cause organisational clashes. Engineering and marketing may clash over the "distinctiveness" of a product i.e. engineering could argue that the desired "distinctiveness" is too expensive while marketing may think that "distinctiveness" is required to be successful with different markets [87].

However, if an SME has a large variety of products components, modules and other assets across a family of products (A.1.15):

- They can be shared – thus helping product management.
- The cost of development could be reduced.
- Increases technological development.
- Increases marketing power.
- Reduces cycle times for NPD.
- Increased learning from using standard and/or tested components.
- Line changeovers are fewer and faster.
- Shorter production runs [87, 88].

2.5.5 Technology Development Planning (Roadmapping)

Technology development planning is directly linked to strategic planning and the new product strategy. It is also linked to product platforms and can be a concurrent process with the product development process, see Figure 2.3 above. Roadmapping is the most common form of technology development planning (A.1.16, A.15.24). Reference [89] provides a definition for a technology roadmap. Roadmaps are created using a cross functional team who eventually carry out the action plan [90, 91].

2.5.5.1 Common Roadmap Framework

The roadmap framework asks the questions: why (scope and boundaries), what (what requirements and drivers), how (how to link drivers to technology) and when (the time it will take to do the action plan). Roadmap creation can start from either a market pull (needs of the marketplace and customers) or with a technology push (define the market needs based on the technology) [90, 92]. See Section 2.3.2.7 and Section 2.11.

2.5.5.2 Types of Roadmaps

The three most common roadmaps are science and technology roadmaps (plots the future of a science or technical field), industry and government roadmaps (plot the future of an industry (e.g. semiconductor) or sector) and Product-technology roadmaps (product roadmaps, manufacturing roadmaps and component roadmaps can be considered corporate roadmaps) [90, 92, 93]. Product-technology and product roadmaps are the most relevant for this research.

2.5.5.2.1 Product-Technology Roadmaps

These roadmaps help product teams link the business strategy, product plans, and technology development (A.15.25). By doing this they help align the technology with the new product strategy, help coordination across product lines, and improve communication between the product teams, customers and suppliers [90, 92]. Table 2.8 shows the areas.

Table 2.8 Product-Technology Roadmap [93]

Market and Competitive Strategy (Why)	Product Roadmap (What)	Technology Roadmap (How)	Summary and Action Plan (When – To Do)
Market Structure and Size	Product Roadmap	Technology Elements and Evolution	Action Programs
Customer Drivers	Architecture	Competitive position	Technology Investment
Competitive Strategy	Product Drivers and Targets	Target Costing	IP and Standards
	Feature Evolution		Risk Roadmap

The Market and Competitive Strategy (Why) defines the market arenas to target. Detailing the competitive landscape results in a SWOT analysis of the competition and allows a differentiating strategy (Type A above, see Section 2.5.2.1.3.2) to be defined. Therefore, creating these roadmaps leads to a prioritised list of customer drivers and choices for strategic positioning in the market [94] and enables strategic use of technology across product lines/platforms/offers [91]. The Product Roadmap (What) is used to convert the customer drivers into product drivers. Using the differentiated strategy these product drivers are mapped into quantitative targets (market segments). Product drivers are also mapped to the architectural elements of the product which ensures that the features of the product are related to the product drivers and hence the customers needs (A.15.26) [92, 94]. According to the PDMA a technology roadmap is a "graphic representation of technology evolution or technology plans mapped against time. It is used to guide new technology development or for technology selection in developing new products" [95]. They show the planned and future planned technology mapped against customer and technology requirements (A.15.27) [96]. Customer and technology requirement elements are broken down by the product drivers they impact the most [92, 94]. The highest priorities required to achieve the objectives are mapped along with the schedule, budget and resources required. It ensures closure of any gaps and ensures that any intellectual property (see Section 2.10) issues are addressed. The risk roadmap highlights any issues which might affect the strategy or plan. During development the risk roadmap is used to monitor the external environment and technology risks [94].

2.5.5.3 Roadmaps for Portfolio Management and Product Platforms

If a company is using roadmaps, then they can be used to support the four goals of portfolio management (maximising the value of the portfolio, balancing the portfolio, strategically aligning the portfolio, and picking the right number of projects) (A.15.28). This is done by using the output/content of the roadmapping process as an input to the portfolio. Roadmaps define a product (with links to strategy, market, technology) and include the drivers and plans to manage the technology portfolio [92].

2.5.6 Conclusion

This section covered the strategic techniques SMEs could use. The techniques covered were Strategic Planning, New Product Strategy, Portfolio Management, Product Platforms and Technology Roadmapping. Strategic findings are in Appendix A.1 and Appendix A.15. The next section examines the organisational structure.

2.6 PD Organisational Structure

This section follows the SME strategy techniques section as changes in strategy may require a new structure for successful implementation. According to Irwin [97], when the strategy changes the structure should be reassessed (A.7.16). New strategies require different skills and key activities (A.21.1). The organisational structure is a tool for aiding the execution of strategy, helping to achieve performance targets, managing individual efforts and coordinating the performance of different tasks. Based on A.5.2, A.7.8, A.7.11, A.7.15 and A.7.17 team working or cross functional teams (CFT) operating in a flat structure with individual autonomy is the preferred structure for SMEs (rigid top down practices are not appropriate). This structure allows innovative ideas to travel through the organisation and teams to form quickly (A.7.2, A.7.10, A.7.12). In addition, it allows team members to experiment and develop learning processes. A.7.11 states that the organisational structure should allow communication between different functional departments. A.7.9 suggests the use of organisation development methodologies to conduct change. This section covers organisational development, organisational structure theory, the common forms of organisational structures, contemporary organisational deigns and cross functional teams. Then the most common business organisational structures will be discussed. A study of organisational design will then lead into a look at specific NPD organisational structures and finally the current industry preferred structures. As these sections are discussed, strategic characteristics will be added to Appendix A.7 and Appendix A.21 and subsequently used to form questionnaire items for the survey (Chapter 3).

2.6.1 Organisational Development

Organisational development takes place due to past decisions (as well as market dynamics). Management try to predict the future environment rather than examine the past. Questions such as, Where has our organisation been? Where is it now? and the meaning behind these answers in relation to where an organisation is going need to be answered. This is based on Greiner [98], who stated that companies fail to see that many clues to their future success lie within their own organisations and their evolving states of development (see Section 2.4.1.6 – the evolutionary path of organisational structures). Without understanding their organisational development problems, companies become frozen in their present state of evolution. The key forces in the development of an organisation are the age of an organisation, size of the organisation, stages of evolution, stages of revolution, and the growth rate of the industry. How these forces interact and the five phases of growth (through creativity, direction, delegation, coordination and collaboration) determines the next evolution. Table 2.9 shows the organisational practices during evolution in the five phases of growth [98].

Table 2.9 Organisational Practices during Evolution (Five Phases of Growth) [98]

Category	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
Organizational Structure	small & informal	centralized hierarchy	decentralized hierarchy	work groups	teams
	(owner-boss +network)	(owner-boss +network)	(multidivisional, matrix, or network)	(multidivisional, matrix, or network)	(multidivisional, matrix, or network)
Management Focus	make & sell	efficiency	expansion	consolidation	innovation & problem solving
Management Style	individualistic entrepreneurial	directive	delegative	watchdog	participative
Control System	market results	standards	reports	plans	mutual goal setting

Category	Phase 1	Phase 2	Phase 3	Phase 4	Phase 5
		cost centers	profit centers	investment centers	
Reward System	ownership	raises	bonus - individual	profit sharing	bonus -team

Based on A.5.2, A.7.2, A.7.8, A.7.9, A.7.10, A.7.12 and A.7.15 an SME should evolve from phase one to phase five i.e. phase five is the preferred SME organisational structure. In order to understand what is involved in this evolutionary path the next section examines organisational theory.

2.6.2 Organisational Structure Theory

The organisation's structure is a framework for dividing, assigning (controlling), and coordinating work. The key elements to an organisation's structure are [98, 99]: Designing Jobs, Creating a hierarchy, Distributing authority and Coordinating and integrating activities, and Forming departments and work units. In relation to creating a hierarchy, A.7.8 and A.7.17 are likely [99-101]. In relation to distributing authority, decentralisation is the delegation of power and responsibility to middle and lower levels of the organisation. Centralisation is the retention of power and responsibility at higher levels of the organisation. The advantage of centralisation is that it allows top managers to exercise control over the organisation. Its disadvantages are that it slows decision making and constrains innovation. The advantages of decentralisation are: an even distribution of control throughout the organisation, decision making is faster and the organisation is more flexible and responsive (A.7.18). The main disadvantage of decentralisation comes from more opportunities for errors in the decision making process. Whether to decentralise or centralise is influenced by the organisation's environment, size and economic performance (A.21.2). A.7.19 and A.21.3 describe formalisation [99-102]. In relation to coordinating and integrating activities, when developing a hierarchy and distributing authority, vertical organisational relationships are established. The other organisational relationship is horizontal or coordination, which is determined by the extent to which people and groups in the organisation are interdependent. The three basic types of interdependence are pooled, sequential and reciprocal. When interdependence is pooled, using the hierarchy and establishing rules and procedures is the most constructive. When interdependence is sequential, using rules and procedures and assigning liaison roles is the most constructive. When interdependence is reciprocal, forming task forces and integrating departments is the most constructive (A.7.20, A.21.4) [99].

2.6.2.1 Organisational Design Decisions

The organisational structure has four contingency factors or design characteristics, which determine the structural design. There are two main structural designs: mechanistic and organic (see reference [100, 103]). In addition, there are also contemporary structures which are examined in Section 2.6.4 [99]. The contingency factors of organisational design are strategy and structure (See A.7.16), size and structure (See A.7.21), technology and structure (the less uncertainty the more rigid the structure), and environmental uncertainty and structure [100, 103].

2.6.2.2 Organisational theory conclusion

The conclusions from this section on organisational theory are that the SME evolutionary path should evolve to phase five by implementing a wide span of control, a flat structure with decentralisation, lower standardisation and formalisation and reciprocal interdependence (reciprocal interdependence is typical in PD activities). It is important for the SME to get the right balance between mechanistic and organic structures in line with the contingency factors (A.21.5). The next sections examine the common forms of organisational structure (Section 2.6.3) and the contemporary structures (Section 2.6.4). Cross-functional teams (CFT) are also discussed (Section 2.6.5).

2.6.3 Common Forms of Organisational Structures

Once jobs have been designed (Section 2.6.2.1), organisations must then group the jobs into logical units. At upper levels of an organisation, the groups may be called divisions, product groups, or units. At middle and lower levels, they are usually called departments. Departmentalisation is the basis on which jobs are grouped together within an organisation. The following are a list of traditional departmentalisation or organisational structures: Simple Structure, Hierarchical, Functional, Product, Customer and Geographic (A.21.6) [104].

2.6.4 Contemporary Organisational Designs

These include the project structure, matrix structure, team-based structure, autonomous internal units, virtual organisation, boundary-less organisation and learning organisations [100]. The project structure, matrix structure, autonomous internal units and team-based structure are commonly understood and will therefore not be detailed here (A.21.6). Of interest here are virtual organisations, boundary-less organisations and learning organisations.

2.6.4.1 Virtual Organisation

Management out-sources and controls all of the primary functions of the business (A.21.7) [101, 105, 106].

2.6.4.2 Boundary-less Organisation

The boundary-less organisation is made possible by networked computers that expedite communication across intra-organisational and inter-organisational boundaries, See A.21.8 for details [100, 101, 105, 107].

2.6.4.3 Learning Organisations

A.2 shows the learning characteristics and how they relate to SME characteristics. The learning organisation is not a structural model or design, but rather a cultural model (mindset) (A.2.9). According to Senge, as referenced by [106], the five core disciplines for building a learning organisation are (A.2.10, A.16.1):

1. Systems thinking – Consider the sum total and its context, not just individual parts when dealing with issues e.g. consider all aspects from planning to completion.
2. Personal mastery – Employees must approach life as a creative work. Living life with a proactive attitude rather than a reactive attitude.
3. Mental models – Poor mental models produce poorly performing organisations. Employees must change their mental models if they are to change the organisation.
4. Shared vision – People working toward a common goal are much more effective, efficient and productive than people working toward different (personal) goals.

5. Team learning – Involves mastering the art of dialogue and discussion. Many viewpoints are useful in understanding since it provides the broadest possible perspective (See A.2.4). Obstacles to open communication must be identified and removed [106].

The learning organisation is constantly growing and changing to stay ahead of the rapidly changing market. The organisational design is boundaryless, team-based and empowered. Information sharing is open, accurate and timely. The organisational culture has strong relationships, a sense of community and is caring and trusting. It also has strong leadership with a shared vision, collaboration and commitment. The organisation's learning methods are as follows (A.2.11, A.16.2):

- On-the-job learning – Every employee should be constantly learning about the processes and products they deal with routinely. This is part of continuous quality improvement (CQI) (A.2.4). Mistakes made in the planning of a new process could turn out to be very expensive and time consuming to diagnose and repair.
- Simulation – Learning from models. Computers are cheaper and faster. Should be used to speed up planning and design processes. This involves hiring/training employees' in the use of these packages.
- Prototyping – Hardware prototyping is expensive and relatively slow, but shows up real world issues that simulations could miss. Rapid prototyping is a method of quickly producing dimensional prototypes from solid models. In some cases, the rapid prototypes can be used directly in a production environment. Virtual prototyping is an extension of both CAD and simulation to model and manipulate a prototype system quickly on the computer (See Section 2.9, which is on Technology for more details on this).
- Vicarious learning – Learn from other peoples experience, mistakes, and successes (A.2.6). Borrow information, read, and send employees to technical conferences and trade shows. Provide regular training for all employees. This is by far the fastest and cheapest learning method.

According to Bogen, C. E. and M. J. English (as cited by Anderson) [106], learning organisations can enjoy the following benefits by implementing the disciplines and methods described above:

- Reduced waste in effort as well as material.
- Enhanced profits and market share.
- Regular, timely innovation.
- Reduced employee turnover.
- Enhanced training effectiveness.
- Rapid process and product improvement.
- Improved customer satisfaction.
- Improved employee morale.
- Reduced cost of operation.
- Reduced response and cycle times.
- Reduced defect and error rates.

See Section 2.12 for a description of a learning organisation. This is the Knowledge Based Development (KBD) system used by Toyota [100, 106].

2.6.5 Product Development Teams or Cross Functional Teams

Concurrent engineering (CE) or integrated product development (see Section 2.12) is based on the integrated design of products and their manufacturing and support processes. Product development teams are a way to reorganise personnel involved in NPD to facilitate informal communication, sharing of requirements, constraints and ideas early in the product development cycle. This therefore satisfies CE key objectives of early involvement and parallel design, leading to the successful development of competitive products. CFT are formed with personnel from different functional departments to support the design, development and transition to production of a new product. Suppliers may also participate in team activities either as formal team members or as consultants, this aids early supplier involvement (A.21.9).

2.6.5.1 Team Collocation

This refers to the collocation of the team, appointment of a team leader, planning, empowerment and self-direction and training of the team. Collocation provides the physical access and improved communication and coordination to achieve the parallel design of products and their processes. Collocation is a very simple, powerful and low cost step to enable concurrent engineering practices [108, 109] (A.21.10).

2.6.6 Conclusion

Traditional approaches to organisation structures (like the hierarchical structure) are mostly used when activities can be divided into simple repeatable tasks which can be efficiently performed in mass quantity. They also suit a situation where benefits from deeper functional expertise exist and where customer needs are standardised. However, current NPD requires a structure that can shift quickly to customer preferences and give excellent customer service, allow short design to market cycles, first-time quality, creativity and innovativeness with a speedy reaction to the competition. This means that organisational structures are becoming leaner, flatter and decentralised such as the description given in Section 2.6.2.2. Based on the 2.6.2.2 conclusion the main organisational structures for SME PD are the project, matrix and learning organisations. In particular, the learning organisation using a CFT approach is in line with Phase 5 of Table 2.9. Organisational Structure findings are in Appendix A.7 and Appendix A.21. The next section examines Tools and Methodologies.

2.7 PD Tools and Methodologies (T&M)

There are two characteristics that are fundamental to the concept of a PD tool [110]:

- It aids in the establishment, accomplishment and/or control of PD related tasks, either by means of formalisation or externalisation of thinking.
- The tool needs an individual, group, or computer system to implement it.

Any tool with the above characteristics can be regarded as being a type of PD tool [110].

2.7.1 Background journal articles

According to Scozzi *et al.* [34], the T&M of A.4.4 to A.4.14 are critical for SME knowledge management, communication (tacit to explicit), learning, innovation, measuring progress and solving problems. According to Wessel and Burcher [111], the essentials of a six sigma organisation are:

- Process improvement using DMAIC method (See Section 2.7.2).
- Product and process design using DMADV method (See Section 2.7.2).

- Underlying process management.
- Cultural implementation e.g. the six sigma ‘belt’ system [111].

Therefore, any references to six sigma, and critical success factors, refer to both process improvement and product and process design (Design for Six Sigma) and can therefore be used to guide this section.

Mole *et al.* [112] conducted research into the use and deployment of T&M in SMEs (engineering and electronic) in the UK. From 1,441 mailed questionnaires, 218 were usable. Their literature review found that although T&M investment requires time but little capital investment the absorptive capacity (the more complex the T&M the less likely it is to be used) of the company is critical (A.4.15) – this is critical when considering T&M for SMEs and **one of the main aims of this section is to examine T&M that can be used by SMEs**. Larger companies have more absorptive capacity as they have more employees. Mole *et al* survey also found A.4.16. Overall, the conclusion from this research was that the adoption of T&M is linked (in this order) to the characteristics of the company, its resources and its competitive environment. In addition the use of T&M combined with formal planning and training, can be used as a technology path for SMEs (See Section 2.4.1.6).

Antony *et al.* [113] carried out empirical research to examine ‘the extent to which six sigma is being implemented within UK manufacturing SMEs’. Four hundred SMEs were mailed a questionnaire with a return of 66 and a usable number of 60. Of these 60 SMEs 16 (27%) were actively involved in six sigma (for one year on average) whereas 80% had implemented ISO 9000 quality management system (nine years on average). Almost 25% had a TQM system (eight years on average) while 5% were using a lean production system (LPS). In terms of not implementing a system 35% stated they were not aware of six sigma, 26% said it was due to lack of resources whereas 20% said their quality system was sufficient. Of the 16 companies, 69% were using DMAIC for continuous improvement, 19% were using DFSS and 6% were using both six sigma and DFSS. Of the 60 companies, 80% said lack of resources (A.4.1) was the main barrier to implementing six sigma. It was found that T&M which outputted visual information, identified the root cause of problems and were easier to use were the most used methods (A.4.17). FMEA had a familiarity of 100%, Poka-Yoke – 94%, Design of experiments – 88%, Taguchi Methods – 81% and QFD – 69%. Another output of this research was the critical success factors for

implementing six sigma (in decreasing order of importance): management involvement and participation, linking six sigma to customers, linking six sigma to the business strategy, organisational infrastructure, understanding what six sigma is, training on six sigma and project prioritisation and selection (See Section 2.5.3).
According to Wessel and Burcher [111], six sigma is the next evolutionary stage of TQM (as it builds on the 1980s TQM movement – See Section 2.4.1.6 and 2.12) – (A.4.18). SMEs supply products and services to large companies and therefore must have a quality output (they affect the economy as a whole). Their survey was conducted in Germany with 1,988 SMEs emailed a questionnaire: 47 were usable. Based on their literature review and the usable survey responses, success factors were compiled for SME six sigma implementation. According to 85.1% of respondents, profitability improvement is the main output from six sigma (six sigma project should be self financing). Many SMEs with ISO 9000 do not have process management elements in place. 74.5% of respondent's wanted improved control of the company e.g. documented procedures (minimal) (A.4.19). Wessel and Burcher also found that six sigma for SMEs needs to be adjusted to the core requirements of ISO 9000 thus enabling certification (42.6%). This is not common in MNC [111]. However, ISO 9000 [114] is concerned with quality management, specifically what the company does to accomplish:

- Customer's quality requirements.
- Any applicable regulatory requirements.
- Enhance customer satisfaction.
- Achieve continual improvement of its performance (while pursuing these objectives).

As can be seen ISO 9000 and six sigma are about meeting customer requirements (95.7% wanted increased customer satisfaction and 97.9% wanted to reduce the number of customer requirement failures) [111]. According to Wessel and Burcher [111] ISO 9000 is fulfilled by six sigma with the adjustment of the process documentation. Appendix A.4.20 to A.4.22 shows the other findings from this research.

The next section of the thesis will therefore detail the Design for Six Sigma approach as this approach uses all the main tools and methodologies in product development.

While examining these T&M an emphasis will be placed on finding T&M for SMEs by understanding what aspects of each T&M can be used by SMEs when characteristics A.4.15 to A.4.20 are considered (A.18.1).

2.7.2 Design for Six Sigma (DFSS)

Six Sigma is also known as the DMAIC (duh-may-ick) methodology and is used to gain cost reduction by finding and fixing problems in manufacturing or in service i.e. it is used on products or services that are out of the development phase. DMAIC has five phases which are Define, Measure, Analyze, Improve and Control. Design for Six Sigma (DFSS) is used to design or redesign a product or service from its inception [115] i.e. DFSS is carried before DMAIC. A definition of the relatively new approach of DFSS can be found in Brue [116]. When a company designs six sigma quality from the beginning of NPD that gain will be kept throughout the product life cycle. Rather than trying to develop a product and only apply six sigma to the manufacture, using DFSS will have six sigma quality built in when it reaches manufacturing and commercialisation. As found by an empirical study of 351 Irish enterprises in the journal article "The effects of design quality on quality performance" [117], designing quality into a product reduces cost, improves quality in the marketplace and the time to market. DFSS is a complex methodology of systems engineering analysis that uses statistical methods and balances cost, cycle time, schedule and quality (A.18.2) [115].

The DFSS approach is also referred to as DMADV (duh-mad-vee) methodology and incorporates five phases; Define, Measure, Analyze, Design and Verify. Variations on this methodology also exist such as DMADOV (optimise), DCCDI (Customer, Concept and Implement), DMEDI (Explore) and IDOV (Identify, Design, Optimise and Validate). Whichever methodology is used the approach basically uses the same tools. However, this discussion will be based around the IDOV methodology and the key tools used by it along with the addition of a plan/prerequisites phase (PIDOV) and the TRIZ tool [115, 116, 118-120].

2.7.2.1 Plan/Prerequisites Phase

This phase is concerned with mapping all the vital steps such as selecting the right project, gaining management support, choosing the correctly trained team members including Six Sigma trained (e.g. black belt, green belt etc) and generally employing all the knowledge established in Section 2.5 (Strategy Techniques). In addition, for a DFSS based exercise it is also necessary to establish the project metrics so that there is a measurable, quantitative scale for assessing performance. This can be done by collecting data on the competition's similar products or services i.e. setting a baseline. It is also then possible to set goals and targets based on this information and the Voice of the Customer (VOC). Process capability data must also be identified so that engineering requirements can be compared to the process capabilities, this data may not be available at the earlier stages but is considered when identified [116].

2.7.2.2 Identify Phase

This phase is concerned with selecting the best product or service concept based on the voice of the customer (VOC) (A.18.3). It uses the following tools: Affinity Diagram, VOC Table, QFD (House of Quality), FMEA, Scorecards, TRIZ, Concept Classification Tree and Concept Combination Table, DFMA, Poka Yoke, DFX, CTQ to CTP translation and CAE [116, 121].

2.7.2.3 Design Phase

This is concerned with building a knowledge base about the product or service and is based on the outcome of the above i.e. the translation of customer CTQ into engineering/functional requirements (A.18.4). It uses the following tools: Quality transfer functions (examined using CAE packages like FEA (See Section 2.8) or using DOE (design of experiments – Section 2.7.3.6.1), Robust Design, FMEA and DFX. [116].

2.7.2.4 Optimize Phase

This is concerned with balancing quality, cost, and time to market while detailing the design (A.18.5). It uses the following tools: FMEA and DOE or Taguchi Methods [116].

2.7.2.5 Validate Phase

This is concerned with ensuring that the product or service designed is aligned with the VOC and the customers CTQs (A.18.6).

All of these tools together cover the full life cycle of the product or service under development, its process, and are mapped over whatever PDP a company is using i.e.

the output of the tools are reviewed at design reviews/milestone checks of the process in place [116].

2.7.3 Design for Six Sigma Tools

Of the tools mentioned above, relevant to product development (not the development of the products process), the following DFSS tools will be discussed in detail in the order in which they are used throughout the method (As can be seen in Section 2.7.2 some are used more then once):

- QFD (Kano Model/VOC/Affinity Diagram)
- FMEA
- Systematic Exploration (Concept Classification Tree and Concept Combination Table)
- TRIZ and Pugh Concept Selection Technique
- DFMA
- Robust Design
- DOE

[116, 121]

In addition, the references in Section 2.7.1 all made reference to FMEA, QFD, problem-solving tools, Poke Yoke, DOE and Robust Design and A.4.3 stresses the need for DFMA. As discussed in Section 2.7.1 SME T&M which follow A.4.15, A.4.17 and A.4.20 characteristics will be considered, this may involve certain outputs of T&M only i.e. not all areas of a T&M would have to be used.

2.7.3.1 Quality Function Deployment (QFD)

Quality Function Deployment is a set of product development tools used to transfer the concepts of quality control from the manufacturing process into the new product development process (A.18.7). The main features of QFD are VOC, Teamwork and HOQ [122, 123].

Lager [124] carried out a meta-analysis of nine studies of QFD industrial usability. This research concluded that although ‘shorter time to market’ is not improved, the use of QFD resulted in ‘better products’ and ‘improved information dissemination/retrieval’. It was found that the cost of implementing QFD was retrieved by having less product failures [124]. The creator of QFD was Professor

Yoji Akao (it was part of TQM – Section 2.12) [124-126]. QFD is used to translate requirements (customer) into critical to quality (CTQ) features, thus identifying and prioritising the features [116].

There are two main QFD systems both of which use the house of quality. 'The Matrix of Matrices' is an advanced system for experienced users. This does therefore not fit with the SME requirement of a simple to use tool (See A.4.15 and A.4.17). The other system is the 'The Four Phases of Matrices' which is mostly used in Europe [124]. As mentioned in references [65, 127] the HOQ and the 'The Four Phases of Matrices' can be considered complicated. Reference [128] states 'The Four Phases of Matrices' was not designed for the development of new products. From the perspective of an SME the Kano Model, VOC and Affinity Diagram are the critical element at this stage of the PDP (A.4.23). However, tools are only as good as the people using them, whatever system is used a manual evaluation process is necessary i.e. an interpretation of what is observed [116, 127]. These are described below.

2.7.3.1.1 Kano Model

The Kano Model is used to understand levels of customer satisfaction based on product attributes divided into three categories; basic requirements, performance requirements and excitement attributes (provide a competitive advantage, an opportunity for a differentiated product, Type A – Section 2.5.2.1.3.2) (A.18.8) [116, 129].

2.7.3.1.2 Voice of the Customer Table

The Voice of the Customer Table (VOCT) is used to help build the House of Quality matrix [123]. Methods of capturing the VOC are shown in A.18.9 [116] and A.7.4 to A.7.7, A.1.5 and A.7.10. It has two parts, VOCT Part 1 (A.18.10) [65, 116] and VOCT Part 2 (A.18.11). These are transformed into reworded statements for use as a customer requirement entry in a House of Quality matrix [65, 123].

2.7.3.1.2.1 Affinity Diagrams (JK Method)

This is a method used by a team to organise and gain insight into a set of qualitative information, such as voiced customer requirements and is simple to use (A.18.12) [116, 123, 130].

2.7.3.2 Failure Modes and Effects Analysis (FMEA)

FMEA is a systematic technique for the identification of the possible modes of failure of a product or process, and of the likely consequences of such failure (A.18.13) [116]. FMEA can be used on global systems functions, design, process, service or software. The FMEA document follows the product through its development cycle. This is because changes are made throughout the cycle that can introduce new failures. These changes can be to the operating conditions, product/process design, due to new regulations or based on customer feedback [131].

2.7.3.3 Systematic Exploration

Ulrich and Eppinger [121] discuss a concept generation method. From this, the two methods of most interest are the concept classification tree and the concept combination table.

2.7.3.3.1 Concept Classification Tree

Firstly, the narrowing of concepts is conducted by systematically examining each option. Secondly, using this method allows the identification of independent approaches (A.18.14). If there is a large difference between the possible concept approaches, teams can be formed to work on each [121].

2.7.3.3.2 Concept Combination Table

The concept combination table acts as a systematic way to examine combinations of concepts. Potential combinations must be developed and refined to find the overall best solution. It helps to make forced associations between possible concept solutions to top-level problems and sub-problems, therefore aiding creative thinking (A.18.15)[121].

2.7.3.4 TRIZ (Theory of Inventive Problem Solving)

Inventive problems (no known solution with at least one contradiction) are the hardest ones to solve. The typical model follows the method of using books, technical journals or subject matter experts. Inventive problem analysis is usually done with psychological methods like brainstorming and trial and error [132]. The result of these methods are an excessive amount of time from trial and error resulting in many different concepts being tried and the solution possibly being in a different area to the expert carrying out the trials. This issue is referred to as psychological inertia [132, 133].

To be creative the problem must be viewed from different perspectives. TRIZ is a series of creativity triggers which help the problem solver see the problem from many perspectives (A.18.16); to fully understand what the problem is, and spot possible solutions. It works on several levels, from individual use of the tools resulting in a number of good answers, to working systematically through a series of TRIZ techniques and finding the best overall solution to a problem. The approach is based on technology rather than psychology [132, 134].

Altshuller recognized that the development of technological systems followed predictable patterns that straddle all areas of technology and that problem solving principles are also predictable and repeatable [135]. According to Domb [136], TRIZ customers/beginners have four requirements: fast success, minimum time spent training, familiar terminology and 'ego protection' (A.4.24). Based on these requirements Figure 2.4 shows a flow chart of problem analysis using TRIZ. The elements of this and what they do to solve problems will now be discussed [137].

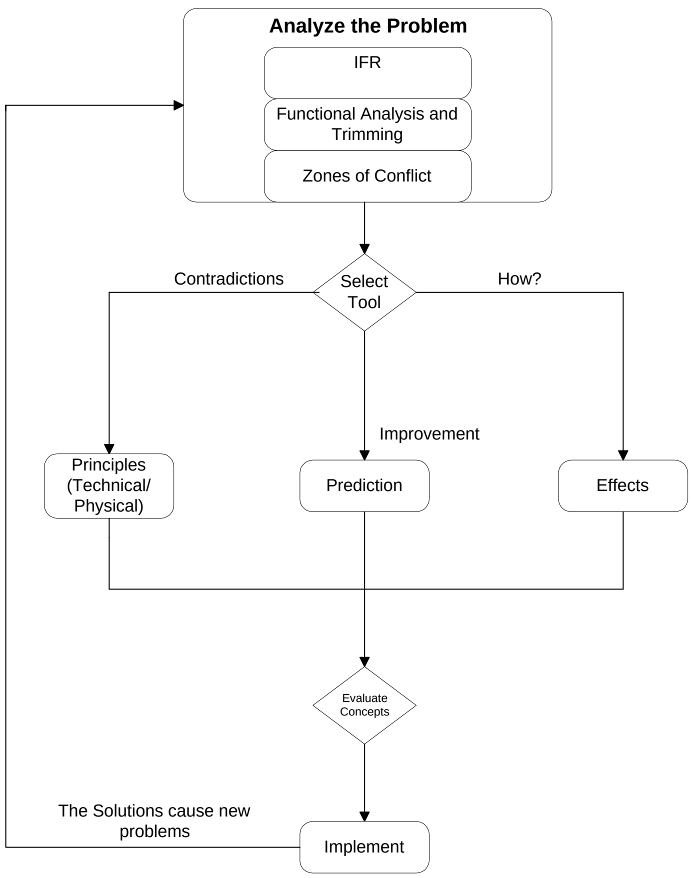

Figure 2.4 TRIZ Problem Analysis Flow Chart [137]

2.7.3.4.1 Problem Analysis

There are three methods used to analyse the problem, they are Ideal Final Result, Functional Analysis and Trimming, and Finding the Zones of Conflict or Zones of the problem [137].

2.7.3.4.1.1 Ideal Final Result (IFR)

The IFR should be defined in terms of the customer's needs (voice of the customer). This can be an external customer or the internal customer i.e. the manufacturing department. The IFR is where the designer envisages the ideal solution to a problem and works towards it as a goal (A.18.17). The formulation of the IFR achieved from solving a problem results in solving it at a very high inventive level [138].

2.7.3.4.1.2 Functional Analysis and Trimming

Functional analysis or functional cost analysis can be used to determine which function is useless/harmful [138]. A.18.18 shows the questions asked during functional analysis (part of value analysis/value engineering). They help develop the problem statement [136].

Technical system trimming is one of the highest forms of creativity. Individual parts make up a technical system and they each carry out system functions (A.18.19) [138].

2.7.3.4.1.3 Zones of Conflict

The 'Zones of Conflict' of the problem is a method of root cause. If the cause is removed, so is the problem. This is carried out by asking the '5W (Who, What, When, Where and Why (ask five times)) and H (How)'[136].

2.7.3.4.2 Contradiction

The normal design process requires an engineer to make tradeoffs or compromise when faced with technical design conflicts. TRIZ makes the designer look for a higher level solution by designing out the contradiction (A.18.20) [138, 139]. There are two kinds of contradiction, technical and physical. With technical contradictions there are trade offs i.e. something gets better, something gets worse (strength v weight). For physical 'inherent' contradictions an object has contradictory (opposite) requirements e.g. hot/cold, soft/hard or time. For these contradictions there are two kinds of principles: 'Matrix and the 40 Principles' and the 'Four Separation Principles' [140]. Reference [141] shows the full Contradiction Matrix (it can also be downloaded from there). Reference [142] explains the 40 principles with examples. Reference [137] explains the separation principles (time, space, transition and super-system).

2.7.3.4.3 Effects

This refers to 'scientific effects' from many sciences e.g. chemistry or electricity. If it is known 'what' to do but not 'how', existing effects can be used i.e. this is the 'how?' in Figure 2.4 above [140].

2.7.3.4.4 Prediction (Patterns of Evolution/Technology forecasting)

While creating the contradiction matrix, Altshuller noticed that technological systems evolve according to certain, statistically proven historical patterns, which take place in both man-made and natural systems. These patterns of evolution can be used for system improvement (without numerous blind trials) and to predict the future evolution of a system (some companies use radar plots) [143-146].

2.7.3.4.5 Evaluate Concepts

The solutions are first compared to the IFR i.e. are the customer needs met and the technology advanced. In addition, the Pugh Concept Selection Technique can be used to evaluate and combine solutions [143].

2.7.3.4.5.1 Pugh Concept Selection Technique

This technique uses a scoring matrix called the Pugh Matrix or the Criteria-based matrix for concept selection (it's a prioritisation matrix usually associated with QFD). The criteria can be based on TRIZ concepts and weak concepts can be removed further by TRIZ analysis i.e. the solution causes new problems (Figure 2.4) (iterative process). A seven-level scale can also be used (A.18.21) [116, 147].

2.7.3.5 Design for Manufacture/Assembly

Design for manufacture and assembly (DFM/DFA) embraces a range of methods that assist in designing a product for ease of manufacture and assembly, therefore the quality and reliability of the product is improved. Time to market and cost of manufacture and assembly can also be reduced [148]. Design methods can be either creative or logical [149, 150]. DFM methods can be applied at different stages of the design process i.e. the conceptual design stage, the assembly stage, the selection of materials/processes and finally the detailed design stage (A.18.22) [150]. The most common methods are the Boothroyd and Dewhurst (B-D) DFMA, Hitachi

Assembleability Evaluation Method (AEM) and the Lucas DFA Method (A.18.23) [149-152]. B-D DFMA is the most popular technique [150].

2.7.3.5.1 General Guidelines

The following general guidelines apply to DFA/DFM - A.18.24 [153]. See reference [154] for general DFM guidelines. A more specific set of guidelines can be developed by a company which suits their product design and manufacturing process requirements (A.18.25) [154]. Reference [155] describes some successful DFM stories and a specific approach of DFM by an employee of Boston Scientific, Ireland. DFX (design for 'eXcellence') is another method which is now considered in industry along with DFMA.

2.7.3.5.2 Design for Environment

Design for Environment (DFE) or eco-design is becoming of significant importance. Reference [156] entitled "Development of sustainable product and services", which is co-written by an employee of Enterprise Ireland, discusses a method for implementing Sustainable Product and/or Service Development (SPSD) throughout the lifecycle of a product or service. With SPSD the products and services are developed to be more sustainable in a Triple Bottom Line perspective i.e. balancing economic, environmental and social aspects as well as the normal product requirements. Therefore, SPSD goes beyond DFE by incorporating economic and social aspects and it is recommended that this is incorporated into the company strategy (A.18.26). Appendix A of [156] provides a checklist for consideration in the development of a SPSD.

2.7.3.6 Robust Design

Robust design is concerned with improving the basic function of a product or process by selecting optimal targets for the inputs and therefore reducing the variability of the outputs [157, 158]. A robust product works whether there is variation in a product's manufacture, variation due to deterioration and/or variation from its intended use [159]. It aides the overall DFSS approach for creating knowledge as it helps increase engineering skills (A.4.25) [158]. According to Ulrich and Eppinger [121] robust design can be used at the concept stage but is mostly used at the detail design phase (parameter design). There are three approaches to Robust Design: Dual

Response (using response surface), Robust Tolerance Analysis (using response surface), and Taguchi Method [157, 160, 161]. According to Taylor [161] all three approaches have strengths and weaknesses with no approach universally superior. However, Taylor compared these three approaches around an example problem where the equation relating the inputs and outputs is not known. First, a comparison of the approaches was conducted based on the example; this was followed by generating and analyzing 100,000 sets of data to study conditions not representative of manufacturing. Finally, another 100,000 sets of data were generated and analyzed to examine measurement error and other variation. This study concluded that the tolerance analysis approach (using response surfaces) is generally the best in terms of accuracy, precision of its estimates and cost [161]. None of these approaches' work if a major source of variation is not included as an input and does not vary much during the study (e.g. a seasonal variable) [161]. References [162, 163] both discuss the disadvantages of the Taguchi Method with reference [162] carrying out a review of parameter design since 1992 and referencing the Nair panel discussion on Taguchi (highlighting its negative points). The Response Surface Approach originated from the work of Box [164] and has its origins in the chemical industry [164, 165]. The response surface approach (dual and tolerance analysis) is mathematically complicated (requires a statistician or mathematician) and a consultant/expert should carry out this work (an examination of references [160, 162-165] will show that an SME would not carry out this analysis themselves) (A.4.26). SMEs would be more likely to control the noise factors (e.g. design a hermetically sealed unit to control humidity) rather than use complicated experiments to design them out (A.18.27) [166]. Generally speaking robust design is complicated, however, basic robust design/design of experiments can be carried out using the Taguchi method [121] or using 'One-Factor-at-a-Time' experimentation [121, 167]. Also, DOE and the Taguchi method were recognised by 88% and 81% of the SMEs in Antony's research [113] (See Section 2.7.1 above) (A.4.27). Both of these are examined in the next sections.

2.7.3.6.1 The Taguchi Method

The product/process Robust Design process can be broken into three stages. Stage one deals with the system design, this is where the functionality of the product is decided (technology, structure, architecture). Stage two deals with the parameter design which is the detailing of the design variables within the chosen design from stage one. Stage three deals with the tolerance design which is where design tolerances are specified for the design parameters or targets from stage two (A.18.28). Traditional engineering approaches to improving quality are carried out at the tolerance design stage (adding product cost by requiring compliance to the tolerances) whereas the Taguchi Method is carried out earlier i.e. at the parameter design stage. In the parameter design stage the design variables are called signal, noise and control. The signal (input) parameters are those set by the user to produce the intended behaviour (response is the output). The noise parameters are the parameters that are only known by their statistical behaviour, are expensive/impossible to control, or occur because of the product's use/misuse. Control parameters are parameters that the designer can use/design in to ensure that the design performs with a minimum loss in quality [159, 168]. There are four steps to robust parameter design (A.18.29):

1. Problem Formulation
2. Data Collection/Simulation/Design of Experiments (DOE)
3. Factor/Parameter Effects Analysis
4. Prediction/Confirmation [169].

2.7.3.6.1.1 Step 1 – Problem Formulation

The problem formulation is the basis of the robustness strategy. It consists of five tools:

- The P-Diagram
- Loss Function
- Signal to Noise Ratio (SNR)
- Experimental Designs e.g. Orthogonal Arrays (See DOE Section) [121, 170]

2.7.3.6.1.2 Step 1 – Data Collection/Simulation/Design of Experiments

The experiments can be carried out in either hardware or through simulation. It is best to have a simple model that captures the design concept such that the specific control, noise and signal parameters can be changed (A.18.31) [169]. Experimental plans determine how to vary factor levels (control and noise) to determine a systems behaviour. These can be full factorial, fractional factorial and orthogonal array plans.

These are simple to complex and thus vary in cost. The orthogonal array is the smallest fractional factorial plan that still identifies the main effects of each factor [121]. Traditionally the approach to working out design parameters, deciding on tolerances and making design trade-offs was intuitive or supported by limited analysis and trial and error experimentation. Design of Experiments (DOE) provides a framework for this work. It is a systematic approach of investigating a system/product/process using a series of structured designed tests in which planned changes are made to the input variables (A.18.30). It is used for problem solving, parameter design and robustness study. Designs of experiments are efficiently designed such that only a small number of the required experiments are required to be representative. DOE can reduce cost, warranty, rejection and the overall cost of the development (A.4.28) [171].

2.7.3.6.1.3 Step 3 – Parameter Effects Analysis

The control parameter effects are calculated and the results analyzed to pick the optimum control parameter settings (A.18.32). The S/N ratio is a trade off between the mean performance (numerator) and the variance (denominator) and is therefore used to find the best trade-off between both [121, 169].

2.7.3.6.1.4 Step 4 – Prediction/Confirmation

Using the baseline and optimum settings of the control parameters the performance of the product design is predicted resulting in optimum conditions. These conditions are then validated by performing confirmation experiments and comparing to the predictions (A.18.33). If the predictions are confirmed the results are implemented otherwise it is back to step one [169].

As can be seen the overall purpose of parameter design is to choose and manipulate the control parameters so that the product/process becomes insensitive to noise [168] or to put it another way the Taguchi Method of Robust Design applies statistical techniques to evaluate the combined effect of various design parameters in order to minimize variation in design performance [116]. These design parameters can now have appropriate tolerances applied [172].

2.7.3.6.2 One-Factor-at-a-Time Experimentation

Frey *et al.* [167] carried out a comparison between adaptive one-at-a-time plans and orthogonal arrays through computer simulations based on data from 66 response variables from 27 full factorial experiments published in science and engineering journals and textbooks (mechanical, electrical, materials, civil and chemical engineering). For one-at-a-time plans information is gathered about one factor in each experimental trial until all factors are studied. In adaptive one-at-a-time plans the optimisation of the response is also carried out. The experiment starts with a baseline set of factor levels and the response is measured. For each experimental factor in turn:

- The factor is changed to each of the levels that have not been tested while keeping all other experimental factors constant
- The factor level that gave the best response is kept

This method gives estimates of the conditional main effects for each experimental factor. However, the disadvantages of one-factor-at-a-time are:

- It requires more runs for the same precision
- It cannot estimate some interactions
- Conclusions from the analysis are not general
- It can miss optimal settings of factors
- It is not possible to randomise and therefore bias is possible due to time trends

According to Frey *et al.* research findings one-at-a-time plans are more effective than orthogonal arrays under certain conditions (Reference [167] shows a method of determining these conditions) (A.4.29). Overall, using one-factor-at-a-time plans can be used in companies where budget and schedule changes affect ongoing experiments, and in dynamic PD environments (A.18.34). These experiments can also be carried out concurrently allowing more options on the best way to proceed [167].

2.7.4 Conclusion

This section examined tools used throughout the PDP. This was done from the perceptive of a Design for Six Sigma (DFSS) framework. The phases and activities in each phase were detailed. In addition, specific T&M were identified. These T&M were examined further while considering the identified T&M characteristics specific to SMEs. These T&M were:

- QFD – The HOQ may be to time consuming for an SME but the Kano Model, VOC and Affinity Diagram should be used.

- FMEA – This should be used by all SMEs
- Systematic Exploration (Concept Classification Tree and Concept Combination Table) – This could be used by all SMEs as part of a PDP. It is simple to use and provides alternative ways of viewing concepts.
- TRIZ and Pugh Concept Selection Technique – This can be applied in a scaled manner from twenty minuets of analysis to days of analysis.
- DFMA – The B-D DFMA method could be used by all SMEs.
- Robust Design and DOE – These were found to be a complicated. However, the Taguchi method and the one-at-a-time plan could be used by SMEs.

The T&M findings are in Appendix A.4 and Appendix A.18. The next section examines Technology.

2.8 Technology

The previous section examined the tools and methodologies used throughout the PDP. According to Marri *et al* [173] Computer Integrated Manufacturing (CIM) is "concerned with providing computer assistance, control and high levels of integrated automation at all levels of manufacturing (and other) industries by linking islands of automation into a distributed processing system" [173]. CIM can supply small customers with a few parts or larger customers with many parts – the product mix is manufactured with consistent quality and minimum waste [174]. PLM/PDM is about management of data whereas CIM is about automation of processes using the input/output of CIM elements – Figure 2.5. According to reference [175] PDM is the basis for data management in the CIM environment. Figure 2.5 [173] also shows CIM benefits and justification for CIM in SMEs. According to Marri *et al* [176] a typical CIM flow starts with a customer sales order entered into a computerised order-entry system, this contains the specification (description of the product) which is an input to the product design department. The product is designed on CAD and a bill of materials (BOM) and assembly drawings completed, the design output is an input to manufacturing where process planning (CAPP), tool design (CAD) and materials requirements planning (MRP) are completed for manufacture [176].

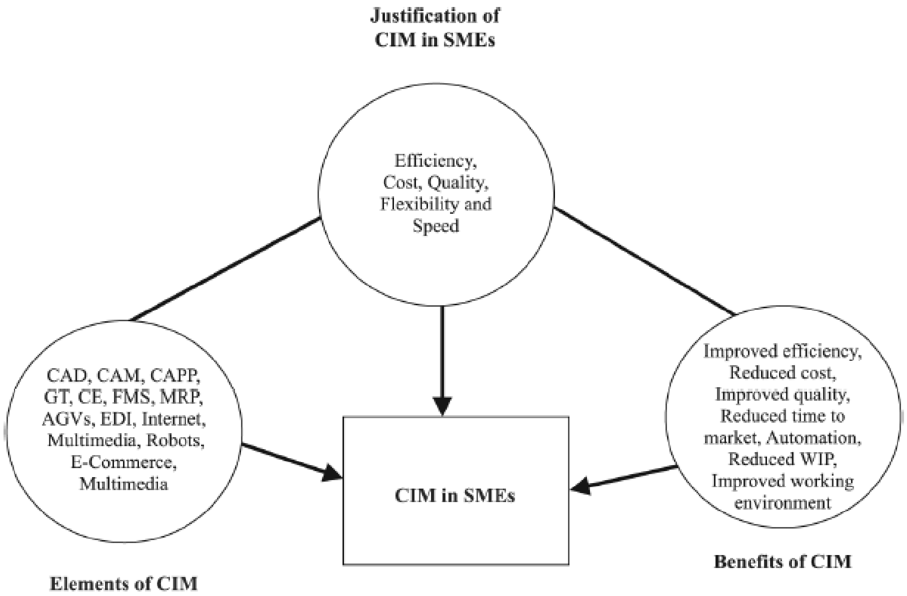

Figure 2.5 Implementation Framework for CIM in SMEs [173]

Another definition by Kalpakjian is cited by reference [177] "computerised integration of all aspects of design, planning, manufacturing, distribution, and management". This definition shows the concern of his research i.e. the integration between design (CAD/CAE), planning (CAPP) and manufacturing (CAM) (PD software tools). According to Marri *et al* [173] CAD/CAM/CAPP/CAE [178] is critical for design and development orientated SMEs as successful implementation of these should "positively influence the manufacturing parameters and ultimately establish the desired competitive priorities of SMEs in order to safeguard their position in the market place" (A.8.9) [173]. From Figure 2.5, the SME benefits gained from integrating these technologies/elements are in line with the SMEC identified in Table 2.1 Section 2.2 i.e. flexibility (SMEC 2c,3c), speed (SMEC 1c, 4c), reduced cost (SMEC 4a,4b,4c), improved quality due to increased automation (SMEC 4b) and reduced human error (A.8.10). Investing in all the elements of CIM is expensive and SMEs must take a long term strategic view (evaluate CIM capabilities to meet goals and objectives, SWOT and manufacturing performance objectives [173, 174, 178]) and understand enough of the CIM technology to gain an advantage without investing unnecessary time and money (A.8.11) [173]. Reference [173] carried out an empirical analysis of the implementation of CIM in SMEs with a work force of 10 to 500 employees. References [176, 178] also conducted investigations into CIM in SMEs (mainly the same researchers), however, reference

[173] is the most recent, this research found: SMEs should identify the most suitable technologies for their business (which were typically MRP, CAD/CAM and the internet); concurrent engineering (CE) and CAPP were not seen as important – however this was considered to be based on the narrow view of CIM advantages taken by SMEs, flexibility was considered the main advantage from CIM implementation (affecting cost, price, quality and speed) and development and training for employees must be considered (A.8.12) [173]. As with all initiatives in SMEs the support of management is also critical [176, 178]. Reference [178] also states the importance of CIM cost and suggests that automated storage and retrieval systems, automated guided vehicle systems (AGVs) and MRPII packages are not suitable for SMEs. Therefore, this section examines the following supporting development technology tools: computer-aided design, computer aided manufacturing, computer-aided process planning and computer-aided engineering. The methods used to integrate these areas are also discussed. In addition, this section also deals with rapid prototyping, rapid tooling, rapid manufacturing and collaborative technology tools.

2.8.1 Computer-Aided Design (CAD)

From reference [179] the definition of CAD is: "The technology concerned with the use of a computer system to assist in the creation, modification, analysis, and optimisation of a design"

The basic role of CAD is to define the geometry of a product design as it is essential to all of the later activities in the product development cycle (A.22.1). Although solid modelling has been around for over thirty years a 2004 [180] study found that only 25% of the USA engineering community are using 3D CAD. This low take up is meant to be due to the perception that it is costly, difficult to use and implement. However, due to low cost computers with higher processing speeds and improvements on the ease of use of the software, current 3D CAD systems are cheaper and easier to use. This study also found that of over 1,000 3D CAD users 95% had an increase in productivity, while 69% had faster time to market, and 90% reported one or more of the following (A.8.13):

- Reduced number of engineering change orders (ECOs).
- Reduced time spent on ECOs.

- Reduced scrap from design errors.
- Reduced scrap from CAM integration.

It should be noted that these results were consistent across several industries [180]. At the very basic CAD level exists 2D-only CAD [181]. In most product development situations it would make sense to use a 3D system as they also produce 2D drawings, however, 2D is used (A.22.2) [182]. The three types of 3D CAD systems are wireframe, surfaces and solids.

Feature-based modelling (See 2.8.2.3) allows users to use a more familiar language (engineering) when constructing geometry. Features have the following characteristics:

- Once applied, the topology must continue to be recognized as a feature (hole, slot, etc.) and allow its defining parameters to be changed (diameter, depth, draft, etc.).
- Features incorporate behavioural rules and continue to observe these rules when applied (a hole stays a hole).
- CAE/CAM/CAPP processes have access to the feature definition of a part to increase process efficiency by not requiring users to specify information already captured (See Feature Recognition Section 2.8.2.4) (A.8.14, A.22.3) [181, 183].

2.8.1.3 CAD Assembly Modelling

50% of a product's manufacturing cost is related to the assembly process (A.8.15) [184]. When the design is completed, the assembly modeller can be queried to provide information on A.22.4. In addition to assembly modelling, design for assembly (DFA), which is discussed in Section 2.7 , and CAE analysis (discussed below) can also be used to consider the assembly of products [184].

2.8.2 CAM/CAPP/NC

After part design the next stage is manufacturing. The tools in the manufacturing process are called Computer-Aided Manufacturing (CAM) and the CAD data can be used with these tools for: NC part programming, Computer-Aided Process Planning (CAPP), Tool and fixture design and Inspection and Robotics Programming (planning) [179, 185]. As discussed in Section 2.8 these are some of the element links in CIM i.e. CAD/CAM/CAPP via Numerical Control (NC). NC Part Programming is described in Section 2.8.2.1 and CAD/CAM integration (Section 2.8.2.3) and Feature Recognition describe an automated CAD/CAM/CAPP process i.e. a fully CIM based process.

2.8.2.1 NC Programming

The two ways of numerical control (NC) programming are manual and computer assisted. NC is not limited to material removal applications, but also extends into the programming of controllers used in a variety of applications e.g. fabrication applications (EDM, Flame, waterjet, laser), Sheet metal development, automated tube/pipe bending, rapid prototyping and robots used in manufacture [179, 185]. NC programming can be conducted using STEP-NC, which is a digital product data model.

2.8.2.1.1 Standard for the Exchange of Product model data (STEP)

According to reference [186], STEP is aimed at eliminating the issues of data exchange, incompatible formatting, lack of interoperability and post-processing (A.8.16). The standard specifies a digital product data model such that all the information about a product, not just geometry, can be exchanged between computer systems [186-188].

2.8.2.1.2 STEP-NC

Figure 2.6 shows the improving methods of STEP CAD/CAM/CNC.

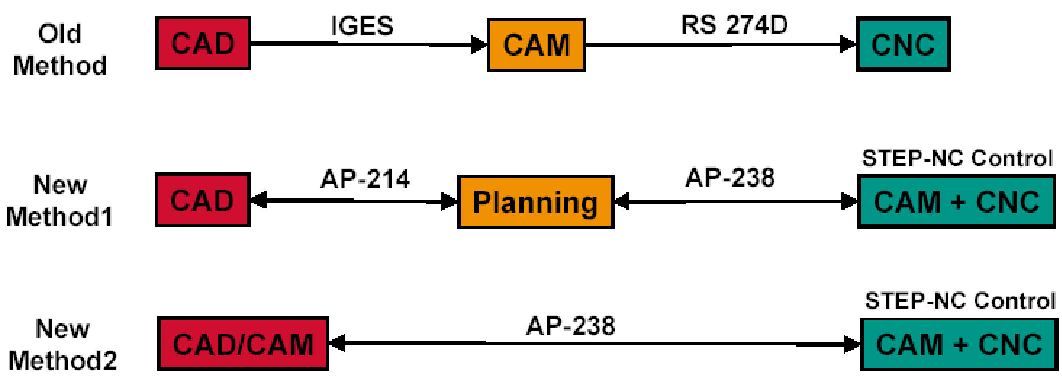

Figure 2.6 The Improving methods of STEP CAD/CAM integration [190]

- With ‘Old Method’ the CAD system sent a description of the part as a drawing in an IGES file. RS274D (or ISO 6983) tells the CNC systems how to make a part using a list of instructions called G-codes and M-codes. Each code tells the CNC machine where to move the cutting tool next (A.22.5).
- With ‘New Method 1’ a AP214 file which contains a 3D model is sent to a process planner who reads the file into a process planning system which outputs an AP238 file containing all the information required to make the part (A.22.6).
- With ‘New Method 2’ an integrated CAD/CAM system creates instructions for making a part on a machine tool (using feature recognition) and sends those instructions (via DNC, LAN, WAN or the Internet) to a CNC milling machine containing an embedded CAM system (A.22.7).

STEP-NC breaks down every machining operation into the steps required to perform the operation, these steps are called “working steps”. They can be built up into a library of specific operations which a CNC machine understands such that a file for a CAD system sent via the web from Navan to Cork can be machined directly [188-190].

2.8.2.2 Computer-Aided Process Planning (CAPP)

The desire to computerise process planning has led to computer-aided process planning or CAPP. The two main areas of CAPP are:

- Variant CAPP or Variant Process Planning (VPP) – VPP uses existing process plans which are edited to the new part requirements and are based on group technology (GT) (A.22.8) [191, 192].
- Generative CAPP or Generative Process Planning (GPP) – In the GPP approach a process plan is generated automatically from engineering specifications of the finished part i.e. from the ground up (A.22.9) [179, 191-193].

2.8.2.3 CAD/CAM Integration

Computerised process planning is essential for the integration of CAD/CAM as it is the link between design and manufacturing. Stronger integration of CAD and CAM is needed to increase productivity and ensure survival of SMEs in increasingly competitive global markets (A.8.17). Computerised process planning ability to automate production is achieved by adding numerical control (NC) capability to conventional machine tools. Fully automated CAD/CAM integration can be achieved by reading specifications directly from a CAD database. For this to happen, the CAPP system must have the ability to recognise the equipment to be used, the required tools and the operating sequence. If the CAD model was modelled using a feature-based approach (See Section 2.8.1 above) then machining features of a part, such as a hole, slot, or pocket would be possible. However, the design features used in the feature-based modelling system may still have to be converted to the proper machining features. Some design features have one-to-one correspondence with machining features, but many require a complicated process. Also, CAD feature-based information does not provide all the information necessary for process planning e.g. tolerance and materials information must be provided manually (A.8.18). Therefore, a fully automatic CAPP system has not been developed yet, although advancements are been made in feature recognition, See 2.8.2.4 below [179, 192]. Planning of Activities Resources and Technology (PART) is a GPP CAPP system (A.22.9) [194]. PART is another (See Section 2.8.2.1.2) example of CAD/CAPP/CAM integration [195].

2.8.2.4 Feature Recognition

The automation of the interpretation of design data is the goal of feature recognition. It is about recognising the design geometry that represents holes, slots, pockets, bosses, fillets, chamfers and other machineable design features (See Feature Based Modelling Section 2.8.1). The automation of this process aides the CNC programmer and allows their time to be spent on more productive activities such as the more complicated programming issues, this in turn speeds up the overall production process and reduces the chance of errors. Machineable features that are recognised automatically can be automatically linked to corresponding machining routines stored in knowledge-based databases. When linked to the automated tool path generation available in most CAM packages the result is a fully automated CAM process (A.22.10).

Feature recognition can be used in conjunction with design for manufacture (DFM) guidelines, See Section 2.7.3.5.1 for more information on DFM [196].

2.8.3 Computer Aided Engineering (CAE)

Before a CAD model goes to CAM it can be analysed to predict product behaviour. The product behaviour is simulated in order to optimise the final product performance (A.8.19). Characteristics related to mechanical, thermal, electrical, fatigue stresses, as well as fluid flow, heat transfer, and noise/vibration/harshness are all analysed using different software tools. Some of these tools include the following: Finite element analysis (FEA), Computational fluid dynamics (CFD), Thermal analysis, Kinematics and dynamics analysis, Electromagnetic analysis, Structural analysis, Mouldflow analysis, Stamping analysis, Acoustic analysis, Crash testing, Product simulation, Virtual prototyping (VP), Durability analysis, Manufacturing simulation, Factory simulation, Electronic design simulation (logic simulation and circuit simulation), and Design visualization and animation [197]. In particular, FEA, CFD, Kinematic and Dynamic Analysis and Visualisation will be discussed below. Before looking at these CAE simulators, the place of CAE in the PDP will be examined.

2.8.3.1 Advantages of CAE and its place in the PD Cycle

CAE was carried out at the back end of PD because CAE software tools, expert users, and the computer hardware to run them were all costly [198]. As a result of this, development cost increases rapidly due to the build and break cycle of physical prototype development while product knowledge is slow to gather [199]. As is now the case with most computer aided software, faster and cheaper computers have meant that these CAE tools are more widely available. The software interface for running these tools is also simpler and a good knowledge of engineering is in the main sufficient to run an analysis. This means that more CAE analysis is being carried out at the front end [198]. Analysis can be carried out early in the development stage resulting in an earlier optimised design and ultimately a smoother prototype to production transition (A.22.11). Now product knowledge increases faster than cost as the test/redesign is carried out on the computer. This simulation allows more testing options and reduces development time on the overall product (A.8.20). However, with all CAE tools the output is only as good as the accuracy of the input and the ability of the engineer i.e. rubbish in = rubbish out [199].

2.8.3.2 Finite Element Analysis (FEA)

FEA is the most common CAE package (A.8.21) [197, 198]. It predicts how a component/assembly reacts to factors such as forces (resulting in stress, strain and deformation results), heat, magnetic field distribution and vibration (A.22.12) [197, 199, 200].

2.8.3.3 Computational Fluid Dynamics (CFD)

CFD is the numerical analysis of fluid flow, heat and mass transfer, and chemical reactions (explosions) in order to predict their behaviour (A.22.13) [201-203].

2.8.3.4 Kinematic and Dynamic Analysis

Using CAD models (either the output of a CAD package into a PDM/PLC system or a directly linked package) kinematic and dynamic analysis can be performed. Kinematic and dynamic analysis are concerned with the movement of mechanical assemblies and mechanisms. Kinematics is the study of motion without concern to the forces that cause it, while dynamics is the study of motion resulting from forces i.e. kinematics studies form while dynamics studies function (see A.22.14 and A.22.15) [204, 205].

According to the 2007 edition of Manufacturers Monthly [206], new CAD systems now have build in FEA (stress and impact loading analysis) and PDM systems which aid engineering change orders and engineering change notices (ECOs and ECNs).

2.8.4 Collaborative Technology Tools

As discussed in Section 2.6 product development work in SMEs should be carried out in cross-functional teams (A.7.12). For SMEs with an export business, these teams can be dispersed across company and geographic boundaries and across time zones and cultures [207]. In addition, SMEs need to collaborate with external customers, partners and/or universities for new technology (A.1.5). Collaboration is the basis for bringing these teams/external people and their knowledge, experience and skills together, and is therefore critical for an effective PDP (A.8.22). The use of a well defined process (Section 2.12), also aid's collaboration. As discussed in Section 2.6.5.1 collocation is another key factor. Finally, the use of collaboration technology is of great importance (A.8.22). CAD Collaboration, web-hosted meetings, and the web-enabling of the product development process will be discussed next [208].

2.8.4.1 CAD Collaboration

According to reference [209], 66% of US manufacturing companies outsource some part of their product design work. This statistic shows the importance of collaboration [209]. Generally, whether an online solution, third party solution or an integrated solution, all CAD design collaboration tools have the following common abilities: web-based collaborative workspaces, visualisation tools (2D and 3D), and Mark-up of models. Reference [210, 211] show the advantages and barriers to collaboration. The collaboration design tool a company picks is dependent on the companies' specific requirements [209].

2.8.4.2 Web-Hosted Meetings

The best way to discuss this area is to look briefly at the market leaders and their capabilities i.e. NetMeeting and WebEx (67% of the web conferencing market) [212].

2.8.4.2.1 NetMeeting

For Windows XP users NetMeeting (or Microsoft Office Live Meeting) is already installed and is also free to download for other Microsoft operating systems. For Windows Vista NetMeeting is now called Windows Meeting Space (A.22.16) [213-215].

2.8.4.2.2 WebEx

WebEx is a communications infrastructure for real-time business meetings conducted across the web. The services enable the user to share presentations, documents, applications, voice, and video on Windows, Macintosh, or Solaris systems. These services are used across the SME in such functions as sales, support, training, marketing, and engineering (A.22.17) [216].

2.8.4.3 Web-Enabled Product Development

Unlike the areas of project management, product data management/collaborative product commerce, and requirements management this is a relatively new area of PD technology. It is the web-enabling of the product development process (or process automation/management), and in addition to collaboration has many other advantages [217, 218]. As described in the above sections the software development of the technical aspect of PD (CAD,CAM etc.) is ongoing for decades. The business side is a new application for IT – See A.22.18, A.8.23 and A.8.24 [218]. The evolution of an organisation's PDP is unstructured (elementary), structured (gated/phased - effective), web-enabled (advanced) and knowledge driven (enhanced). The web-enabled process could be implemented in steps to cater for the resistance to change (See Section 2.10). Whichever route a company takes the ultimate goal is a web-enabled process that leads to a 'knowledge-driven' PDP (See Sections 2.4.1.6 and 2.12.5) (A.8.25) i.e. focused stimuli and processes enhance innovations, new ideas and project/process learning become reusable organisational assets [207, 219]. There are a number of companies selling web-enabled PD tools [218, 220, 221]. The advantages of having a web enabled PD process are numerous [207, 217, 219].

2.8.5 Rapid Prototyping (RP)

Rapid Prototyping is a layer manufacturing additive process which allows parts of completely arbitrary shape from 3D CAD systems, and data from MRI Scans and 3D digitising systems, to be fabricated, offering designers a new freedom to shape parts optimally without the constraints imposed by forming, machining, or joining. RP is also called desktop manufacturing, automated fabrication, tool-less manufacturing, solid-object modelling and free-form fabrication [222, 223]. RP is used across a wide range of industries i.e. consumer, industrial, medical and military, for example, and for the A.22.20 purposes (listed in priority from first to last) [222]. From [222] the main types of RP technology used are A.8.27, A.22.19. From reference [222], 3D printers are the fastest growing RP machine type installed and are used for the early evaluation of product designs. According to Miel [224], companies can buy a 3D system from $20,000 to $40,000 making these systems affordable for SMEs (A.8.26). The ultimate goal of a 3D Printer is for its operation to be as simple as a 2D Inkjet or laser printer. The 3D printer definition states that they are: affordable, easily operated, simple to maintain, small in size and suitable for the office. They will be networked devices which can be used by anyone to translate 3D CAD into a RP model [222, 225].

2.8.6 Rapid Tooling (RT)

The term Rapid Tooling (RT) is typically used to describe a process which either uses a Rapid Prototyping model as a pattern to create a mould quickly (Indirect RT Method, which is the most popular) or uses the Rapid Prototyping process directly to fabricate a tool for a limited volume of prototypes (Direct RT) (A.8.28, A.22.21, A.22.22). Reference [226] also lists the advantages of RT.

2.8.7 Rapid Manufacturing (RM)

It is believed that RM, which is growing rapidly, will eventually be bigger than RP and RT (A.8.29). The definition of RM, taken from Wohlers 2003 Report is that "RM is the direct production of finished goods from a RP device". The technique uses an additive process to deliver finished goods directly from digital data, which eliminates all tooling requirements. Reference [224] states that RM or digital manufacturing is the next major growth area for 3D printers (Section 2.8.5). However, an RM system would produce a finished part with a better surface finish, repeatability and material properties than RP (A.22.23)[222].

2.8.8 Reverse Engineering

Reverse Engineering is defined by reference [227] as "The process of duplicating an existing component, subassembly, or product, without the aid of drawings, documentation, or a computer model". Below is a list of reasons for reverse engineering a part or product (A.8.30):

- The original manufacturer of a product has either ended the product line, has gone out of business, is unwilling to provide parts or is overcharging.
- The original design was not fully documented or was lost.
- The original CAD model does not support modifications or current manufacturing methods.
- Redesign of the product for improvement e.g. excessive wear indicating where a product should be improved.
- To improve the good features of a product based on observations from long-term usage.
- To analyse the good and bad, or discover new ways to improve a competitor's product performance and features.

- Product improvement from the point of view of materials or manufacturing processes.
- To compress product development time [227].

The 3D data acquisition technologies used in reverse engineering are broken into two categories, contact and non-contact. Contact uses coordinate measuring machines (CMM) while non-contact uses optical (white light), laser (red light) and medical imagery (X-ray and magnetic resonance imaging (MRI). Anyone involved in reverse engineering must be familiar with the patent and copyright laws (A.8.31, A.22.24)) [228, 229].

2.8.9 Conclusion

The CIM benefits for SMEs were shown in Figure 2.5. This section dealt with the supporting development technology tools used in new product development. In particular, computer-aided design, computer aided manufacturing, computer-aided process planning, computer-aided engineering, rapid prototyping, rapid tooling, rapid manufacturing and collaborative technology tools. All of these can be used to achieve these benefits.

CAD increases productivity, results in faster TTM, reduces design errors (and changes) and scrap from CAM. NC programming or STEP-NC could be used for CAD/CAPP/CAM integration. Fully automated CAD/CAPP/CAM was discussed using Step-NC 'New Method 2' (Figure 2.6) and PART (GPP CAPP system). Both these require Feature Based Modelling and Feature Recognition which is still in development for fully automated CIM. However, SMEs can develop CAD/CAM using Step-NC AP214 (New Method 1). CAE (FEA/CFD/Kinematic and Dynamic Analysis) should be used at the concept stage as knowledge/learning increases faster than cost and there is an overall reduction in development time. It can also reduce the number of prototypes although a balance of both can be used.

CAD collaboration, WebEx (have solutions for SMEs) and NetMeeting (available free) can be used to improve communication internally and externally during the development process. The advantages for using collaboration are given in Section 2.8.4.1.1. SMEs could also consider the benefits of using a web-enabled PDP as outlined in Section 2.8.4.3. Web-enabled PD and Collaboration both reduce TTM, reduce design and manufacturing errors and improve communication, although there are barriers to implementation.

Rapid prototyping has many purposes and aids learning and experimentation e.g. can be used as a functional model or for fit/assembly tests. As can the use of CAD and CAE. The use of CAD/CAPP/CAE/RP can also reduce the number of resources required for a PD project.

One of the main purposes of reverse engineering is to analyse competitor's product performance and features which can be used during the market analysis stage. The Technology findings are in Appendix A.8 and Appendix A.22. The next section examines Intellectual Property.

2.9 Intellectual Property

According to the Irish Patent Office (IPO) Intellectual Property (IP) can be defined as "the result of a person's mental effort" which is called an intellectual property right (IPR) [230]. Intellectual capital is deep-rooted in a company and in order to gain from it a company must identify it [230] (Reference [230] and [231] have a checklist to aid this process). IPRs are a means of protecting IP and fall under different types i.e. Industrial Property (patents) and Others (copyright and related rights).

2.9.1.1 Patents

In order to acquire a patent the product, process or use must be:

- Patentable, it must follow European Patent Convention laws. These restrict patents for 'matter' such as artistic creations or methods of applying mental acts.
- Novel, it does not already exist and was not publicly disseminated.
- An Inventive Step, the solution must not be obvious to a person with average knowledge of the specific technical field.
- Practical, it must have an industrial application and not be just theoretical.
- Agreeable to public order or morality [230].

2.9.2 Methods of IPP and SME IPP issues

The methods of capturing and protecting the competitive advantage of processes and products follow [232] (A.27.1): Patents to prevent copying, Patents to secure royalty income, Secrecy, Lead time i.e. Fast Time To Market, Moving quickly down the learning curve and Sales or service efforts.

Levin *et al.* [232] received 650 responses from a cross section of industry to their survey on IP. The respondents were asked about the effectiveness of these six means of protection for new products and processes. Hanel [233] carried out an extensive analysis of IPR business management practices literature. Levin *et al.* and Hanel found A.13.1 to A.13.7 (A.27.2). Industries that produce complex products (hard to copy e.g. aerospace) with high barriers to entry (tacit knowledge/expertise or large investment) can use the other methods (not patents) of protection mentioned above. Hanel also references a University of College Dublin (UCD) study of 600 EU SMEs (they obtained an EU or USA patent between 1994 and 1997) and found A.27.3. Jensen and Webster [234] stated that there is a lack of research on IP usage in SMEs. Therefore, they investigated the relationship between company size (20 to 200 employees) and the intensity of IP usage in Australia (applications per employment). The ratio of IP usage to potential innovation was calculated based on the IP applications filed between 1989 and 2001 using the applicant's name i.e. the names were related to their company and hence the company size (size was determined based on proprietary enterprise databases). Jensen and Webster found A.13.6, A.13.8 to A.13.10. The next section examines SME policy and IP strategy.

2.9.3 Company Policy/Budget

According to Egbert [235] all companies should take basic steps to protect their work and lessen the potential for loss of profit and market value (A.13.11). This protection should be part of the day to day activity of the company and explained in company policy and company budget (A.13.12) [231, 235]. From the perspective of company policy (A.27.4):

- Employees should be aware of the benefits of protection e.g. greater profits, prestige.

- Employees should sign agreements such that the rights of their inventions remain with the company. This can be supported with incentives such as bonuses [230, 231, 235].
- Employees could be restricted from moving to competitors (non-competition contracts) for a set time and from taking confidential documents.
- Employees can be trained on company specific methods of IPP.
- Employee notebooks and timesheets should be used – these establish dates of conception of a patentable invention and project diligence. Both are required for establishing priority of invention while pursuing a patent.
- Companies should provide routine backup and archiving of data (can also provide dating of work for priority of invention). Hard copies can also be kept in case of softcopy loss.
- Routine generation of the word 'confidential' should be implemented on documents. Thus providing security and secrecy.
- Confidential agreements should be signed with outsiders.
- Computer passwords, security cards, swipe badges and limiting access to facilities can be used [231, 235].
- Employees should use an invention disclosure form – gives details on how the invention was made and its potential uses and applications [230].

An SME should gauge the level to which they take this protection against the cost of security [235]. The IPO [230] discuss means of limiting the expense factor for SMEs (A.27.5). In addition, awareness within the organisation will improve information flow and knowledge sharing between employees and the creation of an IP strategy (discussed below) should be considered (A.13.13). With these in place an organisation's IP will generate revenue by capturing the return on the investment and protect it from others [230].

2.9.4 IP Strategy

Innovation could be linked to IP and IP to innovation via a company's business strategy. If company finances can support an IP strategy it can aid a company in creating and retaining its inventions IP along with tracking its competition's technology. A company's IP strategy will vary depending on many factors including it goals, product and business strategy. The following is a list of best practices for IP strategy (A.27.6):

- Create awareness of the importance of IP strategy.
- Ensure new technology is kept confidential until its IP potential is understood.
- Ensure a link between the business strategy and the IP strategy.
- Add value to product and services using IP.
- Capture all current and potential IP.
- Keep the IP portfolios up to date i.e. protect current technology and stop old technology protection.
- Use market intelligence to ensure no infringement on the company's technology and defend if necessary.
- Use IP information from national patent offices and private suppliers to track innovation trends and the competition's marketing strategies and technology (Section 2.7.3.4.4 describes TRIZ patterns of evolution which can be used to determine trends and break patents).

As mentioned above, there should be an IP portfolio (A.27.7). This is created by keeping records of all inventions. A technology watch will ensure that the organisation is aware of development in its field and competitive market. Any filing should be made as soon as possible to ensure protection; this is done by tracking the records. The portfolio should be reviewed regularly to ensure it is up to date [230]. The sole purpose of IP protection, IP strategies and IP portfolios is to create value for the SME. This is done by linking these to the overall PDP via the Innovation strategy or New Product Strategy and developing commercially successful products (A.13.14).

2.9.5 Conclusion

The decision to use patent protection is not an easy one for SMEs. The main factors to consider are cost and imitability. The other methods of protection must be considered as well. If financing is an issue (SMEC 4a) the combined use of secrecy, lead-time and moving quickly down the learning curve can be used for protection. Using these methods also avoids the possibility of costly litigation. In order to use these methods an SME would require a company policy as outlined in Section 2.9.3, the level of which is based on a ratio of cost versus potential security required (the IPO guidelines can be used to aid this). Depending on company finances an IP Strategy can be developed. A combination of Company policy and IP strategy could be created based on the ratio of cost versus potential security required. The Intellectual Property findings are in Appendix A.13 and Appendix A.27. The next section examines Change Management.

2.10 Change Management

Section 2.3 discussed the innovation strategy and how innovation is a combination of technical and marketing skills as described in the Section 2.3.1 (Fuzzy Front End). Senge states A.10.1 [55]. In other words, an Owner/Manager can not just command and control employees during major changes. Reference [236, 237] also give other reasons why change is required (A.10.4). A.10.4 changes bring company innovativeness (A.3.2) to the SME which, according to A.3.3, must travel through the organisation (A.10.5). Therefore, change management must happen from the bottom up rather than the top down where the O/M is seen in the role of a facilitator (A.9.3). However, the O/M must be a visionary and committed to the change (A.9.4). The conclusion of section 2.3.1.2 was that in order to become an innovative organisation an SME must become a learning organisation where every employee is engaged in learning (A.2.2), this is also aided by using change management as employees are involved in the entire innovative change. Section 2.10.2 deals with a method used to achieve this called 'Whole-Scale Change' [238]. Firstly, the issues and solutions to change management are discussed in more detail.

2.10.1 Why use a Change Management Process?

There are a number of common issues with change (A.24.1):

- Lack of communication [236-240].
- Lack of 'buy in' to change (resistance) [236, 238-240].
- Fear of change – People below management see change as threatening or negative and can fear it (fear of the unknown, of loosing status, of being shown as incompetent) [236, 239].
- Lack of commitment from all levels [236, 239].
- Lack of retraining [237].

According to references [237, 238, 240] these issues come from Top-Down Change or Command and Control methods of change i.e. focused but limited tasks for each worker, thinking/changes done by top management (A.10.1). They lead to long implementation timeframes as change can be seen as "the flavour of the month" or the latest "fad" [238]. Lack of commitment is a result of command and control or assigning the change process to a cross functional team of employees who study the current process (say a product development process) and make recommendations to improve. These recommendations then have to be sold/pushed to the management and the employees they affect. Employees must be involved in the change process [237] and according to Metcalfe [239] pre-emptive communication is the best way to do this i.e. employees are engaged as early as possible in the change process (A.10.6). Metcalfe [239] mentions issues with getting early involvement: lower priority (people are two busy), waiting game (wait until everything is clear), too much involvement (if too many are involved it will get confusing) and caution (someone will try to stop it). However, by involving the key stakeholders early:

- There is access to information that otherwise would not be known.
- Critical information not known by management is discovered – As employees are the closest to the problem or process undergoing the change.
- Problems are seen earlier.
- Trust is built/increased (even if they are against the change).
- Risk analysis is aided.
- There is no delay in accessing any information required.
- A more innovative change can be found by involving the whole group (synergy) [236, 238, 239].

According to references [236, 239] it may take more time to plan and conduct the change initially but overall it will save time. When everyone is involved in the decision making process the implementation happens faster and with less resistance i.e. no need to tell, resell and beat (the change into everyone). What a company gets is ownership, commitment, alignment and speed [238]. However, in a work culture where employees do not have decision making skills the owner/manager must lead the change until the stage employees can contribute (A.10.7) [237]. References [236-238, 240] all discuss processes for change management which achieve the positive aspects mentioned above and deal with the change process issues. Reference [237] carried out a literature review and case studies of change and developed a framework for change. However, one specific method will be mentioned below as it is the most comprehensive and specifically examines a process (e.g. PDP) change i.e. Whole-Scale Change [238].

2.10.2 Whole -Scale Change

Whole-Scale Change or Large Group Interventions, Whole-System Change, Large Scale Organisational Change, The Conference Model, Future Search, and Simu-Real are all change processes (A.24.2). All these methods involve a critical mass of people affected by change (internally; employees and management, and externally; suppliers and customers) and participating in (A.24.3):

- Comprehending the need for change.
- Analyzing the current situation and understanding what needs to change.
- Ideation about how to change existing processes.
- Implementing and supporting change and making it work.

The issues to be addressed must affect people across the entire organisation for these methods to work. The name Whole-Scale comes from the word "Whole" meaning the whole system and "Scale" because it can be used on a large or small scale [238]. It is a "process that allows the simultaneous creation and implementation of new organisations with whole system involvement" [238]. The Whole-Scale method can be applied to the types of change mentioned A.10.4.

2.10.3 Conclusion

The size of the SME, the decision making ability of the staff and the scope of change required determine the approach to the change process. For SMEs with poor employee decision making the owner/manager must lead the change process until such a time as staff can contribute. For SMEs with good employee decision making the command and control approach of the owner/manager will no longer work. In order to overcome resistance to change (and the other issues mentioned in 2.10.1) early communication and engaging all levels of employees is critical. One method to achieve this is Whole-Scale Change. The Change Management findings are in Appendix A.10 and Appendix A.24. The next section examines Marketing and Branding.

2.11 Marketing (Backend)

According to Simpson *et al.* [241] the lack of study of marketing in SMEs has been an issue for over twenty years. Siu and Kirby [242] stated in their 1998 study of SME marketing that insufficient knowledge about marketing in small business remains and an appropriate small business marketing theory is required – this was reiterated in the 2006 literature review of Simpson *et al.* (A.12.2) [241]. According to Cooper (as cited by [243]), the marketing function, if executed well is a key critical success factor in new product development (A.12.3).

The development of differentiated superior products was discussed in Section 2.5 [243]. However, marketing or marketing orientation (See section 2.3.1.2) within a company is very complex and other orientations can be equally successful in SMEs i.e. product orientation, sales orientation, production orientation and engineering orientation [244], (See 2.5.2.1.3.1 and 2.5.2.1.3.2 on Type A Differentiated Strategy). The marketing function in relation to product development can be split into the front and back end. The front end (Idea Generation and Screen, Preliminary Investigation, and Detailed Investigation) deals with marketing analysis i.e. both defining the target market and the competitive analysis (SWOT). This has already been covered in Section 2.5, specifically by the Strategic Plan (which includes SWOT). The front end also deals with developing a marketing strategy. This is where the issues identified in the market analysis are dealt with and this was covered by the New Product Strategy (NPS) again in Section 2.5. Another method of looking at these areas was briefly covered in Technology Development Planning (Roadmapping), also in Section 2.5 [70, 245-247]. The overall result of the front end marketing stage is a product that is developed based on the customer's requirements and the target market. This is referred to as marketing pull as distinct from technology push, which is where a company develops technology in isolation from the customer and then tries to promote it. Unless, in innovation terms, the product is creating a new market, NPD is better done using marketing pull but with the aid of T&M for radical innovation, (Section 2.3.2.7 explained this in more detail). The back end (Development, Testing, and Product Launch) deals with the marketing mix or as it is also known, the 4Ps – Product, Price, Promotion and Placement (A.12.4) [70].

According to Siu and Kirby [242] there are four theoretical approaches to marketing. The 'Stages/Growth' model considers the stage of development of the business and thus is a starting point for further analysis. However, it requires the owner/manager to bring the business through changes and assumes that the manager has the ability to make these changes (O/M could have a technical background and not a marketing one). This model does not consider the business from the external perspective. The 'Management Style' approach accounts for SME owner/manager characteristics (SMEC 5c,5f,5g,5h,5i) but does not explain how management style and culture of SMEs change the marketing planning process. The 'Management Function' approach confirms the importance of backend marketing as a function and concept in SME growth and survival (A.12.5). Marketing is seen as a functional approach and not seen as a strategic process encompassing front-end and backend activity. Also, this approach ignores SME specific characteristics. The 'Contingency' approach considers the fact that strategy-performance relationships vary across different environments and company sizes (A.12.6).

Although marketing processes (such as the 4Ps) are universal and transferable between SMEs the implementation processes are different (A.12.7). Reference [242] suggests SME research based around combining process models and the contingency approach. Therefore, the main marketing issue for SMEs is the combination of front end and back end marketing with SME characteristics (SMEC Table 2.0). Also, according to Simpson *et al.* [241], the SME business environment is dynamic and can therefore lend itself to a variety of successful approaches and strategies (A.12.8). An example of a contingency approach is provided by Simpson and Taylor and Simpson *et al* [241, 244] whereas a process model was proposed by Brooksbank [248]. Both of these will be discussed next.

2.11.1 Role and Relevance Model

The Role and Relevance Model design methodology was based on a literature survey, theoretical development and initial testing on three carefully chosen SMEs (based on the authors' prior knowledge of their marketing capabilities) [244]. This model describes the relationship between the role and relevance of marketing within SMEs. The role of marketing has an internal focus whereas the relevance of marketing has an external marketing focus such that the company can remain competitive in its business environment. SMEs with a major marketing focus carry out the majority of the techniques listed in Section 2.3.2.8 (Table 2.3). In competitive or dynamic businesses, a big marketing effort would be required to maintain market share (A.12.9) [244]. According to Simpson and Taylor [244] the role and relevance model can be used as a diagnostic tool for the current marketing situation and for selecting strategies to achieve future goals (A.12.10), the following are the characteristics of each organisation (A.26.1).

2.11.1.1 Marketing-Led Organisation (MLO)

- Marketing is very important to company success.
- Plays a key role in direction of the SME.
- Competition is strong in the SMEs markets.
- Marketing orientation – follow the principles and practices of marketing.
- Marketing department with a reasonable budget.
- Best practice in dealing with external business environment [244].

2.11.1.2 Marketing Dominated Organisation (MDO)

- Marketing dominates the strategy making process.
- Uses many resources and produces many plans.
- Plans are useless because they do not serve the relevant markets.
- May have one large guaranteed customer (local authority or larger company).
- SME may be trying to supply to a new company but may not have achieved this i.e. trying to become an MLO.
- A fit between SME aspirations, strategy and business environment is required [244].

2.11.1.3 Marketing Weak Organisation (MWO)

- Requires marketing expertise to maintain and grow its current market share.
- Marketing is therefore highly relevant to survive with no time allocated.
- Very poor marketing effort.
- May have a sales orientation with an emphasis on price rather than the other attributes of the product.
- No marketing department and maybe no marketing employee skills.
- The SME knows nothing of marketing, has tried marketing and failed or has no intention to grow (happy with their current business).

- Training can resolve the lack of knowledge [244].

2.11.1.4 Marketing Independent Organisation (MIO)

- Similar to MDO except there has not been a big commitment to marketing.
- SME has a guaranteed business and does not need to carry out marketing to ensure survival.
- Role and relevance are minor as competition is non-existent.
- Heavy reliance on one customer – competition may arise from the domestic or international market [244].

2.11.1.5 Role and Relevance Strategies

Simpson *et al.* [241] carried out full scale testing/assessment of their role and relevance model in their paper on marketing in small and medium sized enterprises. This involved a pilot study (12 usable replies) and a survey of 853 SMEs (43% were micro, 38% were small, 19% were medium) and was based on the original questionnaire (20 SMEs were also interviewed post survey). Of the 853, 18% or 156 replies were received with 17% or 143 usable. They found A.12.11 to A.12.16 [241].

2.11.2 Marketing Planning Process

As described above the marketing mix is part of the back end of the PDP or as defined by Brooksbank [248] the Implementing Phase of marketing. Brooksbank's framework was used to develop a marketing plan for a small technology company (seven employees) and has four phases of the marketing process i.e. analysing, strategising, implementing and controlling. It is suggested that it can be used to dismantle and improve an existing marketing planning system. It is based on three principles without which the framework will not be successful: adopt a marketing orientation to business (See 2.5.2.1.3.2 on differentiated strategy), employ a comprehensive planning approach (to all four phases) and ensure it is dynamic and evolving. As briefly described above, Section 2.5 discussed New Product Strategy, which includes Strategic Planning (including SWOT) and the identification of markets and how to attach them. Section 2.5.2.1.3.1 also suggests a focused new product effort which is aimed at closely related markets (according to reference [248] this is concentrated marketing and is the segmentation mostly used by SMEs). These are the first two stages of this process. This section is concerned with linking the front end with the backend of marketing and therefore the remaining two phases. At the Implementing Phase the positioning strategy or attach plan is translated into a reality by assembling an appropriate 4Ps mix (A.26.2). It is critical that the 4Ps are assembled in a complementary fashion and are internally consistent e.g. a high price with low product quality and a promotional message of value for money would be inconsistent. Branding is part of the product marketing mix consideration (A.12.4). Branding provides a product with a strong identity such that it is difficult to copy or damage by competitors. It is critical in consumer markets. The advantages of branding are viewed from three perspectives (A.26.3) [246].

Also under the implementing phase is the organisation of the marketing effort. This is concerned with fitting marketing into the organisational structure, See Section 2.6 for more detail on this topic specific to PD. In the case of this case study, the SME used a cross-functional team. The last phase is the controlling phase the aim of which is to maintain the efficiency and effectiveness of the marketing effort over time. Brooksbank suggests designing a marketing information system – this facilitates strategic and tactical marketing control.

Control is tactical and strategic. Tactical control is about short-term operational efficiencies at the level of the marketing mix (A.26.4). Strategic control is about long-term strategic objectives e.g. the emergence of a new product requirement which is innovative and different from the current offering. There are three capabilities for a good marketing information system (A.26.5). In addition to these capabilities the SME must be able to compare the feedback reality to the original plan i.e. performance measurement (A.14.1) (See Section 2.13). Although not comprehensive, this framework provides a structure, which can be adapted and built upon by any SME. This therefore closes the loop between the front end and the back end of marketing.

2.11.3 Networking

The above studies examined traditional marketing but do not cover new areas such as e-commerce, e-business, internet marketing and networking. According to reference [241] there is plenty of evidence in literature that SMEs are poor at e-commerce, e-business and internet marketing. However, this is not the case for networking [241] (A.12.17). Reference [249] carried out a longitudinal study of networking in SMEs by interviewing 60 owner/managers from various industries in Northern Ireland. This longitudinal research approach was taken as the majority of previous studies were cross-sectional and resulted in data on size, range and density of networks rather than content of network relationships. The aim of this research was to investigate how SME owner/managers network and how this activity contributes to marketing activity (A.26.6). A.26.7 is an example of networking as instinctive but it is also a competency that can be built upon. External skills are also gained through asking advice of people in the network about whom can carry out a particular task. In general networking was seen as an activity that must bring benefit to the company if it is to be pursued [249].

2.11.4 Conclusion

The main issues with SME marketing lies in the combination of front end and back end marketing with SME characteristics. The initial studies of SME marketing concluded that there were two main approaches i.e. contingency and process. Simpson *et al.* stated that market leading organisations (MLO) perform better and invest more in marketing. They also found some specific characteristics for SME marketing – specifically that SME marketing evolves with the company (stages/growth approach). Brooksbank discussed a process model which could be used to aid this evolution from marketing weak organisation to a marketing lead organisation. This process combines the front end and back end marketing together and also considers SME characteristics. Key to combining the front end and back end is performance measurement which is discussed in the next section. Marketing in SMEs is also carried out through networking and O'Donnell and Cummins [249] found characteristics of this activity from the perspective of the SME and its customers and competitors and in relation to entering new markets. The Marketing and Branding findings are in Appendix A.12 and Appendix A.26. The next section examines Product Development Process sequence.

2.12 Product Development Processes

Section 2.1 to 2.11 discussed PDP elements (Table 2.0 and Figure 2.0) whereas this section gains an understanding of different process structures as per this list of product development processes:

- Sequential Product Development Process
- The Stage-Gate Process
- Evolutionary Prototyping
- Design to Schedule/Budget
- Knowledge Based Development
- Systems Engineering
- Concurrent Engineering

SME PDP usage should allow for A.5.1 and A.5.6 and must consider A.5.10 and A.5.12. It should not be rigid or laden down with paperwork (A.5.2) and the process used should have experimentation, iteration and customer engagement (A.5.3, A.5.8, A.5.14). However, SMEs have a lack of interest in systematic PD (A.5.4) but due to A.5.13 should be trained on a process (A.5.9). An SME PDP also creates data recording between projects (A.5.15) which increases organisational learning and allows for performance measurement.

2.12.1 Sequential Product Development Process

The sequential PDP is known as the 'over the wall' method. As the design reaches each department, the time and money invested grows such that minor enhancements would be ignored and major revisions become very expensive – each phase stops at a functional department 'wall' and is 'thrown' over (A.19.1) [250, 251]. This increases the time to market of the product. There is a detailed Product/Process Engineering 'design-build-test' cycle. The concept of the products and processes are laid out, captured in a working model (which may exist on a computer or in physical form), and then subjected to tests that simulate product use. If the working model fails to deliver the desired performance characteristics, engineers search for design changes that will close the gap and the design-build-test cycle is repeated or looped (A.19.2) [68].

2.12.2 The Stage Gate Process

This is the most widely used process (it has been dominant in USA industry for 30 years) in NPD and is also called the waterfall, phase-gate, or life cycle [252]. According to the Product Development & Management Association (PDMA) [253] best-practices study, 68% of leading U.S. product developers use a form of the stage gate process (A.5.16) [65]. This is a time sequenced staged process divided by management decision gates which brings the product from idea to launch (A.19.3). A.19.4 and A.19.5 provide information on stages and gates. This process structure is good for well understood technologies and projects that are dominated by quality requirements rather than cost or schedule requirements. This is because quality and error avoidance are high priorities. If speed and time to market are more important than extra functionality or total quality then it is not a good process. Also, stage gate process documentation can be difficult and time consuming (A.5.17). Therefore it may not be a suitable process for high technology SMEs. Parallel tasks within stages result in lengthening the NPD due to the stage taking the path of the longest task – this would lengthen NPD for SMEs and remove their advantage of developing products in less time (SMEC 3i) [252, 254].

2.12.3 Evolutionary Prototyping Process

This is based on learning and gaining feedback from actual prototypes of the product (A.19.6). It starts with the initial concept, designing and implementing the initial prototype, redefining until acceptable (iteration) and prototype release. The SME can use this process where the application and requirement specifications are vague as they can be changed during prototype iterations. It works well when development speed is used to gauge project progress and where customer involvement is early in the process (VOC). However, there is no clearly defined end and it is thus difficult to determine project duration (iterations continue until final product agreement is reached) and cost (A.5.18) [255, 256].

2.12.4 Design to Schedule/Budget Process

This process is based on the status of the schedule and/or budget by controlling project time and/or cost risk (A.5.19). A.19.7 gives details on the process where strict budget and schedule limits almost guarantee SME time and cost risks are controlled. However, in this process the risk is technical, so when the time/cost limit is reached there may be still functional problems resulting in the necessity for more design/testing iterations [255, 256].

2.12.5 Knowledge Based Development (KBD)

Knowledge Based Development (KBD) [257] is also known as Lean Product Development (LPD). LPD comes from the same world as lean manufacturing. Lean manufacturing is also referred to as world class manufacturing (WCM) or high performance manufacturing [258]. The main premise of Lean is the elimination of waste, where waste is anything that prevents the value added flow of material from raw material to finished goods [259, 260]. Lean manufacturing is well established in industry at this stage; however lean applied to product development is relatively new. Unlike manufacturing which is a repetitive process, product development is a non-repetitive process. PD information and communication flow is not in one direction (A.5.20). It has to travel back and forth from say rapid prototyping to the product designer, which makes it difficult to find where the waste is occurring [261, 262]. The objectives of Knowledge Based Development are a product design that meets customer requirements for value; can be produced to the necessary quality, volume and target costs; and delivered on time. According to work carried out by the IAPD, reference [263], the leaders in KBD are not surprisingly Toyota, who have spent 100 years developing this process. Toyota's strategy for success is in the continuous improvement of the value stream with an excellent connection to the customer and is achieved through their management philosophy [264]. A LPD (KBD) environment can be looked at as a learning environment; this is because KBD is supported in Toyota by the management philosophy that "management is learning" (A.5.21) – therefore KBD is supported by A.2.1 through to A.2.4, A.2.7 and A.2.8. A definition can be taken from Kennedy, reference [257] (supported by A.2.9):

"Lean product development is an overall environment that produces a stream of products – it is not a process of steps".

Kennedy's work came from a study carried out by the NCMS (National Centre for Manufacturing Sciences in the USA). A consortium was formed comprising of Delphi, Raytheon, Cincinnati Machine, Ortech, Sandia National Labs, and Lear and they identified primary drivers for product development excellence (process, organisation and culture) [257]. Using these drivers a comparison was carried out between western culture and the way in which Toyota carried out its PD. These differences can all be summed up as a structured-based (western) v knowledge-based (Toyota) company paradigm (A.19.8):

- Structured-Based – The basis of the engineering environment is the *structure of the operational activities*: procedures, control, compliance, related training.
- Knowledge-Based – The basis of the engineering environment is the *knowledge of individual workers:* understanding of needs, information availability, responsibility, and team interaction.

The Knowledge Based Development (KBD) system emerged from the NCMS study in the form of four cornerstones. These four cornerstones can be adapted and implemented by a company using a method called Whole-Scale change (See Section 2.10). Figure 2.7 below shows a typical PD process using the four cornerstones and the outcome from a whole-scale change implementation.

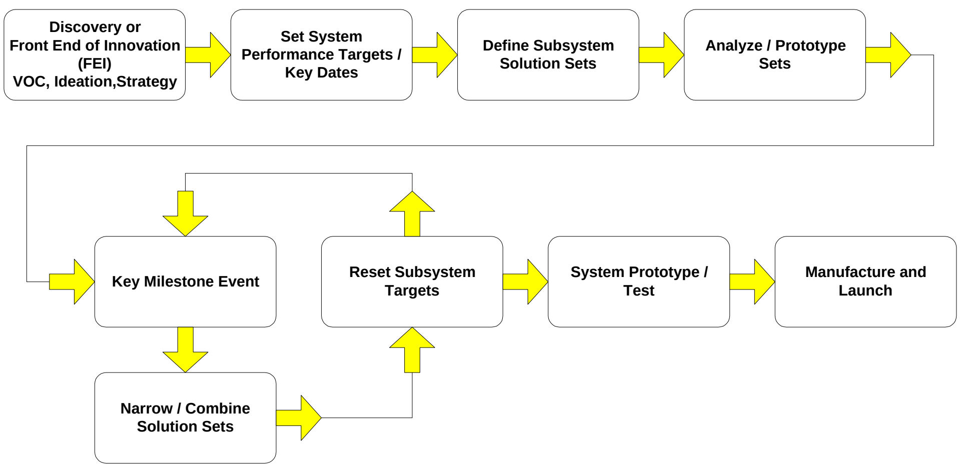

Figure 2.7 Knowledge Based Development PDP [257]

The key points (cornerstones) of this process structure will be discussed below [257].

2.12.5.1 Trade-off curves and Subsystem targets (Performance Targets)

Different alternative subsystems solution sets for different radiator designs are examined in the form of a trade-off e.g. heat rejection capacity versus size (or weight, cost) of a radiator. The data for these curves is gained from prototypes ('live' knowledge for decision making) with the different trade-off design alternatives representing different performance targets for the radiator design (A.19.9). The solutions deemed too risky are placed in a knowledge base to be used by other projects across the company (this is done for every subsystem) (A.19.10). The trade-off curves and analysis data equal the traditional company's quality procedures and process documentation. Engineers are individually responsible and learn from their managers [257].

2.12.5.2 Set-Based CE v Point-Based CE (Narrow and Combine)

These set-based designs are carried out to different targets – Section 2.12.5.1. Figure 2.8 below shows the set-based and point-based view of concurrent engineering.

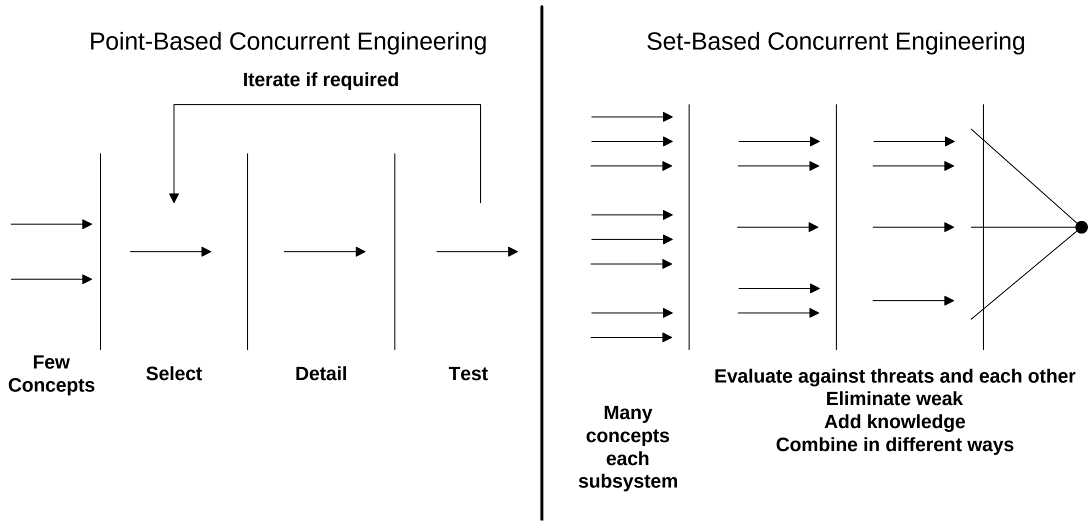

Figure 2.8 Point-Based CE v Set-Based Concurrent Engineering [257]

By using a set-based rather than a point-based design process there is more knowledge available (A.5.22). Set-Based Design is a simple, repetitive development cycle that achieves high innovation in products and manufacturing systems without the risk by using redundancy, robustness, and knowledge capture. Multiple sets of possibilities (concepts) are worked on by all functions at the subsystem level against broad targets, systematically eliminating or combining to tighter targets (See A.18.14 and A.18.15 for another method of doing this) (A.19.11) (Figure 2.8). Redundancy is achieved by the designer always having a sub-system unit that will work. As knowledge of what will work is gained redundancies are dropped. According to Kennedy [257] one of the main advantages of the set-based CE process is the fact that redundancy is cheaper than loop-backs (A.5.23,A.19.12). This can be seen from Figure 2.9 and 2.10 below. Figure 2.9 compares point-based and set-based cost alternatives over time. The point-based cost rises over time as the impact of any changes in the latter phases of the design take effect. However, the set-based cost reduces over time. The main cost is incurred at the early stages of alternative evaluation when the costs are less. Thus, there is more innovation in less time and at less cost.

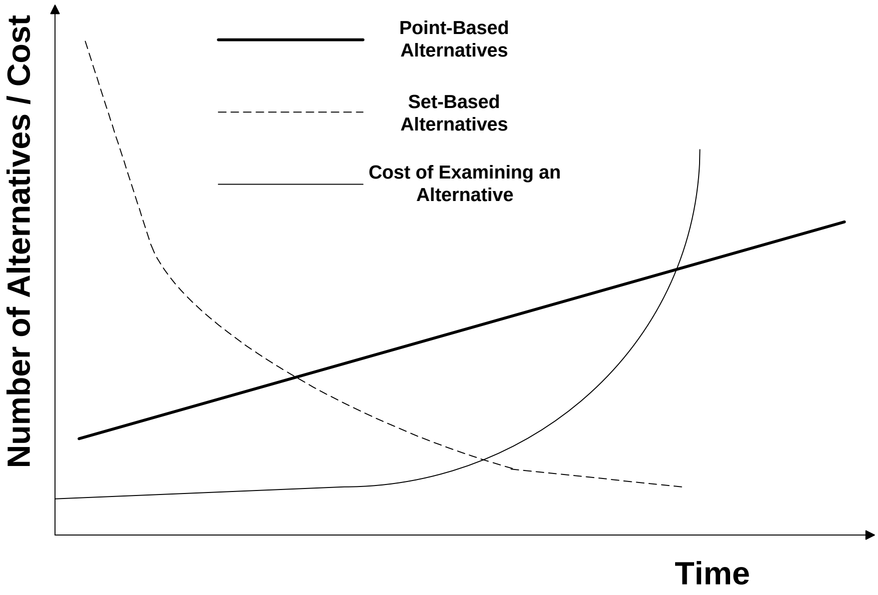

Figure 2.9 Number of Alternatives/Cost v Time [257]

Figure 2.10 below shows the typical overall impact on a total project cost for set-based against point-based process. The ideal curve inclines rapidly, levels and declines rapidly during the development timeline (concept to production handoff). The typical cost curve peaks later and higher (time delay and cost) then the ideal one. This is due to resource issues such as dealing with other projects, fire-fighting, confusion, loop backs and general delays in decision making [257].

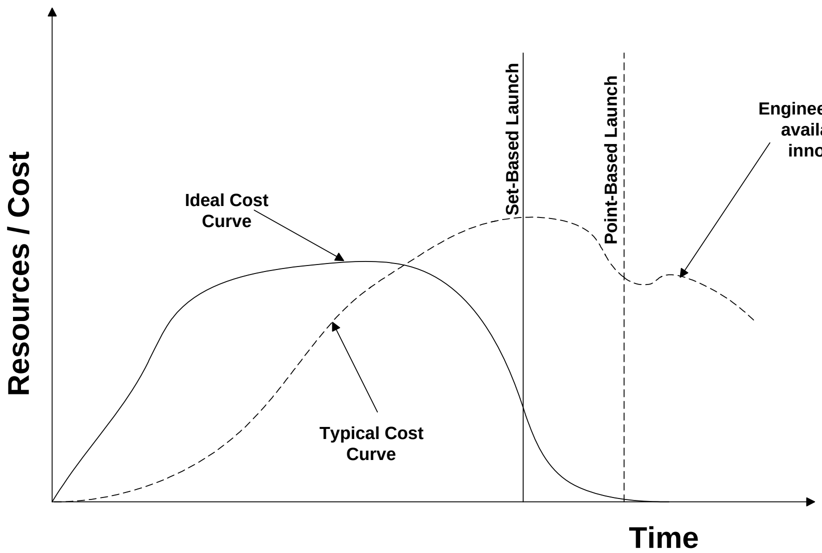

Figure 2.10 Resources/Cost v Time [257]

2.12.5.3 Responsibility Based Planning and Control (Key Integrating Events)

The Chief Engineer (A.19.13) sets a number of target times for Key Integrating Events e.g. styling approval or tooling release. This is a target based on when things come together, it is established exactly what is needed at those times (some subsystems may miss the deadline but there is always a backup). The Chief Engineer sets responsibilities for the results and the engineers work out their plans to meet the dates and communicate the plan to the chief engineer who consolidates the plans to ensure coordination and confidence (A.19.14). The design reviews are hands on i.e. technical managers reviewing the technical results of a highly knowledgeable workforce (not the amount of tasks completed) (A.19.15). At the design reviews the combining and narrowing takes place i.e. set-based decisions from the heavy prototyping and trade-off curves. This approach keeps execution aligned as the overall schedule is the completion of the individual plans. The Key Integrating Event dates never slip. Typical integrating events drive both product delivery and the narrowing of choices. Therefore, responsibility based planning and control has accountability, ownership and rapid response flexibility (A.5.24) [257]. A process similar to this, but less detailed, was discussed at the National Institution of Technology Management (NITM), Dublin, Ireland, at their international seminar. The objectives of this seminar were to show practical and proven ways for the successful management of new product development by SMEs. Reference [265, 266] presented a "new approach to rapid product development" comprised of evolutionary product development, shortening of control cycles (more up front analysis), and self-organisation and coordination (similar to responsibility based engineering).
Also, the KBD process is in line with a 'Knowledge-Driven' PDP, Section 2.8.4.3.

2.12.6 Systems Engineering (SE)

The reference documents on this process [267-270] all start by giving a definition of SE. SE is a set of project functions which ensure that the customer/user get the system they want. There is a great deal of similarity between systems engineering and concurrent engineering (CE) – See Section 2.12.6 [268, 270]. SE takes an uncertain and complex set of requirements and applies a structured NPD process (A.5.25). The SE 'V' model is typical used for SE, where requirements are taken and functionally (based on analysis) decomposed into modules (the down stroke of the V), then the system modules are synthesised into the completed system (the upstroke of the V) which is concerned with validation and verification (testing) (A.19.16) [269]. This SE process ensures that the end product or system meets customer requirements, all of the subsystems and parts fit together and the completed product will perform to the initial expectations [269].

2.12.7 Concurrent Engineering

A.8.12 found that CE was not important for SMEs although it was assumed that this was due to a lack of understanding of CE. Concurrent Engineering is also known as Simultaneous Engineering, Integrated Product Development, Total Engineering, Team-Based Development, and Parallel Development [271-274]. The universally accepted definition for CE comes from The Institute for Defence Analysis (IDA) R-338 Report (June 1986) [271]. The CE approach results in better quality product rather than trying to fix prototypes, tooling, manufacturing lines, and contracts with suppliers late in the process [250, 251] – See Section 2.12.1. In addition to A.5.26 and A.19.17 the following apply to the CE process [269, 271, 272, 275, 276]:

- Analyse the market and understand your customer and their requirements (using voice of the customer (VOC)).
- Get a strong commitment from senior management.
- Develop project leaders that have an overall vision of the project and goals.
- Create an efficient and streamlined development approach to reduce cost and design cycle time (manage costs from the start).
- Develop Robust Designs.
- Transfer technology between individuals and departments.
- Benchmark PDP to competitors.

2.12.8 Conclusion

This section covered seven product development processes. Depending on the SME business a stage gate process could be used. Although relatively new the KBD process could be used by SMEs. It is a process that creates a learning organisation and therefore an innovative organisation. SE and CE all provide alternative PDP. The PDP findings are in Appendix A.5 and Appendix A.19. The next section deals with performance measurement.

2.13 Performance Measurement

According to Neely *et al.* as cited in Garengo *et al.* [277] a performance measurement system (PMS) is a balanced and dynamic system that is able to support the decision making process by gathering, elaborating and analysing information. Garengo *et al.* carried out research to investigate the relationship between performance measurement systems (PMSs) and SMEs which involved a systematic literature review of PMS, SME characteristics and SME PMSs. There is a limited amount of research on PMS in SMEs [277-281] and specifically empirical research [277, 281]. The factors influencing the use of PMS in SMEs are typical SME characteristics' (as shown in Table 2.1 in Section 2.2), so from [277] and SMEC Table 2.1 they are A.14.2 through to A.14.7. Due to A.14.2 to A.14.7, SMEs require specific models and approaches to PMS which are efficient and easy to implement, manage uncertainty, support product innovation and sustain evolution and change processes [277]. Other characteristics of PMS in SMEs are shown in A.14.8 through to A.14.15.

Reference [277] carried out a comparison of eight PMS models (spanning 20 years) of which only two were specific to SMEs i.e. six are the most popular generic models developed in the last 15 years with no reference to company size and two are SME specific PMS models. Garengo *et al.* [277] found A.14.12 and A.14.16 [277].

Hudson *et al.* [281] carried out theoretical and empirical research into strategic PMSs in SMEs. Empirical data was gathered on eight SMEs (12 to 240 employees) based on the typologies using semi-structured interviews and used to confirm the output of the evaluation, concluding that few of the typology characteristics were shared in practice (only that measures should be both simple and practical – A.14.17). The Cambridge PM process model was used for an empirical study of an SME and the measures that were produced covered all the dimensions of PM identified by the typology. However, the implementation failed due to the PMS implementation process being too resource intensive and too strategically orientated. This is a major issue for PMS in SMEs as they require strategic long-term thinking and to be strategically focused (A.14.18) [281]. Yet according to A.1.8 the development of strategic plans aids performance measurement. The remaining finings from this section are A.14.19 to A.14.21. Combined, Garengo *et al.* and Hudson *et al.* examined 14 different models. The requirement from this section is to choose a PMS that can be used for this research and not to measure what type of PMS system SMEs have.

However, all the models discussed by references [277, 281] are used to measure the extent or understand the content of a PMS whereas the requirement for this research is to determine both financial and non-financial (balanced) measures and find actual values of measures in order to compare SME performance to the findings from Section 2.3/2.5 to 2.12. This is also true of the SME specific models, Organisational Performance Measurement [282] and Integrated Performance Measurement for Small Firms [283], mentioned in Garengo *et al*.. With this in mind, other studies were examined. Hvolby [284] presumed that SMEs have very few non-financial performance measures/indicators and this study viewed PM from the perspective of lead time only. Sousa *et al*. [280] carried out a survey which examined performance measurement (and level of implementation) and quality tools in SMEs in Portugal. They stated that performance measurement is diverse and chose Kaplan and Norton's Balanced Scorecard (BSC) model because of its simplicity, general acceptance among authors and its close connection with strategy. This is in contrast to Garengo *et al*. who cited Hvolby and Thorstenson, and McAdam as stating that it is not suitable for SMEs. It was also part of the Hudson *et al*. [281] study mentioned above. Hudson *et al.* [278] proposed a performance measurement process which allows SMEs to name the top priorities for improvement, act on performance measures to drive the prioritised issues and use and learn from the measured outputs in an iterative manner. Chiesa *et al* [29] also examined performance measurement from the perspective of PD although not specifically for SMEs. Again, these studies did not propose an SME measuring system that could be used directly. The models which described performance measures were examined to understand the types of measures that are typical in SMEs, Table 2.10 below shows these models mapped against measures. The measures (left side of table) start with the thesis sections. This is to ensure that appropriate performance measures are taken on each section of the thesis. Quality, Time, Financial, Customer Satisfaction, Human Resource, Flexibility and Stakeholders are taken from Hudson *et al* [281] and are the result of their survey as mentioned above. Delivery Performance and Service Measures were added from the BSC. The BSC as detailed by Sousa *et al* [280], Griffin [285], Brooksbank [248], Hudson et al [281], Hvolby and Thorstenson [284], Ledwith [15], Hurst [17] and Chiesa *et al* [29] were mapped across these 'Measures' to see what metrics they covered. The main purpose of this section is to choose product development performance measures for SMEs and this table was analysed by going through each measure and its corresponding (Y) and choosing the appropriate one.

Table 2.10 Comparison of Performance Measures

Measures	BSC (Sousa et al) (A)	Griffin (B)	Brooksbank (C)	Hudson et al (D)	Hvolby (E)	Ledwith (F)	Hurst (G)	Chiesa et al (H)
Thesis Sections								
Strategy	Y	Y						
Organisational Structure		Y						
Tools and Methodologies	Y	Y						Y
Technology		Y						Y
Intellectual Property						Y	Y	Y
Change Management								
Marketing (backend)								
PD Process	Y	Y				Y	Y	Y
Quality	Y				Y			
Actual Product Performance v predicted	Y							
Process - % of units reworked								
Defects - % units of defect	Y					Y		
Scrap Levels (cost of scrap)	Y			Y	Y			
Suppliers								
Time							Y	Y
Work in Progress								
Output					Y			
Lead Time (performance of manufacturing)	Y				Y			
Delivery Time (actual v promised)	Y			Y	Y		Y	
Financial Measures	Y				Y			
Inventory								
Orders/Receipts								

Measures	BSC (Sousa et al) (A)	Griffin (B)	Brooksbank (C)	Hudson et al (D)	Hvolby (E)	Ledwith (F)	Hurst (G)	Chiesa et al (H)
Profit (ability to reach target)	Y							
Turnover	Y							
Costs - actual cost compared to budget and ability to budgeted cost reductions	Y					Y		Y
Cash Flow - ability to reach target or ROI, return on assets, return on equity	Y							
Sales Growth - ability to reach budgeted sales target	Y		Y	Y		Y		
Quotes Converted								
Income								
Productivity	Y							
Expenditure								
Customer Satisfaction	Y		Y					Y
User Problems	Y							
Product Usage	Y							
Service	Y			Y				
Returns						Y		
Complaints and Retention rates	Y							
Human Resource								Y
Safety								
Staff Turnover								
Personnel								
Employee Training	Y							
Flexibility								
Production Volume Responsiveness				Y				

Measures	BSC (Sousa et al) (A)	Griffin (B)	Brooksbank (C)	Hudson et al (D)	Hvolby (E)	Ledwith (F)	Hurst (G)	Chiesa et al (H)
Production Capability				Y				
Stakeholders								
Employee/manager Satisfaction	Y			Y				
Group contacts				Y				
Delivery Performance								
% of orders delivered to schedule	Y							
Number of custom detected design faults	Y					Y		
No. of complaints regarding delivery	Y							
Service Measures								
Customer Satisfaction Surveys	Y							
Third party assessment of customer and/or product satisfaction	Y							
Lead time to market	Y							
Ability to adapt or tailor products to customer needs	Y							
Waiting time in a service prior to transaction	Y							
Response time to customer requests for specials	Y							

2.13.1 Selection of Measures for Product Development

As stated the models which described performance measures were examined to understand the types of measures that are typical in SMEs, Table 2.10 above shows these models mapped against measures – A, B, C, D, E, F, G and H relate to the references in Table 2.10 and their corresponding performance measures. From this, the measures chosen are shown in Appendix A.28 (Performance Measurement Questions). Section 2.3.2.5 concluded that Prospector, Analyzer and Defender were suitable business strategy types for SMEs. The corresponding performance metrics for these business types are also accounted for in A.28.

In addition, Cooper [65] states that companies measure short term metrics (immediately) and long term metrics (years after launch). The long term metrics chosen can also be found in A.28 (percentage of sales generated by new products after 3 years and the percentage of growth generated by new products after 3 years) [65]. Therefore, all the measures chosen are shown in Appendix A.28 (Performance Measurement Questions) and these could be used in the final questionnaire. As can be seen from Table 2.10 no measurements were found for change management and marketing (backend).

2.13.2 Conclusion

A.14.1, A.14.2, A.13.3, A.14.5, A.14.6, A.14.7, A.14.10, A.14.11, A.14.14 and A.14.18 characteristics describe both the difficultly in SMEs implementing a PMS system and the reasons it will be difficult to get performance measurement information from SMEs. In addition, Eccles as cited in reference [283] states that a company's business model must be understood before a scorecard of performance measures can be chosen and implemented. According to Neeley [286], issues with measuring performance measurement still exist today (2007). Therefore, it will be difficult to get a measure on SME performance.

In terms of the thesis sections both organisational structures and tools and methodologies measurement methods are weak. This thesis will add to these measures – A.4.6. Also, no consideration is given to marketing (backend) or change management.

Chapter 3
Research Approach

3.1 Introduction

Chapter 2 covered the literature review which yielded 232 PDP characteristics and 163 unformatted potential questions (Appendix tables A.1 to A.14 and A.15 to A.28 respectively, as per Table 2.0). This chapter deals with the process of deciding the nature of the survey, the design of a questionnaire plus selection of destination companies from a sampling frame.

3.2 Research Approach

According to Creswell [287], the research approach (Qualitative, Quantitative, or Mixed Methods) is decided based on interrelated levels of decisions which when made dictate the approach and the research design process. These decisions are based on which knowledge claims, strategies of inquiry, and research method is used. The following Creswell definitions explain how these are combined:

"A quantitative approach is one in which the investigator primarily uses postpositivist claims for developing knowledge (i.e. cause and effect thinking, reduction to specific variables and hypotheses and questions, use of measurement and observation, and the test of theories), employs strategies of inquiry such as experiments and surveys, and collects data on predetermined instruments that yield statistical data" [287]

"A qualitative approach is one in which the inquirer often makes knowledge claims based on constructivist perspectives (i.e. multiple meaning of individual experiences, meanings socially and historically constructed, with an intent of developing a theory or pattern) or advocacy/participatory perspectives (i.e. political, issue orientated, collaborative, or charge orientated) or both. It also uses strategies of inquiry such as narratives, phenomenology's, ethnography's, grounded theory studies, or case studies. The researcher collects open-ended, emerging data with the primary intent of developing themes from the data" [287]

“A mixed methods approach is one in which the researcher tends to base knowledge claims on pragmatic grounds (e.g. consequence-orientated, problem-centred, and pluralistic). It employs strategies of inquiry that involve collecting data either simultaneously or sequentially to best understand research problems. The data collection also involves gathering both numeric information (e.g. on instruments) as well as text information (e.g. on interviews) so that the final database represents both quantitative and qualitative information” [287]

Based on these definitions and the work of O’Leary [288] this can be summarised as shown in Figure 3.0.

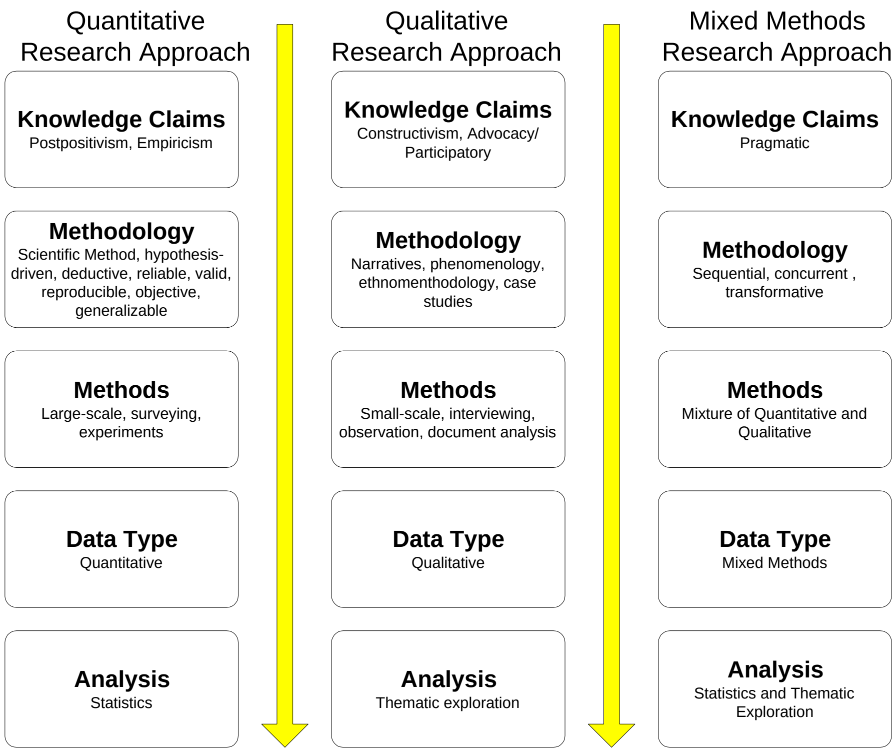

Figure 3.0 Research Approach Flow Charts [287,288]

Therefore, based on Figure 3.0, the Quantitative Research Approach would appear to be the approach to use in this thesis. Thus, the next section will discuss this approach further, starting with a Quantitative Research Approach Model.

3.2.1 Quantitative Research Approach

Figure 3.1 shows the Quantitative Research Approach Model as described by reference [289]. This is comprised of Theory, Hypothesis, Operationalisation of Concepts, Selection of Respondents, Survey or Experimental Design, Data Collection, Analysis and Findings.

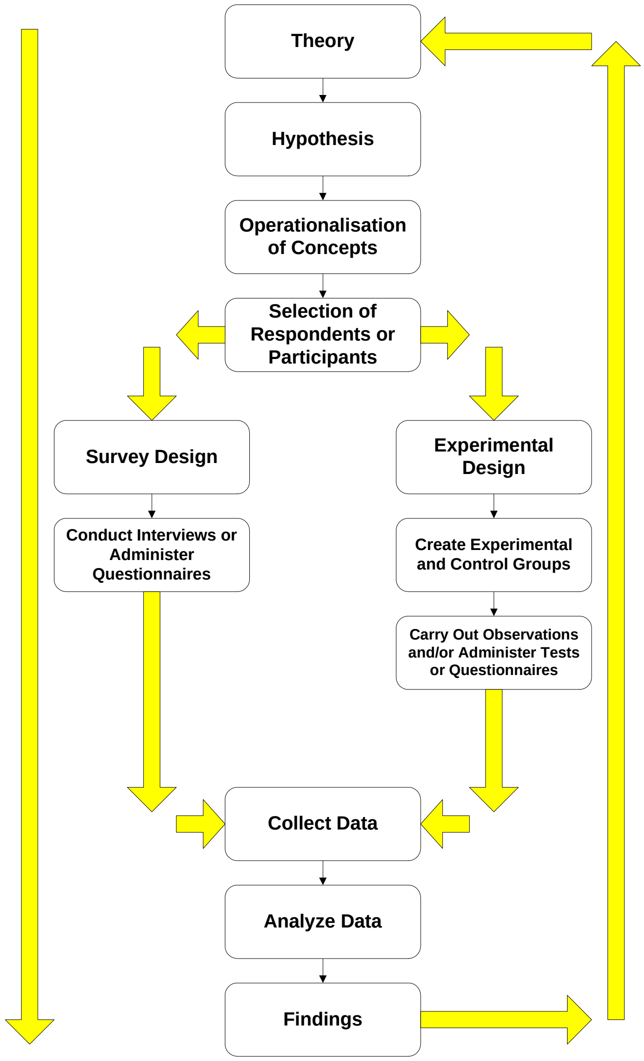

Figure 3.1 Quantitative Research Approach Model [289]

3.2.1.1 Theory

Empirical theories are at a low level of generality. For this thesis the general theory or hypothesis, based on the previously defined gap, is that indigenous SMEs do not follow 'best practice' approaches to product development (Section 1.4.3) [289].

3.2.1.2 Hypothesis

The next step is to test this hypothesis by establishing if it is true using empirical evidence. Figure 2.1 shows how Sections 2.3/2.5 to 2.13 interact as concepts or elements. Due to the many variables in these concepts they could be described as having a “richness of meaning” [289]. Within these concepts specific sub-hypotheses of 'best practice' are examined which cover these areas:

- Strategy usage/understanding
- Organisational Structure/PDP Environment/Culture
- T&M usage/understanding
- Technology and Technology Development
- IP Strategy and Portfolio Usage
- Issues with Change Management
- Marketing Usage (Front and Backend)
- PDP Usage (Stage Gate, CE and KBD)
- Performance

Also, the interrelationships between product development concepts, the industry sector, SME size and SME success are analysed (Appendix C.4 Final Analysis gives a more detailed breakdown of the individual sub-hypotheses).

3.2.1.3 Operationalisation of Concepts

These concepts (elements) must be measured, a process called operationalisation. The concepts are translated into variables or attributes on which objects, in this case SMEs, vary. By measuring these concepts the hypothesis and the overall theory is checked for validity [289, 290]. Again, Figure 2.1 shows Sections 2.3/2.5 to 2.13 of Chapter 2 which are the concepts. Appendixes A.1 to A.14 have 232 characteristics associated with these concepts. These characteristics are linked to Appendix A.15 to A.27 – the rough format of the final questions. As can be seen in Appendix A.15 to A.27 there may be one or more characteristics associated with a question; these characteristics are converted to 146 variables (according to Fink [291] a variable is a characteristic that is measurable). These then formed the link concepts-variables-questions (A.15 to A.27 show these variables in Column 3). An example of this conversion is A.18.6 where nine different characteristics (A.4.6 to A.4.14) support the use of T&M and become the variable ‘Why SMEs should use T&M’. The next stage was to create the questionnaire from A.15 to A.27 and the corresponding thesis section text (column 5). An analysis of the variables and the corresponding questions and sub-questions was conducted. As can be seen questions were removed if:

- The item was asked in another section.
- It was 'Not a Critical Variable' i.e. it was a nice to know.
- It was 'A critical variable but removed to reduce the number of questions' – this meant that although it was a critical variable it was going too in-depth for this research and was only removed to reduce the number of questions. The item could be used in another study.
- It was a 'How do you' type question. Generally, this research is checking the 'use' of certain concepts/variables not 'how' they are used. When the extent to which it is used is better understood further research can investigate how it is used.
- They violated the 40 item checklist shown in Appendix B.1. This is a Checklist for any given Questionnaire Item compiled from Babbie [290], Meagher [292], Evans and Mathur [293], Fink and MSU [294].

As shown in Figure 2.1, Appendix A.15 to A.27 are the core processes (inputs) or independent variables whereas A.28 shows the performance measurement (outputs) or dependent variables. There were 96 potential performance measures from Section 2.13 (Appendix A.28). They were narrowed down to 14 by using the relevant PM metrics related to the thesis sections, by considering which metrics were most likely to receive the most responses and by using those most applicable to product development (some were more manufacturing biased). At this stage the linkages between different items were also considered to help analyse the results of the survey. In addition, this research asks details of some variables to see if they are being used without the SMEs explicit knowledge. For T&M, they may not know the formal name of the tool they are using or do not recognise its function (and could therefore be using it incorrectly) e.g. FMEA item 16.6 (Appendix C.2): The possible modes of failure of a product or process, and of the likely consequences of such failure are identified, whereas item 17.5 asks do you use FMEA. These two items can be compared for consistency/understanding.

The PM metrics (Appendix A.28) are numerical values whereas A.15 to A.27 are mostly ordinal scales (interval rating scale) as defined by Fink [291] i.e. used when a rating of quality or agreement is required i.e. 'To a very great extent', 'To a great extent', 'To some extent', 'To a very little extent' and 'Not at all'. The nature of the items determine how specific or general the measurement of the variable is [290] and the items in this questionnaire are quite specific. According to Babbie [290], indexes are ordinal measures and data reduction devices or composite measures of variables i.e. based on responses to more than one questionnaire item. In the case of measuring strategy (e.g. Item 5.0 To what extent do you – Appendix C.2) – a respondent's score on an index gives an indication of that company's relative strategy with respect to other respondents. The respondents score on this index is determined by the specific responses to several questionnaire items (5.1 to 5.9) each of which provided some indication of strategy [290].

Like Meagher [292], background questions are not related to variables but were used to understand findings. Chapter 4 discusses online surveys.

3.2.1.4 Selection of Respondents or Participants

In the case of a survey this is the selection of a sampling frame [289]. A population is the sum of all the elements (universe) or units of analysis (typically a person) i.e. an SME. The Sampling Frame is a list of sampling units from which the sample is selected e.g. students from a roster, where the roster is the sampling frame. The researcher can have a universe or population which they consider suitable. From this they search for possible sampling frames, and based on these choose which frame best represents a survey population. Section 3.2.1.4.1, on government bodies, covers the possible universes [290].

3.2.1.4.1 Sampling Frame

A major issue for this thesis was where to obtain or create a list of enterprises to survey. A common approach taken to create a population, and from this a sample frame is to use Kompass [295] (as used by Ledwith [15]). Hurst [17], used the Central Statistics Office's (CSO), Census of Industrial Production (1990) to obtain his sample frame. For the present research, it was first decided to try and obtain a population and therefore a sampling frame. In order to do this it was required to understand the framework for research policy in Ireland i.e. who worked with indigenous SMEs. The research frame is shown in Figure 3.2 below [296-299].

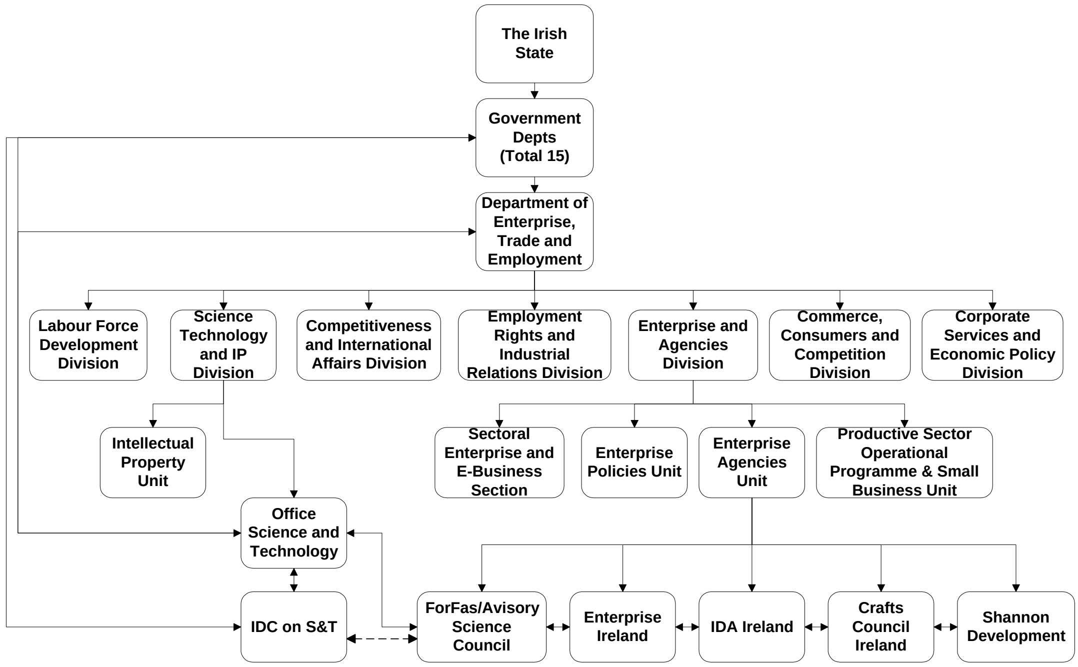

Figure 3.2 Framework for Research Policy in Ireland [296-299]

The Department of Enterprise, Trade and Employment (DETE) strategy is to "Work for Government and the people to equitably grow Ireland's competitiveness and quality employment". The seven divisions of the DETE are shown above [297]. As can be seen Forfás operates under the backing of the Department of Enterprise, Trade and Employment via the Enterprise Agencies Unit. Forfás is the national board responsible for providing policy advice to the Government on enterprise, trade, science, technology and innovation [300]. Forfás sister agencies and advisory councils are Enterprise Ireland (EI), Irish Development Authority (IDA) and Science Foundation Ireland (SFI) [14]. The Industrial Development Agency (IDA) is an Irish Government agency with responsibility for securing new investment from overseas in manufacturing and internationally traded services sectors. In other words IDA is concerned with Foreign Direct Investment rather than indigenous business [301]. In response to the Enterprise Strategy Group report "Ahead of the Curve – Ireland's Place in the Global Economy" [8] Enterprise Ireland (EI) published their Strategy for 2005-2007 entitled Transforming Irish Industry" [302]. Figure 3.3 shows their strategy overview.

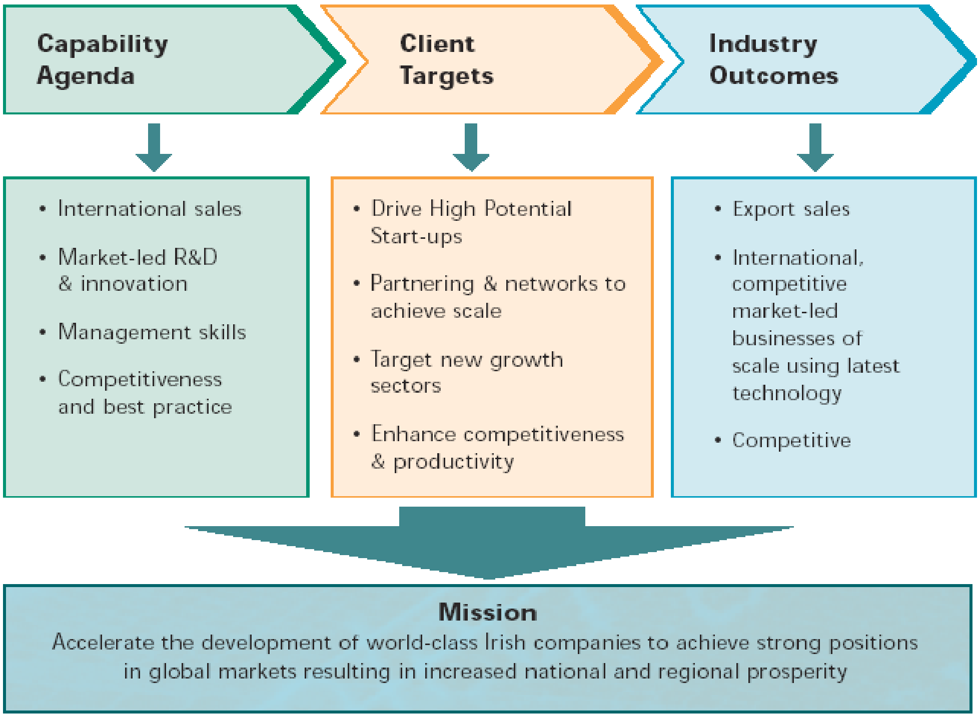

Figure 3.3 Enterprise Ireland Strategy Overview [302]

As can be seen the overall outcome of their strategy is to maximise export sales through the utilisation of applied research, technology and innovation. Overall the EI strategy is striving to be a holistic business creation and development strategy for indigenous industry [302]. Therefore, based on this framework review, and including other research, the following organisations were contacted:

- Forfás – Innovation, STI Data and Trade Relations Department and National and EU S&T Policy Department
- Enterprise Ireland
- Small Firms Association (SFA)
- The University of Limerick's Small Firms Research Unit (SFRU)
- Engineers Ireland
- The Champions of Innovation (Irish connection to the Product Development Management Association (PDMA))
- Irish Management Institute (IMI)
- Irish Small and Medium Enterprise Association (ISME)

The below email was sent to all of these potential informants of indigenous SME sources:

Dear Mr/Mrs,

I am a part-time PhD student in DCU and am carrying out research in Product Development. I am researching the product development approaches of indigenous small to medium size enterprises (SMEs) in order to get an understanding as to where Irish enterprises are in relation to best practice.

In order to do this I need to get a list of small to medium size enterprises developing software and/or physical products that I can survey.

I note/see – [statement specific to person/organisation being contacted].

Naturally this will all be done in the strictest of confidence and their information only used for my survey or your purposes if applicable and allowable.

Can you help me to attain this or point me in the direction of someone who may be able to help?

Thank you for your time,

Barry.

Phone Number

P.S.

This research arose from the need for Ireland to get its GNP to the same level as some of Europe, the USA and Japan as per the EU and therefore the Irish governments mandate.

Out of the people contacted, three out of ten returned an email. However, one of these supplied an excel spreadsheet list of 5484 indigenous SMEs (population), with company names and general email addresses, who all received a grant from Enterprise Ireland for development purposes. This list comprised of all types of industry and in order to understand what the 5484 enterprises were involved in and therefore if they met the criteria of this survey they were all researched on the internet. 1189 of these could not be found, with the majority being individual names (sole traders) with no email address or telephone number. This left 4295 enterprises. 3553 of these were involved in either: food, drink, pharmaceutical, biotechnology, fibre optics, recycling, chemical, joinery/furniture/woodwork, marine, masonry, jewellery design, electrical/control engineering, pottery, cutlery, linen, oil and co-operatives. This left 742 companies. As mentioned in chapter 2 it was decided not to survey individual software companies. Of the 742 companies 459 were software. Table 3.0 shows the final breakdown of the 283 companies meeting the criteria for this survey i.e. the sample frame:

Table 3.0 Sample Frame

Industry	Qty
General Mechanical	179
Plastic/Moulding	30
Electronic	39
Packaging	11
Medical	24
Total	**283**

This represents 5.2% of the original population. It was decided to survey all 283 companies so this sample represents 100% of the sample frame and therefore survey sample design was not required.

3.2.1.5 Setting up a Research Design

There are six methods of quantitative science research design, namely: the controlled experiment (as shown in Figure 3.1), content analysis, analysis of existing data, case studies, participant observation and survey research design (as shown in Figure 3.1) [289, 290]. This thesis's strategy of inquiry is based on a survey research design which will provide original research results [287].

3.2.1.5.1 Survey Research Design

Survey research is also referred to as survey design or the environmental arrangement [290, 303]; a definition of a survey is given by Fink [303]:

"Surveys are systems for collecting information to describe, compare, and predict attitudes, opinions, values, knowledge, and behaviour"

Babbie [290], states that survey research, like science and social science is logical, deterministic or postpositivist (based on cause and effect), general, specific, and parsimonious i.e. it should look to find the greatest amount of understanding from the smallest number of variables. It is a method of empirical validation [290]. This is in line with the quantitative research approach as discussed in Section 3.2 e.g. Figure 3.0. The design of the survey is as important as the results analysis. This is like product development in that poor initial development stages will lead to a poor final product. The survey design of this thesis is as follows: This survey's purpose is descriptive as it is describing what is happening in relation to product development in the indigenous SME industry. Also, the group or target population is a naturally occurring group i.e. a collection of indigenous SMEs. It is also cross sectional (not longitudinal) as cross sectional designs are commonly used with survey based measurement instruments such as mail, self-administered questionnaires and telephone or face to face interviews for collecting data. This data is then used to generalise from sample to population. They provide descriptive data at one fixed point in time assuming the survey is carried out within a reasonable time frame so as to prevent the possible changes to the questionnaire answers [290, 303].

3.2.1.6 Collect Data

Data is collected based on the research design chosen. In this case it will be via a questionnaire [289]. This is covered further in Chapter 4.

3.2.1.7 Analyze Data

The respondents are described in terms of the variables using statistical analysis [289]. This is covered further in Chapter4, 5 and 6.

3.2.2 Conceptualisation and Instrument Design

With the exception of facts (like a persons age), a survey does not collect data it creates it. The answers to the survey are a description (this is a descriptive survey) of the respondents. Conceptualisation and instrument design deals with ensuring that the concepts, in this case of product development, are converted into questions such that relevant empirical data can be analyzed (Section 3.2.1.3). In addition, the quality of the survey measurement is very important. Two techniques cover this, reliability and validity [290].

3.2.2.1 Reliability and Validity

The quality of the survey research is established by examining the reliability and validity of the survey [304].

3.2.2.1.1 Reliability

Measurement error is related to how well or badly a survey achieves its purpose in a given population [304]. According to reference [304] reliability is:

"A statistical measure of how reproducible the survey instruments data is".

There are four types of reliability:

- Test-retest reliability [304] or Stability Reliability [305] – This is the most common used indicator of instrument reliability. The same set of respondents are measured at two different points in time and the stability of the responses analysed (in order to do this the survey must not be effected by time). The correlation coefficient or "r" value must be ≥ 0.70. This can be done for a group or individual observer and the whole instrument can be tested [304].
- Alternate-form – This involves using different worded items (questions) to measure the same attribute. This is a method of getting around the practice effect, where respondent become familiar with the instrument and can respond with the answer they gave the last time [304].
- Internal consistency reliability – This is applied to groups of items that measure different aspects of the same concept, not single items. It is a measure of how well the different items measure the same issue (Cronbach's Alpha – see Chapter 4) [304].
- By Pre-testing a self administered questionnaire through interviewing a sample of the respondents in their respective categories [290].

The goal is to measure concepts in a way that helps us understand the world around us [290]. As the survey is cross-sectional Test-retest can not be used, also, alternate-form requires the addition of repeat question which in this case would make the survey too long. Thus, reliability will be checked using pre-test and pilot studies and internal consistency (See Chapter 4).

3.2.2.1.2 Validity

According to reference [304] validity is:

"The measure of how well the survey measures what it sets out to measure"

Reference [305] explains that there are two types of validity, internal and external. External validity is concerned with how well the sample population findings apply to the entire population (generalization) and the ability of research to relate to a persons experience i.e. can they connect to it (transferability).

Internal validity is concerned with how well the study was carried out i.e. the study's design, what was and was not measured and how well it was measured. There are four types of internal validity [304, 305]:

- Face Validity – It is a review of items by untrained judges. It is the least scientific and considered worthless by some [290, 304].
- Content Validity – If a survey was conducted on mathematical skill and only asked about addition, the content of that survey would not be valid [305]. This content is reviewed by people with knowledge of the research topic resulting in the identification of gaps in content [290, 304].
- Criterion Validity – The comparison of one instrument against another which has proven to be valid. Can be broken into two components, concurrent (measure of a variable against a gold standard) and predictive (the ability of a survey to forecast future events) [290, 304, 305].
- Construct Validity – This is the measure of how good a scale or survey instrument is in practical use and is based on years of experience with a survey instrument [290, 304].

Validity will be checked for by using content validity – using the pre-test and pilot study and using a Senior Lecturer from the University of Limerick with knowledge of Product Development in SMEs [15].

3.3 Conclusion

The research approach is quantitative. Sections 2.3/2.5 to 2.13 (Figure 2.1) shows the concepts and how they relate in terms of inputs and outputs i.e. A.15 to A.27 are core processes (inputs) and A.28 is the output in terms of performance measurement. Therefore, the inputs are independent and the outputs are dependent variables when the concepts are operationalised. Section 3.2.1.3 resulted in 225 items (Appendix B.2). A sampling frame was received from one of the enterprise agencies units which was based on Enterprise Ireland grants for development and comprised of 5484 enterprises. This was eventually narrowed down to 283 SMEs. The survey design of this thesis is descriptive with a target population that is a naturally occurring group i.e. a collection of indigenous SMEs. It is also cross sectional (not longitudinal) as cross sectional designs are commonly used with survey based measurement instruments such as email. The data will be used to generalise from sample to population. Chapter 4 discusses the methodology and the pilot study.

Chapter 4

Pre-Test, Pilot Analysis and Final Questionnaire Methodology

4.1 Introduction

Chapter 3 covered the research approach. It discussed the design of the questionnaire (Section 3.2.1.3) plus the sampling frame (Section 3.2.1.4). This chapter discusses online surveys with an emphasis on increasing response rate. It discusses how the questionnaire was tested i.e. via a non-expert review, two pre-tests and a pilot. Initial analysis is carried out on the pilot data to validate the final survey. The chapter closes with reference to Appendix C.4 which shows the Final Analysis plan.

4.2 Online Surveys

Evans *et al.* [293] discuss the major strengths (16 in total) and potential weaknesses of online surveys. Of interest are the weaknesses and methods of mitigating them – these weaknesses are also considered in relation to this thesis methodology:

- Sample Selection – according to references [293, 306-310], the main issue with online surveys is the lack of representativeness. This is not an issue for this survey as the sample frame is specific to this research (Section 3.2.1.4.1). However, a multimode (email and postal) approach is offered during the telephone call (pre-notice) for ease of response and in cases where anonymity is a priority [309]. Also, reference [308] suggested multimode can be used for specific online populations such as these SMEs.
- Perception as junk mail – all SMEs were telephoned so this is no longer an issue. The telephone call gives them the opportunity to opt-in, and the survey email offers an opt-out. According to Bannan (as cited by Evans *et al.* [293]), and [306], respondents should not be contacted by email unless they give permission.
- Skewed attributes of internet population – the population was not gathered from the internet.
- Respondents lack of online expertise – all the potential respondents are company owners or R&D managers and the use of email and the ability to do

a web-based survey would be expected. In addition: the instructions are simple, the survey can be accessed through a URL, the survey is designed in accordance with the checklist in Appendix B.1 and a paper option is offered.

- Technological variations include the type of internet connection and different screen configurations – the majority of companies now have broadband rather than dial-up with an internet explorer screen configuration and a Windows operating system. Pre-testing and pilot testing also highlighted any issues.
- Unclear answering instructions – along with the checklist (Appendix B.1), the non-expert test, two pre-tests and pilot should help eliminate this issue.
- Impersonal, resulting in a limited ability to probe in-depth and lack of motivation to participate – See Section 4.2.1 on personalisation. Motivation to participate is gained by offering the results of the survey as it will give 'best practice' findings – acts as a reward [293]. According to references [306, 310] rewards improve non-response and is referred to as social exchange theory [310].
- Privacy and security issues apply to security of transmission and data usage. This online survey states that it is confidential [293, 310]; it also requires a password to enter the survey web page. There is no email attachment as the email contains a web-based survey and thus no virus concerns. As respondents are phoned before the survey is emailed they know the origin – however, a paper option is offered.
- Low response rate – see next section [293].

4.2.1 Non-response

This is improved by developing the best possible survey (checklist, non-experts, pre-testing, pilot), offering incentives ('best practice' findings), having a relevant and interesting survey sent to respondents, reducing respondents' time and resources (cost), gaining permission, using pre-notifications, personalisation (improved by 7.8% by using salutations) and follow-up [293, 306, 310]. According to Evans *et al.* [293] personalisation is not as big an issue with telephone surveys and it is hoped that contacting the sample frame by phone will help to personalise the survey but not lead to refusal to participate. As the survey is not conducted on the telephone, phone contact is brief and not as intrusive. The survey email will also be sent to a named person [309]. However, the disadvantage of this is that anonymity cannot be ensured [293, 309] – according to references [306, 309] the extent of this relationship needs to be further researched. If anonymity is a major concern, a paper-based survey can be returned by post [308, 309]. An incentive such as survey findings may help overcome the anonymity issue as respondents choose to lose anonymity in order to gain a reward. Reference [306] mentions the sample frame issue of outdated or inactive email addresses reducing response. In many cases, the sample frame respondents of this thesis have sales or information type email addresses and not the contact of the right person (company owner or R&D manager). This is another reason to telephone the SMEs. The call will also check if they are still in business and gain acknowledgement of R&D/Product Development activity – a sample frame check. Reference [306] also states that an email with a web-enabled link is best practice (according to Ilieva *et al*. [307] combining the advantages of email and web-based surveys) while [307] states they are very appropriate for cross-sectional surveys. Comley [311] put forward a formula which links the number of scroll-downs on the first page to the response rate for pop-up surveys:

Response rate (%) = 40% - (8% x number of scroll downs)

Although this is not a pop-up survey (when a website is accessed a survey pops up) section one on strategy was split in two reducing the scroll-downs to one. This is one of the longest pages in the survey and it was thought that it would give the overall impression of a difficult and long survey. After the pre-test this section was moved to a later stage in the survey however the split was kept. Reference [307] suggests that some surveys should not be delivered in the summer, this is relevant to this thesis as respondents could be on holidays during the summer months. The final survey was conducted before the August Bank Holiday with only a few 'third' reminders going out after this date – this was in cases where the SME had responded and wished to be contacted again after this date. Although some members of staff were on holidays, it was possible from phoning to identify another member of staff that could help or establish when the correct respondent was returning. The survey software used was SurveyMonkey [312] – this software has a status bar and percentage completion option which was enabled in order to give respondents an indication of progress. Also, this software prevents multiple responses and improves item response rate by preventing the respondent from progressing until the item is answered (each individual question is an item e.g. Q19.4 is one item whereas Q19.0 is the entire question on technology containing 13 items – Appendix C.2). The only exceptions to this were some items on performance measurement. As explained in Section 2.13 performance measurement information is difficult to obtain. Therefore, it was decided not to increase non-response by restricting completion of items 28 to 34. According to Schaefer and Dillman [309], another way to increase response rate is multiple contact. Schaefer and Dillman researched literature surveys and found a single contact response rate of 28.5%, two contacts was 41% and 57% response rate for three or more contacts. As suggested by [309] the SMEs were contacted four times – the pre-letter will be replaced by a phone call, the questionnaire emailed, thank you/reminder (with questionnaire) emailed and the replacement questionnaire emailed. Due to the fact that emailed surveys get a quicker response (one of the strengths [293]), Schaefer and Dillman [309] suggested compressing the contact period. They suggested the questionnaire would follow pre-notice within 2-3 days, reminders 2 days later, and replacements a week after the reminder. However, if respondents were out of the office for a week they could be missed by the compressed timeframe. A traditional posted mail survey takes seven weeks. Thus, the strategy used was:

- Telephone call.
- Questionnaire emailed within ten minutes of telephone acceptance.
- Reminder one (with questionnaire web-enabled link) emailed after 7 working days (for the pilot this was replaced by a telephone call).
- Reminder two (with questionnaire web-enabled link) emailed after 6 more working days – this covers a period of a month.

Also, a return postal address was included in the email for respondents requiring the attached survey in order to post and return. According to Klassen and Jacobs [310] this is an establishment-level survey i.e. management research survey. Klassen and Jacobs [310] stated in 2001 that a decline in management research (company owners/R&D managers) survey response rates has been observed over the last two decades (survey fatigue). In order to increase survey response rate the above counter measures to these issues were used.

4.3 Non-expert and Pre-test 1 and 2

Five non-experts examined the questionnaire (including a project manager with a multinational company and a primary schoolteacher). This led to rewording of questions Q6.0, Q20.0, Q22.0, Q31.0, Q48.0 and Q54.0 (in Appendix C.2 they are Q8, Q3, Q11, Q14, Q34 and Q42). The gap between their understanding and the intended understanding was closed. Also, the project manager and the teacher thought it was too long. The first pre-test was conducted with six respondents and it took a month to complete. Similar to Hurst [17] one of these respondents was an expert on the product development process and familiar with the collection of data from similar populations to the intended research sample. The other five were product development practitioners:

- Company one: 3 employees (plastics industry).
- Company two: 25 employees (general mechanical industry).
- Company three: 30 employees (medical industry).
- Company four: 30 employees (electronics industry).
- Company five: 120 employees in Ireland plus 100 in Hungary. All R&D is based in Ireland (general mechanical industry).

The pre-test therefore covered the range of SME populations (<10, <50, <250 – Figure 1.6) and industries. All were contacted by phone and agreement reached to do the pre-test online. The respondents were asked to comment on each section as per the online pre-test questionnaire. They were sent the pre-test instructions as per Appendix C.1 and were all called for further clarification after completion of the questionnaire. The findings from the expert were as follows:

- The survey was too long i.e. 216 items.
- Too many questions were too similar.
- Variation in the style of response could yield increased accuracy in responses.
- Q44.0 to Q47.0 (A.28.59, A.28.94 to A.28.96) would be difficult to get responses too.

The practitioner findings were as follows:

- Two of five thought the survey was too long.
- Some of the questions were considered confusing.

- The respondent in the large SME was involved in the strategy of the company but felt that it should be answered by somebody from marketing. It was also thought it was too general and some questions were the same.
- It was suggested to change the colour of the page background to help increase response – 'snow blindness' was an issue. The background was changed to two darker contrasting colours.
- The survey went into the email spam folder of two respondents when sent via SurveyMonkey. This was tested further and discovered that there were no issues with sending the survey web link within an email sent independently of SurveyMonkey.
- One respondent picked 'other' as their industry sector. It was therefore difficult to tell from this response what the SME did. This was resolved by adding a 'describe' box.
- Q44.0 to Q47.0 (A.28.59, A.28.94 to A.28.96) were not answered by four of the five respondents. This was because the performance indicator was not measured or not available to the respondent.
- In general, the five practitioners thought the survey was "beneficial", "comprehensive", with the right PD "issues" and "areas" addressed.

The questionnaire went through more iteration after the pre-test, which:

- Considered the criticality of each item based on its variables.
- Combined variables.
- Identified items asked within other items and selected the item to keep with the most relevant variables/characteristics.
- Removed sections not part of the main thesis structure.

The identified confusing pre-test questions were simplified or eliminated by this item reduction process. A skip question was added to the Strategy Section i.e. Are you involved in your company's strategy development? Although the respondent said that strategy was not his area he did answer the questions. Therefore, adding the skip question removes the chance of inaccurate responses and reduces the time for respondents not involved in strategy. This should increase the response rate and reduce the chance of respondents cancelling half way through because they think the survey is irrelevant to them. Pearce *et al.* [313] correlated subjective performance measures against objective performance measures and reported strong support for substituting subjective techniques for objective techniques. This method was used successfully by references [292, 314, 315] and therefore was adapted in this research to overcome the issues with Q44 to Q47 (replaced with Q35, 36 and 37 in the pilot questionnaire, Appendix C.2 – A.28.97, A.28.98, A.28.99). In relation to Q8 and Q16 (Q10 and Q20 in Appendix C.2) the style of the questions were changed from an interval rating scale (the distance between each adjacent pair of points are at cognitively equal intervals) to a fixed sum or fixed allocation question format. As discussed in [316] fixed sum combines the interval scale with forced ranking. According to reference [317] Interval scales are not suitable for measuring importance among a set of factors, in this case Q10 five strategy types, whereas rank ordering forces respondents to chose one item over the other. However, rank ordering does not provide cognitively equal intervals. Fixed sum captures relative distinctions and has interval properties (data can be added and averaged). Reference [316] states this type of question results in a greater depth of thinking from the respondent but increases respondent burden and should not be used at the start of a questionnaire – it was only used in two cases in this survey. It was used to find the most common response (compare). It also achieved the purpose of variation in the questions while keeping the idea of the same response format to speed up respondent response for the respondent. The format of question Q27 (Q26 in Appendix C.2) which was two ordinal scales was changed to a 'pick one' response. It was decided to have a definite answer to this question rather than an interval rating in order to aid analysis. These changes were made to the questionnaire reducing the number of items from 216 to 130 and the pre-testers contacted again via phone. They agreed to retake the survey (Pre-Test 2) with all responses received in 8 working days. Again follow up calls were made with one respondent being interviewed in person (on an airplane – it was not intended to do personal interviews). No more issues were identified and completion time was reported as 15min. This second reduction of items (for the pre-test 2) is shown in Appendix C.3.

4.4 Pilot Study

The SMEs were not made aware of the fact that this was a pilot study (See Appendix C.2). Table 4.0 shows the combined Pre-Test (5 SMEs) and Pilot calls (52).

Table 4.0 Pre-Test and Pilot Call Breakdown

	SMEs Called	Bought Over	Out of Business	Not in PD	Miscellaneous	Surveys Sent
Mechanical	22	1	0	2	0	17
Plastics	7	1	1	1	0	5
Electronic	7	2	1	3	1	4
Packaging	11	1	1	0	2	7
Medical	10	2	0	0	0	4
Total	57	7	3	6	3	37

For the pilot, 32 surveys were sent (minus the 5 pre-test) with commitment from respondents to respond (chosen in alphabetical order). From this 8 responses were received. The 24 non respondents were followed up with reminders – email and phone. Those called were the SMEs that were the most enthusiastic about completing the survey. 12 more responses were received giving 20 responses in total (20/32 – 62.5% response rate). Although 5 responses were started but not finished as the SME said it was not applicable to their business (A small moulder (employing 2 people) and 4 packaging companies) – some sent emails explaining. In relation to the 11 packaging companies – 1 response was received. Based on the calls to these SMEs this was not surprising as most did not fit into the 'physical' product development category.

During all stages of this process two or three calls were made to the same company as the person with product development knowledge was out of the office or unavailable. It was decided to examine the Pre-test 2 responses to see if they could be added to the pilot to bring the pilot study up to 25 responses. There were very minor changes to the following questions – Q3.0, Q11.0, Q15.0, Q16.2, Q16.4, Q27.0, Q29.0 to Q31.0 and Q42.0. There were slightly bigger changes for Q5.5 (was 'To what extent do you use product platforms'), Q9.0 (was 'To what extent do you map external arena (market, technology, product) opportunities and high internal business strengths against each other to identify target arenas') and Q20.0. All were compared visually with no major difference in responses seen. Q20.0 was an ordinal scale format but was converted into the pilot question format (the pre-test 2 SMEs businesses were known which made this accurate). The findings from this pilot study can be split into non-analytical and analytical.

4.4.1 Non-Analytical Findings

Based on the pilot study the following changes will be employed for the final survey:

- Mention that the survey should be competed by the Company Owner or the R&D Manager. It was mentioned on the phone that this was a survey of Product Development but it often went to purely marketing people who could not answer the technical side of the survey. This is particularly important when a receptionist/secretary was 'sending' on the survey.
- Be more specific about the benefits of the survey for the SME i.e. it is hoped that the results of this survey will enable policy development that helps you carry out Product Development while considering your lack of resources (time, money, human).
- Talk to companies about their products – try and make the survey mean something specific to them. Mention their website.
- In the final reminder email put in deadlines to have the survey returned. This will mimic their work environment. During the pilot the question was often asked 'When do you want this done by?'
- For ease of tracking change the subject box on the email for the reminders.
- Mention that the strategy section could be related to 'services' and not just products.

4.4.2 Analytical Findings

Figure 4.0 shows the analysis carried out on the pilot data using SPSS [318] (as is all the analysis):

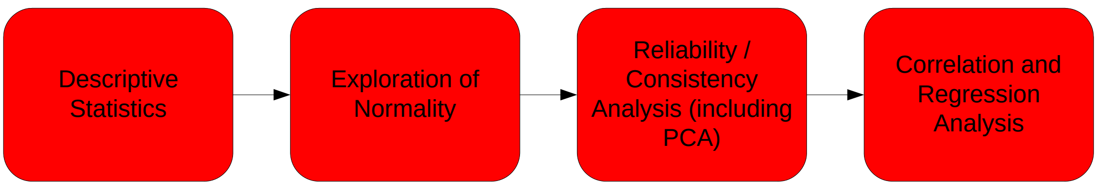

Figure 4.0 Pilot Study Analysis

4.4.2.1 Descriptive Statistics

As can be seen in Table 4.1 below 68% of pilot survey responses were from SMEs in the East (including Dublin) of Ireland (Q41.0). This can be compared to the final study results.

Table 4.1 SME Locations by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	North East	3	12.0	12.0	12.0
	East (Inc Dub)	14	56.0	56.0	68.0
	South	2	8.0	8.0	76.0
	West	5	20.0	20.0	96.0
	Midlands	1	4.0	4.0	100.0
	Total	25	100.0	100.0	

As can be seen in Table 4.2 the majority of responses (36%) considered themselves to be 'Other' (Q38.0). As all the companies were researched on the internet before contact and their product development activity confirmed on the phone before the survey, these responses are valid.

Table 4.2 SME industry sector by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Plastic (No. 1)	2	8.0	8.0	8.0
	Machinery (No. 4)	6	24.0	24.0	32.0
	Elec m/c and Equip (No. 5)	3	12.0	12.0	44.0
	Fab Metal Prod (No. 7)	1	4.0	4.0	48.0
	Healthcare (No. 11)	4	16.0	16.0	64.0
	Other (No. 12)	9	36.0	36.0	100.0
	Total	25	100.0	100.0	

Table 4.3 shows the response count by SME size (Q39.0). As can be seen 32% of responses were from companies with between 51 and 100 employees. However,

between 1 and 50 accounts for 56% so over half the SMEs are small. The spread of SME sizes will be compared with the main study to see if it is typical.

Table 4.3 SME size by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1 – 5 (No. 1)	1	4.0	4.0	4.0
	6 -10 (No. 2)	2	8.0	8.0	12.0
	11 – 20 (No. 3)	5	20.0	20.0	32.0
	21 – 50 (No. 4)	6	24.0	24.0	56.0
	51 – 100 (No. 5)	8	32.0	32.0	88.0
	101- 250 (No. 6)	3	12.0	12.0	100.0
	Total	25	100.0	100.0	

Table 4.4 shows the Total Number of Patents held (Q28.0). 36% of SMEs have no patents while 16% have 5. One SME has 65 patents.

Table 4.4 Total Number of Patents Held

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	9	36.0	37.5	37.5
	1	1	4.0	4.2	41.7
	2	2	8.0	8.3	50.0
	3	2	8.0	8.3	58.3
	4	1	4.0	4.2	62.5
	5	4	16.0	16.7	79.2
	10	2	8.0	8.3	87.5
	19	1	4.0	4.2	91.7
	20	1	4.0	4.2	95.8
	65	1	4.0	4.2	100.0
	Total	24	96.0	100.0	
Missing	System	1	4.0		
Total		25	100.0		

Figure 4.1 shows the Total Number of Patents held (Q28.0) in relation to industry sector (Q38.0).

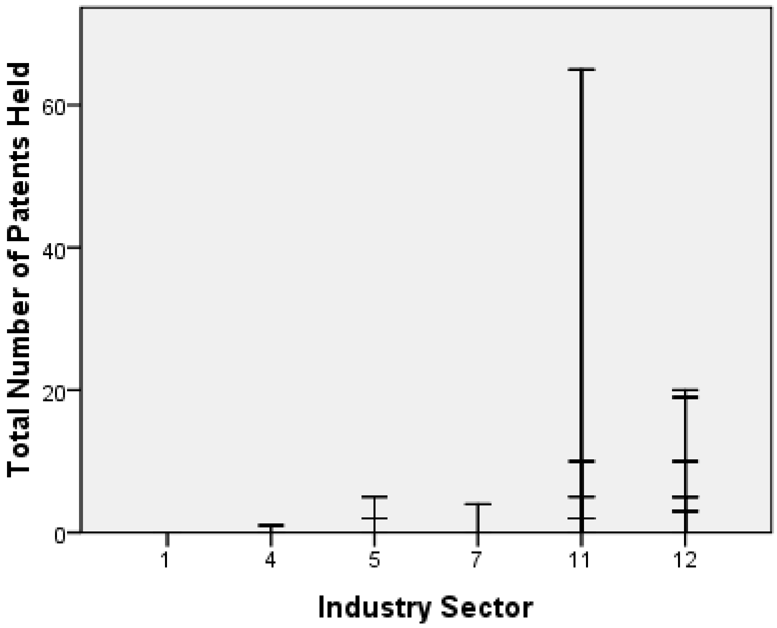

Figure 4.1 No. of Patents Held by Industry Sector

The sector 'Manufacture of Machinery' (Sector No. 4) accounted for 24% of responses. These SMEs do not have products of their own as they design and develop Special Purpose Machines (SPM) to customer specifications. All SMEs choosing Sector N0.4 were examined on the internet. If they were manufacturing equipment as a company product there were put into Sector No.12 (Other) or another applicable sector thus leaving Sector No.4 for special purpose machines (SPM) only. The expectation would be that responses to questions Q21.0, Q22.1, Q22.2, Q22.3 and Q23.0 show low values and Q22.4 higher values i.e. signing of confidential agreements with outsiders; this will be examined further in the final analysis. Figure 4.1 shows SPM sector only has one patent (Sector No. 4). Between Table 4.4 and Figure 4.1 it can be seen that one company in the Healthcare sector (No. 11) has 65 patents and that 'Other' sector (No. 12) has the most patents held.

Figure 4.2 shows that the three sectors (5, 11 and 12) with the highest number of patents held also have the highest number of sales derived from export (Q42.0). Sector No.5 has 12% of SMEs unlike Sector No.11 and No.12 which combined have 52% (Table 4.2).

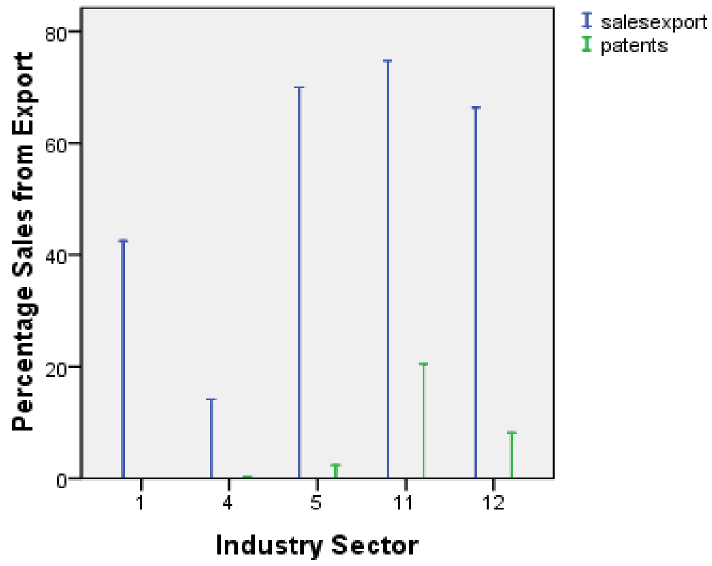

Figure 4.2 Mean sales from Export by Mean Patents held

Figure 4.3 shows that although 'Total number of patents held, (Q28.0)' is high in the 'Other' sector (No.12), these 36% of respondents showed a high mean number of percentage projects failed due to lack of resources (Q33.0). It is interesting to note that lack of resources is generally considered a bigger issue for each industry sector than lack of funding (Q32.0). Also, sectors 5, 7, 11 and 12 all have patents filed in the last year (Q30.0) whereas the SPM sector does not. The one patent filed in this sector is considered an outlier (Figure 4.1).

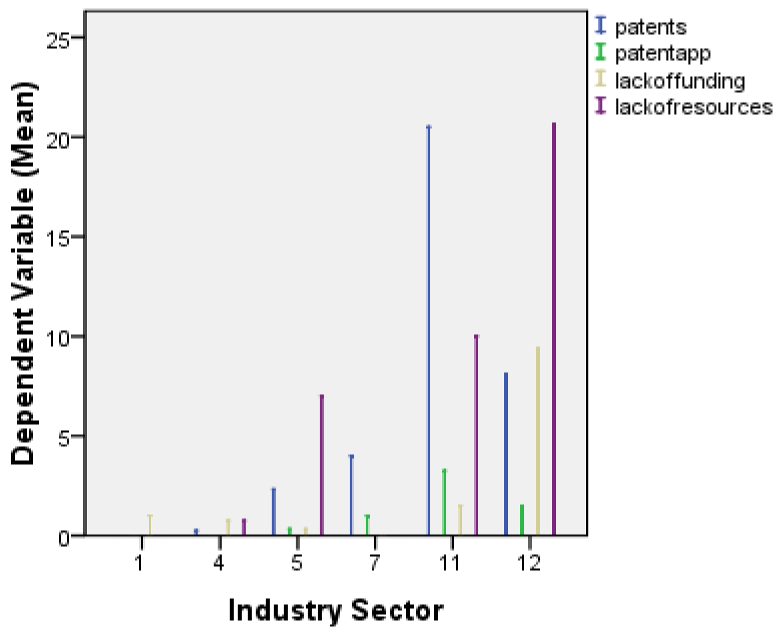

Figure 4.3 Mean Dependent Variables by Industry Sector

Figure 4.4 shows the same variables as Figure 4.3 only now these are compared to the number of employees in an SME (Q39.0). As can be seen the greater number of patents held is in the employee range of 6 – 10 employees (Table 4.3) which is 8% of responses. However, one company in this range has 65 patents and the other has 3. So ignoring the SME with 65 patents the most innovative SME size is the larger range of 101 – 250 employees. SME sectors 3 to 6 have the biggest issue with a lack of resources i.e. 88% of SMEs. The range 6 – 10 has the biggest issue with a lack of funding delaying or cancelling projects (12%).

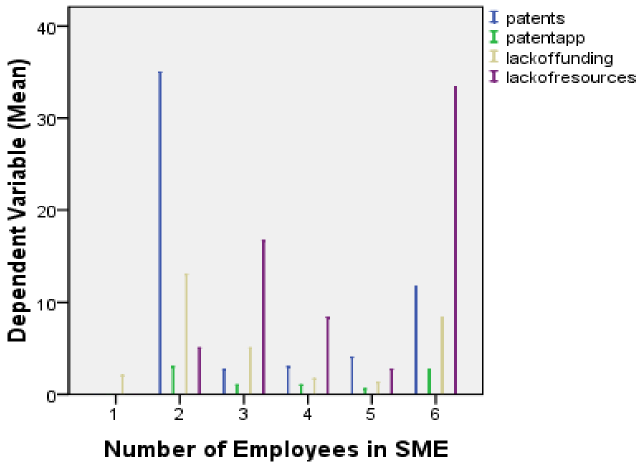

Figure 4.4 Dependent Variable (Mean) by Number of Employees

From Figure 4.5 it was shown that the industry sector ‘Other’ (No. 12) with 36% of respondents had the highest number of design changes from customer complaints (Q31.0) although the number of new product ideas (Q29.0) and the number of patents (Q28.0) is similar (ideas to patents should be a higher ratio to allow for failed ideas).

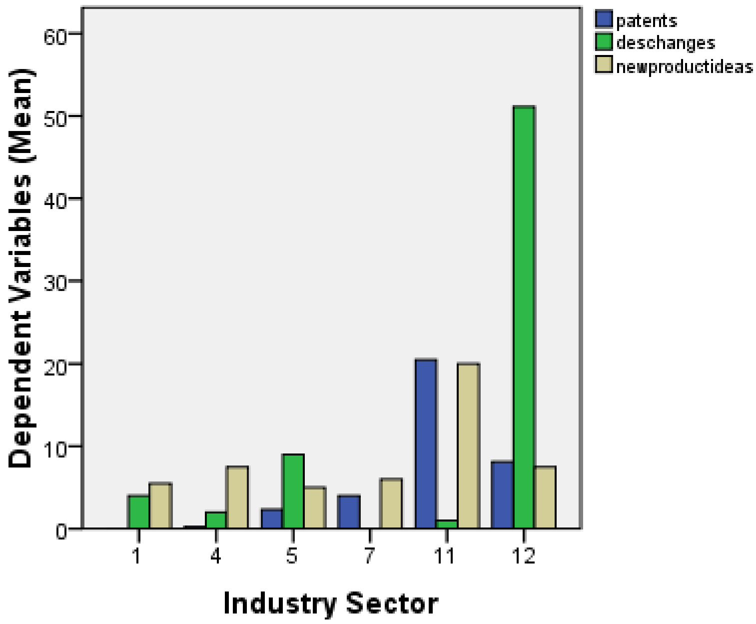

Figure 4.5 Dependent Variable (Mean) by Industry Sector

Figure 4.6 shows that the number of design changes from customer complaints (Q31.0) is also higher in the employee range of 101 – 250 (No.6).

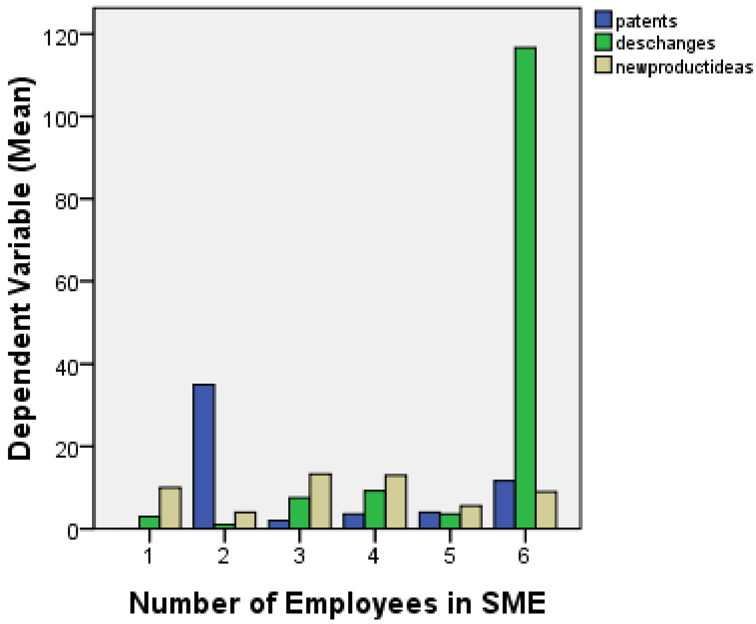

Figure 4.6 Dependent Variable (Mean) by Number of Employees

In relation to the SMEs quality culture (Q27.0) and product development environment the vast majority (21) chose ISO as at least one of their quality environments 84% whereas 4 also said they had a Lean environment (Table 4.5). None of the respondents use a Six Sigma approach. It is therefore assumed from this that they do not use Design for Six Sigma (DFSS) in the product development environment. However, this was investigated in more detail in the final study.

Table 4.5 Quality Culture

	N
ISO	21
Six Sigma	0
Lean	4
TQM	0
Hybrid	1
Other	3
Valid N (listwise)	0

From Table 4.6, 88% of respondents said their product development environment was best described by a Knowledge Based Development or learning environment (Q26.0, A.5.21). As per A.5.20 and A.21.4 this supports the thought that PD is a non-repetitive process with the organisational structure of SMEC 2c (flexible with information flow). In addition A.5.13 is supported in terms of SMEC 3f – however this will be examined further in the final analysis. This finding also relates to A.21.3 via A.7.19 where SMEC 3b is shown to be the case (Informal evaluation and control system/process).

Table 4.6 Product Development Environment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3	12.0	12.0	12.0
	2	22	88.0	88.0	100.0
	Total	25	100.0	100.0	

Table 4.7 shows the percentage of product sales consisting of industrial components sold to other companies rather than sold as the SMEs own product (Q34.0). As can be seen 54% of SMEs sell their own stand alone products whereas 8.3% sell 100% of their products as part of others products (the smaller percentages in-between were deleted).

Table 4.7 Q34 Percentages of Products Sold as Part of Others Products

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	13	52.0	54.2	54.2
	100	2	8.0	8.3	100.0
	Total	24	96.0	100.0	
Missing	System	1	4.0		
Total		25	100.0		

From Figure 4.7 the best represented sector (Other – 36%) is developing more incremental than breakthrough products (Q20.0). The terminology of incremental and breakthrough were used as it removes the need to explain what sustaining and disruptive technology development are because sustaining is incremental or breakthrough (90% incremental) whereas disruptive are predominantly radical or breakthrough. As expected Sector 4 (SPM) is more inclined towards incremental development as their SPM would be mostly one-off 'products or technology' developed incrementally with the customer. Sector 11 (Healthcare – 16% response) on average develops more breakthrough than incremental products. In general Sector 7, 11 and 12 (56% of responses) have a good balance between breakthrough and incremental development.

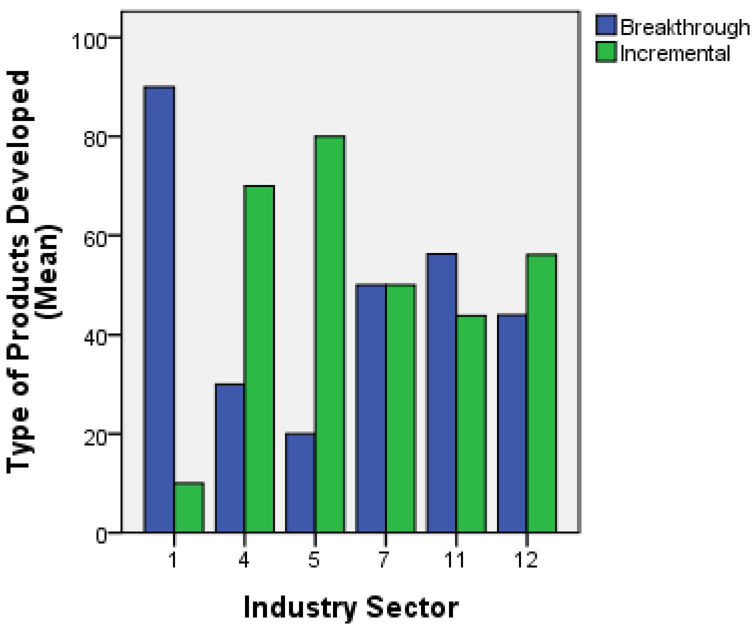

Figure 4.7 Type of Product Developed by Industry Sector

Figure 4.8 shows that as the SME size gets bigger there is a shift from breakthrough to incremental development. This is in line with the thought that SMEs are more innovative.

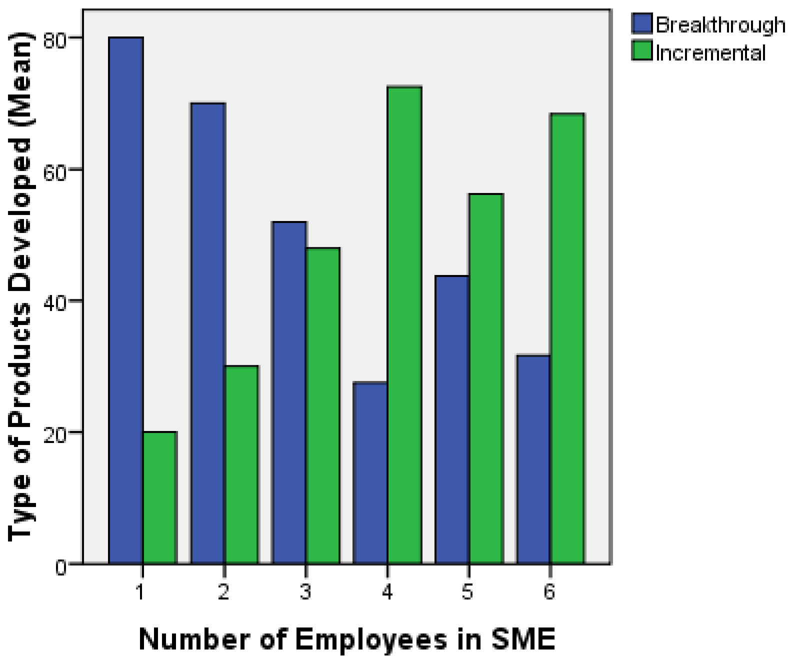

Figure 4.8 Type of Product Developed by No. of Employees in SME

4.4.2.1.1 Descriptive Statistics Conclusion

The three biggest sector responses are 36% from the 'Other' sector, 24% from SPM and 16% from healthcare. The range of 1 – 50 employees accounted for 56% of responses. 84% and 16% of responses had an ISO and Lean environment respectively with no use of Six Sigma reported. 88% chose a Knowledge Based Development environment as the most like their own.

The 'Other' sector has the most patents, SMEs with sales derived from export and highest number of design changes from customer complaints. Sector 7, 11 and 12 (56% of responses) have a good balance between breakthrough and incremental development. Sectors 4, 5, and 7 basically have 100% of their products sold as part of others products whereas sectors 11 and 12 were both 50%. Therefore the healthcare and 'others' sectors are developing more of their own products.

The 101 – 250 employee range has the highest number of design changes from customer complaints. In the range of 11 – 250 (88%) of SMEs had projects delayed or cancelled due to lack of resources rather than lack of funding delaying or cancelling projects whereas the 1 – 10 (12%) range had projects delayed or cancelled due to lack of funding. As SME size gets bigger there is a shift from breakthrough to incremental development.

4.4.2.2 Exploration of Normality

This section examines central tendency, dispersion and distribution i.e. it is looking for normality. This is because normality is assumed in the population the sample of SMEs (respondents) is drawn from. Descriptive statistics are used to examine or explore one variable. This is done by reducing the response data down to descriptive summaries e.g. mean and standard deviation and examining skewness and kurtosis. A measure of central tendency gives a description of the ‘average’ score or response in the distribution; however, the mean and standard deviation are affected by ‘outliers’. Therefore, reference [319] recommends examining the mean, median and mode together (for a normal distribution they are the same). The mean is also affected by skewness, therefore skewness and kurtosis were also examined (deviation from symmetry) with a normal for both being zero. However, according to references [319, 320], if skewness falls between +/- 2 times standard error of skewness and kurtosis falls between +/- 2 times standard error of kurtosis (responses less than 50) the distribution is considered acceptable or normal. According to StatSoft [321], if a distribution is multimodal (many peaks) it may not be homogenous but its sub-samples could be normally distributed. A normal curve is distributed over the histogram in SPSS to aid histogram analysis [320]. The following questions were not checked for normality as they are not discrete variables (could be a continuous variable e.g. 10.56): Q10.0, Q14.0, Q20.0, Q28.0, Q29.0, Q30.0, Q31.0, Q32.0, Q33.0, Q34.0, and Q42.0. For Q27.0, Q38.0 and Q39.0 normality is not a concern, whereas for Q40.0 the answer will not be interval data. Table 4.8 shows the exceptions to normality based on the above criteria and also the items with more than one mode. Positively skewed (to the right) means skewed towards lower values.

Table 4.8 Questionnaire Exceptions to Normality

Item	Skewness	Kurtosis	Mean	Median	Mode
Q3.3	No	No	2.76	3	2*
Q5.5	No	No	3.18	3	3*
Q5.9	Positively	No	2.86	3	2*
Q7.1	No	No	3.5	3.5	3*
Q11.3	No	No	1.56	2	1*
Q11.4	No	No	2.48	2	1*

Item	Skewness	Kurtosis	Mean	Median	Mode
Q16.1	Negatively	No	3.88	4	4
Q17.2	Positively	Leptokurtic	1.24	1	1
Q17.4	Positively	No	1.48	1	1
Q17.7	Positively	No	1.56	1	1
Q17.8	Positively	Leptokurtic	1.32	1	1
Q17.9	Positively	Leptokurtic	1.24	1	1
Q17.11	No	No	2.64	3	1*
Q17.12	Negatively	No	2.56	4	4
Q19.2	No	No	2.72	3	2*
Q19.4	No	No	3.6	4	3*
Q19.5	Negatively	Leptokurtic	4.4	5	5
Q19.7	Positively	No	2.08	2	1
Q19.11	No	No	2.8	3	2*
Q19.13	Positively	No	1.92	2	1
Q21.3	No	No	3.08	3	3*
Q22.4	Negatively	Leptokurtic	4.16	5	5
Q24.4	Negatively	No	3.72	4	4
Q24.8	Negatively	Leptokurtic	3.96	4	4
Q24.9	Negatively	Leptokurtic	3.88	4	4
Q24.13	No	No	3.28	3	3*
Q26.0	Negatively	Leptokurtic	1.88	2	2
Q35.0	Negatively	Leptokurtic	4.16	5	5

* Multiple modes exist. The smallest value is shown.

From Table 4.8, Q3.3 is multimodal with 28% choosing both very little and great extent for fear of organisational change. Q5.5, platform usage, is dependent on the type of products the respondent SMEs develop, which in itself is dependent on the industry e.g. industry sector Q38.4 (SPM) would probably not develop products based on platforms as they develop one off machines. However, Q5.5 is multimodal with 28% of respondents both choosing some extent and great extent and in total 68% using platforms to a some extent or more, implying platform based products among the majority of pilot SMEs. Item Q5.9 shows responses are skewed towards lower values but are also multimodal – both very little extent and some extent are shown as 36%, although no respondent chose ‘not at all’ therefore giving a valid cumulative percentage of 81.8% to some extent or less carrying out market and industry trend analysis. Items Q11.3 and Q11.4 relate to having a guaranteed business and heavy reliance on one customer respectively. Both cases are multimodal with 96% of SMEs not having a guaranteed business and 80% having to some or less of an extent a reliance on one customer. Therefore the pilot respondents should be using a marketing pull strategy (the emphasis of this thesis – See Section 2.11) – this will be examined further in the final study. Item Q7.1 has two modes resulting in a symmetrical response to considering a technology driven strategy when developing their business strategy (mean is 3.5).

Q16.1 is skewed towards lower values which are in line with Table 4.5 where a Six Sigma quality management environment is shown not to exist in the pilot SMEs. This also could affect items Q17.2, Q17.4, Q17.7, Q17.8, Q17.9 which were all skewed towards lower values implying that they are used to a smaller extent than Q17.11 and Q17.12. Especially items Q17.2, Q17.8 and Q17.9 which are leptokurtic i.e. 80%, 76% and 80% not using/familiar with the Kano model, TRIZ or Pugh (whether they are using but are not familiar with these method names will be examined in the final analysis). Q17.12, DFMA, which is skewed towards higher values, has been taught in courses as a design methodology long before Six Sigma or Design for Six Sigma. Item Q17.11 has three modes and a frequency analysis shows that 72% of respondents use DOE to some extent or less. Item Q19.2 and Q19.4 are both multimodal with Q19.2 showing 76% developing technology offline and merging it with new products to some extent or less whereas 84% are developing technology within the PDP evenly between some extent, great extent and a very great extent (28% each). It is unsurprising that SMEs engaged in design activity are skewed in a leptokurtic manner towards CAD (Q19.5) usage. According to Q19.7 responses are skewed towards lower values. Depending on SME size and if they have multiple locations the usage of Netmeeting or WebEx (Q19.7) will vary (to be examined further in the final analysis). Depending on industry sector the use of rapid prototyping (Q19.11) could vary. The responses from the pilot show that 72% of respondents use rapid prototyping to some extent or less – it could be argued that as 64% of respondents are from 'Other, Special Purpose Machines and Fabrication of metal products' industries they would not use Rapid Prototyping unlike the 36% from the other sectors (See Table 4.2). Q19.13 is skewed to lower values which are evident from its mean of 1.92 and the fact that 88% of respondents used CAPP to some or less of an extent.

The negatively skewed leptokurtic Q22.4 shows that SMEs use confidential agreements to a high extent (76% to a great extent or more). Item Q24.4 and Q24.8 are both features of Knowledge Based Development and are shown to be skewed towards higher values (especially the leptokurtic Q24.8). Item Q24.9 is also skewed towards higher values is a leptokurtic manner which implies that most SMEs consider design and manufacturing issues early in the PD process (a characteristic of

Concurrent Engineering). Q26.0 was examined under descriptive statistics (Section 4.4.2.1). Table 4.8 suggests that responses are negatively skewed or skewed towards the higher value of response (Q26.2) which supports the finding that 88% of respondents chose a Knowledge Based Development environment as the most like their own – also in line with responses to items Q24.4 and Q24.8 (this will be examined further in the final analysis). Item Q35.0 is also skewed is a leptokurtic manner towards higher values with 80% reporting a small to significant increase in market share. All of these finding will be compared to the final analysis and in most cases the final analysis will examine these findings further.

4.4.2.3 Reliability/Consistency Analysis

According to Gliem and Gliem [322], single item constructs are not as reliable as summated multi-item scales for drawing conclusions (inferences). Correlation analysis is used to describe the relationship between two or more variables [319, 323]. This is achieved using Cronbach's alpha, which measures how well a set of items (or variables) measures a single one-dimensional latent (hidden) construct. If the data is multi-dimensional then Alpha will be low for all items with 0.70 or higher been acceptable and implying a one-dimensional scale [323]. Cronbach's alpha is used to check for internal validity/consistency [322]. Table 4.9 shows Cronbach's alpha for the multi itemed questions. Questions Q2.0, Q4.0, Q6.0, Q9.0, Q13.0, Q14.0, Q15.0, Q25.0, Q27.0, Q28.0 to Q34.0, Q35.0, Q36.0, Q37.0, Q38.0, Q39.0, Q40.0, Q41.0 and Q42.0 were not analysed as they are all single item questions. In addition, Q10.0 and Q20.0 are both fixed sum or fixed allocation question formats which could result in zero variance between answers whereas Q26.0 gives the option of picking only one answer.

Table 4.9 Cronbach's Alpha for Scaled Items

Question	Cronbach's Alpha	No. of Items	Consistency
Q1.0	0.522	4	No
Q3.0	0.878	5	Yes
Q5.0	0.903	9	Yes
Q7.0	0.478	4	No
Q8.0	0.458	3	No
Q11.0	0.142	5	No
Q12.0	0.795	3	Yes

Question	Cronbach's Alpha	No. of Items	Consistency
Q16.0	0.763	7	Yes
Q17.0	0.791	13	Yes
Q18.0	0.791	7	Yes
Q19.0	0.772	13	Yes
Q21.0	0.784	3	Yes
Q22.0	0.835	4	Yes
Q23.0	0.902	2	Yes
Q24.0	0.865	13	Yes

As can be seen in Table 4.9 four questions would appear to be multi-dimensional i.e. of the 15 questions and their corresponding items capable of been added to the same scale, four questions cannot. Based on these results Principal Component Analysis (PCA) was conducted on Q1.0, Q8.0 and Q11.0. Q7.0 was not processed with PCA as it is not considered as one scale due to the nature of the question (See Section 5.4.2). According to references [320, 324], Principal Components with Eigenvalues greater than (>) 1 should be retained (Kaiser's criterion) although it is also recommended to use a scree plot for questionnaires with more than 30 variables and less than 250 respondents. Scree plots are used in the Section 5.4 to ensure that a high percentage (as below) of the variance is accounted for by the extracted components. Also, the PCA solutions were rotated to get loadings close to one or zero therefore making interpretation of the results easier [324]. According to SPSS Software [320] rotation maintains the cumulative percentage of variation explained by the extracted components and spreads it more evenly over the components.

4.4.2.3.1 PCA for Q1.0:

Table 4.10 PCA of Q1.0 items

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.795	44.870	44.870
2	1.037	25.927	70.797
3	.677	16.929	87.726
4	.491	12.274	100.000

Extraction Method: Component Analysis.

As can be seen Q1.1, Q1.2 and Q1.3 do not measure the same latent construct as Q1.4. A principal component analysis was conducted resulting in two principal components (Q1PC1, Q1PC2), Table 4.11 below.

Table 4.11 Q1PC1 and Q1PC2

Rotated Component Matrix[a]

	Component	
	1	2
Q1.1 CFT	.817	.047
Q1.2 Invite	.808	-.202
Q1.3 desfeed	.682	.264
Q1.4 compeval	.024	.966

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

These two components account for 71% of the variance.

4.4.2.3.2 PCA for Q8.0:

Table 4.12 PCA for Q8.0 items

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.507	50.231	50.231
2	1.044	34.809	85.040
3	.449	14.960	100.000

Extraction Method: Principal Component Analysis.

PCA produced factors Q8PC1 and Q8PC2 as shown in Table 4.13.

Table 4.13 Q8PC1 and Q8PC2

Rotated Component Matrix[a]

	Component	
	1	2
Q8.1 balanced	.884	-.186
Q8.2 aligned	.834	.302
Q8.3 prioritised	.027	.974

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

These components account for 85% of the variance.

4.4.2.3.3 PCA for Q11.0:

Table 4.14 PCA for Q11.0 items

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.667	33.336	33.336
2	1.222	24.435	57.771
3	1.070	21.409	79.180
4	.645	12.900	92.080
5	.396	7.920	100.000

Extraction Method: Principal Component Analysis.

PCA produced factors Q11PC1, Q11PC2 and Q11PC3 as shown in Table 4.15 which account for 79% of the variance.

Table 4.15 Q11PC1, Q11PC2 and Q11PC3

Rotated Component Matrix[a]

	Component		
	1	2	3
Q11.1 veryimport	.872	.080	-.096
Q11.2 priceemphasis	.113	.890	.231
Q11.3 guaranbus	-.334	.751	-.284
Q11.4 relianonecust	-.023	.029	.973
Q11.5 networking	.759	-.191	.090

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 4 iterations.

Table 4.16 shows the new factors resulting from the PCA on Q1, Q8 and Q11. These factors can therefore be used to draw conclusions (inferences) from the survey. However, they will be recalculated based on the final study data.

Table 4.16 PCA factors from Q1, Q8 and Q11

Original Question	Number of Items	Factor 1	Name	Factor 2	Name	Factor 3	Name
Q1	4	Q1PC1	Teamwork, probing, paths	Q1PC2	Eval Comp Prod	N/A	N/A
Q8	3	Q8PC1	Balanced, aligned	Q8PC2	Prioritised	N/A	N/A
Q11	5	Q11PC1	veryimport, Networking	Q11PC2	Priceemphasis, guaranbus	Q11PC3	Relianonecust

4.4.2.4 Correlation and Regression Analysis

The regression line predicts the dependent variable or response 'Y' (axis) from the independent variable (factor or regressor) 'X' (axis). For high scatter a least-squares regression line is 'fitted' where a good fit makes the error (error is 'deviation or residuals' – random (stochastic) and measurement) small [319, 325]. Regression analysis in SPSS also outputs Pearson Correlation r (a measure of linear correlation). If two or more variables are correlated then information about one variable can be used to predict the values of another [319, 326]. It can be used to compare one item to another and determine if they are correlated. Variables are perfectly correlated at -1 or 1 where the larger r (ignoring sign) the higher the correlation (zero means no correlation). Also, for a positive correlation relatively high scores on one variable are paired with relatively high scores on another whereas for a negative correlation relatively high on one variable means relatively low on the other [319]. From [324-327], the estimated regression equation (the equation to fit a line which makes the total error small) is:

Y $= \hat{\alpha} + \hat{\beta}x$, where

$\hat{\beta}$ is the estimated slope and $\hat{\alpha}$ is the intercept or constant (the model-predicted value of the dependent variable 'Y' when the value of all the predictor 'X' or independent variables are equal to 0).

According to references [325, 327] outlying observations in regression exert a 'relatively heavy influence' in the calculation of $\hat{\beta}$ and the more spread out the X axis values the more reliable $\hat{\beta}$. Also, as the sample size increases the distribution of $\hat{\beta}$ and $\hat{\alpha}$ will approach normality (central limit theorem), which is also an assumption used for correlation. In addition, interval data is a requirement. The ordinal data used in the survey has a five point scale which was converted to an interval scale of 1, 2, 3, 4 and 5 for SPSS – this scale has wide response categories from 'not at all' to 'very great extent'. According to Garson [327] this is 'extremely common in literature'. It is also extremely important that the regression model not have important causal variables or extraneous variables excluded or included as they will affect the beta weights and thus the interpretation of the importance of the independent variables [327].

Below is an analysis of Q1PC1 (items Q1.1, Q1.2 and Q1.3) and Q5.4 using the Analysis, Regression and Curve Estimation function of SPSS. Figure 4.9 shows the scatter plot of the dependent variable Q1PC1 against the independent variable utknowledge (5.4) with its 'best fit' line.

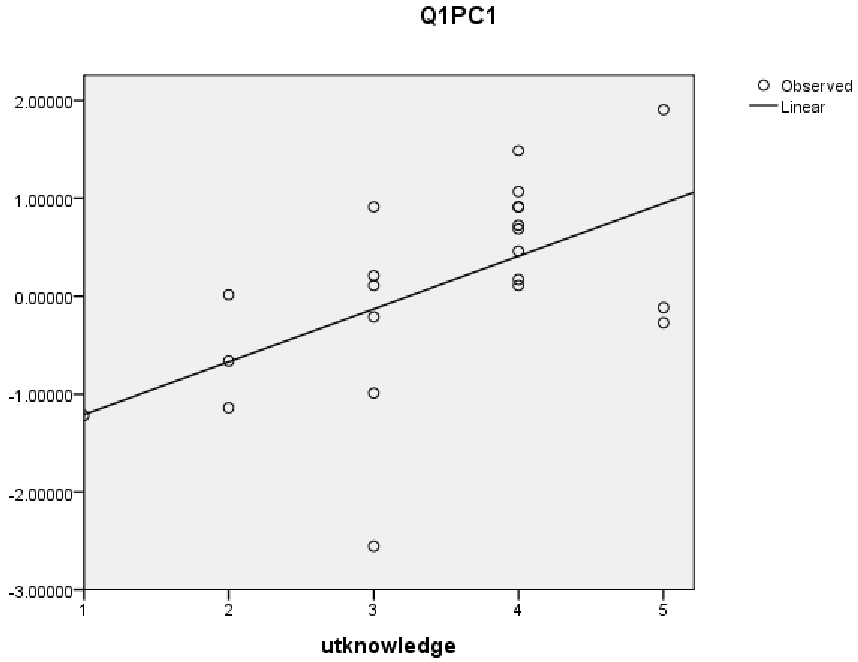

Figure 4.9 Scatter plot of Q1PC1 and item 5.4 Utknowledge

As can be seen the majority of responses were around 3 and 4 i.e. either some or to a great extent. With the exception of one variable the Q1PC1 falls between -1.5 and 1.5 range of responses and the direction is positive. Although there is some scatter it is a relationship which requires further examination because as can be seen in Table 4.17 the significance of the regression model as displayed by the F statistic, 0.006, is less than 0.05 which means that the variation of the model is not due to chance i.e. sampling error (there is a 95% confidence that a relationship of at least this size holds in the population) [320, 327].

Table 4.17 Model Summary and Parameter Estimates

Dependent Variable:Q1PC1

Equation	Model Summary					Parameter Estimates	
	R Square	F	df1	df2	Sig.	Constant	b1
Linear	.319	9.373	1	20	.006	-1.748	.539

The independent variable is utknowledge.

Model	R	Adjusted R Square	Std. Error of the Estimate
1	.565[a]	.285	.85332974

a. Predictors: (Constant), utknowledge

As can also be seen from Table 4.17 there is positive Pearson r = .565 (multiple correlation coefficient) which is closer to 1 than 0 although it is a modest linear correlation (according to reference [326] the rule of thumb is that 0.40 to 0.69 is modest). Q1PC1 (teamwork, probing, paths) – Q1.1, Q1.2 and Q1.3 are evenly spread in this representative factor (Section 4.4.2.3.1) – they are related to A.21.9, A.21.13, A.21.14, A.21.15 and A.19.17 and this examines their relationship to Q5.4 (related to A.21.18 and A.15.29). R-squ, the coefficient of determination, is 0.319 which means, according to references [324, 326], the variation in the variable Q5.4 has explained 32% of the variations in Q1PC1 (dependent variable) in the pilot sample (and vice versa as causality can not be assumed). Table 4.16 also shows the estimated regression equation values, where:

Q1PC1 = 0.539 * utknowledge -1.748 + e1 (where e is the error)

This means that team working, probing and paths changes 0.539 units when the dependent changes one unit. As Q1PC1 is teamwork, probing and paths and Q5.4 measures creation of paths and probing the future with new partners (which would imply teamwork) this means they should be correlated. This will be examined again with the final analysis data.

No further regression analysis will be conducted on the pilot data. This is because with 25 responses it may not be possible to get statistically significant results (possibility of excessive Type I errors). Also, as will be discussed below, the pre-test 2 data and pilot data (these 25 responses) will be used in the final analysis. However, the survey was analysed to understand what relationships and findings will be examined using this combined pilot and final data. This can be seen in Appendix C.4. The next section discusses the final questionnaire methodology.

4.5 Final Questionnaire Methodology

Like Meagher [292], the final questionnaire methodology was the option of an online survey (PDF of which is shown in Appendix C.2 (the pilot questionnaire and final questionnaire were the same), or to fill in the survey in as a word document and email back or to print out and post back. When the companies were contacted (all companies we phoned prior to survey distribution – See Appendix C.5 for the Cold Calling Strategy) they were asked for their preference in terms of these options. No SMEs requested the postal option and in some cases an element of resistance was detected until it was understood that the survey was neither postal or phone based and that they could do it in their own time with the knowledge of it taking only 15min. The final questionnaire followed the same strategy as described in Section 4.2.1. Appendix C.6 shows the Final Questionnaire Email Instructions. As can be seen this comprises two styles. As all companies were phoned prior to sending the survey it was possible to get through directly or via reception to the respondent (Managing Director or R&D Manager or whoever the person in charge of the design and development activity was). However, in some cases the receptionist or whoever answered the phone said they would send it onto the responsible person. Therefore, the style of email changed to style two. As can be seen in Appendix C.7 this also affected the reminders i.e. two styles for both reminder one and the final reminder. As can be seen from Appendix C.5 Cold Call Strategy, Appendix C.6 final questionnaire email and Appendix C.7 reminders all incorporated the findings described in Section 4.4.1. Table 4.18 below shows the final survey call breakdown:

Table 4.18 Final Survey Call Breakdown

	SMEs Called	Bought Over	Out of Business	Not in PD	Miscellaneous	Surveys Sent
Mechanical	157	4	13	21	17	101
Plastics	23	0	2	3	4	14
Electronic	32	4	1	4	7	16
Medical	14	1	1	0	0	11
Total	226	9	17	28	28	142

As can be seen 142 surveys were sent out of a potential 226 (63%). The response rate from the final survey was 70 full responses (49%). The total response rate, between both pre-tests and the pilot was 53% (based on Table 4.0 and Table 4.18) i.e. 95 responses from 179 sent (37+142). According to Ilieva *et al.* [307] a 30% response rate for self-administered questionnaires is considered reasonable. A 2001 study referenced in [307] showed the response rate from email surveys varying between 25% and 50% although one 'business' sector survey referenced was 19%.

4.6 Conclusion

The number of respondents requiring the findings of the pilot survey (Q44.0) was 96% which goes towards proving external validity (24 out of 25). The findings from the exploration of normality (Section 4.4.2.2) will be examined further in the final study. Cronbach's analysis (Table 4.9) showed internal validity for the majority of the scales. For those that were not consistent principal components analysis was used to understand their factors. An example of the correlation and regression analysis was shown in Section 4.4.2.4. Correlation and regression analysis will be used on the hypotheses in Appendix C.4. Therefore the pilot survey was used for the final survey (Appendix C.2). One outcome of the pre-test, pre-test 2 and pilot study was a high level of confidence that the survey can be answered within 15min and that the survey addressed areas relevant to the SMEs to be surveyed. Chapter 5 deals with the analysis of the final responses.

Chapter 5

Final Questionnaire Data Analysis

5.1 Introduction

Chapter 4 covered the non-expert review, pre-tests and pilot study of the questionnaire. Initial analysis was carried out on the pilot data to verify the survey was useable for the final survey. This chapter will conduct the same analysis as shown in Figure 4.0 with the exception of the correlation and regression analysis which will be carried out in Chapter 6.

5.2 Descriptive Statistics

This section describes the final data and also compares it to the pilot findings in order to demonstrate consistency as the same survey was used. As can be seen in Table 5.0 below the majority of respondents (36.8%) were from the East (including Dublin) of Ireland (68% in the pilot). The North East, South and West had a similar number of responses.

Table 5.0 SME Locations by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**North West**	2	2.1	2.1	2.1
	North East	14	14.7	14.7	16.8
	East (Inc Dublin)	35	36.8	36.8	53.7
	South East	9	9.5	9.5	63.2
	South	13	13.7	13.7	76.8
	West	13	13.7	13.7	90.5
	Mid West	5	5.3	5.3	95.8
	Midlands	4	4.2	4.2	100.0
	Total	95	100.0	100.0	

Table 5.1 shows the industry sector by response count. There were no respondents from the manufacture of domestic appliances sector (No. 9) and the manufacture of office equipment and computers (No.2). There was only one respondent from both the 'electronic components' and 'communications equipment' sectors and two from the 'transport and transport equipment' sector. As can be seen the majority of responses were from the sector 'Other' (33%), as were the pilot study responses (36%). Unlike the pilot the next highest sector response count was Fabricated Metal Products at 14.9% (4% in the pilot) with Manufacture of Machinery or Special Purpose Machines representing 12.8% (this was 24% in the pilot). Healthcare also accounted for 12.8% (16% in the pilot) with Rubber and Plastic Products having 7.4%. Like the pilot all SMEs choosing Sector 4 were examined on the internet. If they were manufacturing equipment as a product there were put into sector 12 or another applicable sector thus leaving Sector 4 for special purpose machines (SPM) only.

Table 5.1 SME industry sector by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**Rubber and Plastic Products (No.1)**	7	7.4	7.4	7.4
	Instrumentation (No.3)	5	5.3	5.3	12.8
	Manufacture of Machinery (No. 4)	12	12.6	12.8	25.5
	Manufacture of Electrical Machinery and Equipment (No.5)	9	9.5	9.6	35.1
	Transport and Transport Equipment (No.6)	2	2.1	2.1	37.2
	Fabricated Metal Products (No.7)	14	14.7	14.9	52.1
	Electronics Components (No.8)	1	1.1	1.1	53.2
	Communications Equipment (No.10)	1	1.1	1.1	54.3
	Healthcare Products (No.11)	12	12.6	12.8	67.0
	Other (N0.12)	31	32.6	33.0	100.0
	Total	94	98.9	100.0	
Missing	System	1	1.1		
Total		95	100.0		

As can be seen in Table 5.2 a relatively even spread of responses in terms of SME size was received from the sample frame with 30.5% falling between 1 and 10, 42.2% between 11 and 50 and 27.3% between 51 and 250 employees. Small SMEs accounted for 72.6% (between 1 and 50) whereas this was 56% for the pilot. The smallest response was received in the large SME range of 101 – 250. The fact that the largest percentage responses are in the small SME range makes the results of this thesis more interesting. The findings are from SMEs who have further to grow their business therefore making the results more relevant to smaller SMEs with perhaps considerable potential for expansion.

Table 5.2 SME size by response count

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	**1 – 5 (No. 1)**	14	14.7	14.7	14.7
	6 – 10 (No. 2)	15	15.8	15.8	30.5
	11 – 20 (No. 3	20	21.1	21.1	51.6
	21 – 50 (No. 4)	20	21.1	21.1	72.6
	51 – 100 (No. 5)	18	18.9	18.9	91.6
	101 – 250 (No. 6)	8	8.4	8.4	100.0
	Total	95	100.0	100.0	

Table 5.3 shows the Total Number of Patents Held. As can be seen the respondent from the pilot with 65 patents appears again in the data. The majority of respondents, 37%, have no patents (the pilot value was 36%) with 14% having one. 98% of SMEs have 20 patents or less with 30% having between 2 and 5.

Table 5.3 Total Number of Patents Held

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	35	36.8	41.2	41.2
	1	13	13.7	15.3	56.5
	2	7	7.4	8.2	64.7
	3	7	7.4	8.2	72.9
	4	7	7.4	8.2	81.2
	5	7	7.4	8.2	89.4
	8	1	1.1	1.2	90.6
	9	1	1.1	1.2	91.8
	10	3	3.2	3.5	95.3
	19	1	1.1	1.2	96.5
	20	1	1.1	1.2	97.6
	40	1	1.1	1.2	98.8
	65	1	1.1	1.2	100.0
	Total	85	89.5	100.0	
Missing	System	10	10.5		
Total		95	100.0		

Figure 5.0 shows the Total Number of Patents Held in relation to industry sector.

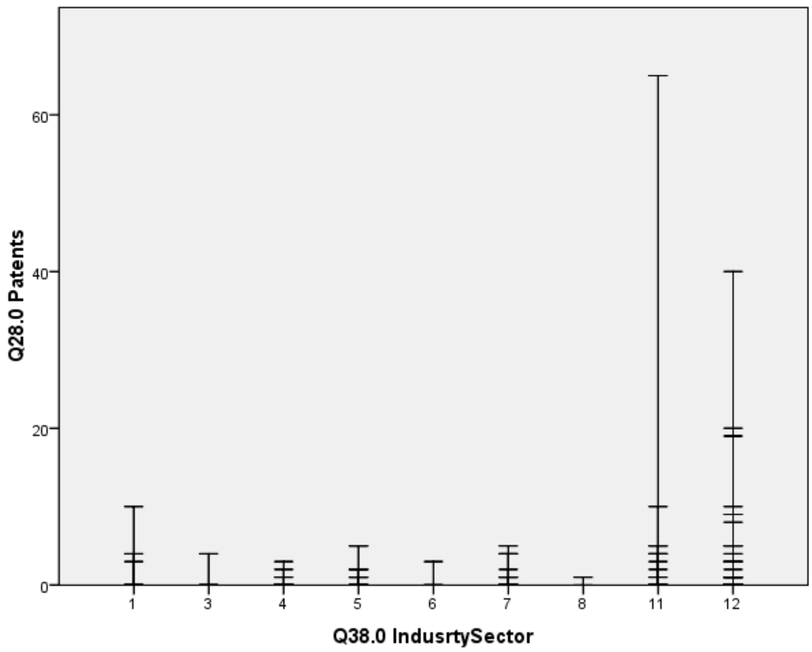

Figure 5.0 No. of Patents Held by Industry Sector

Similar to the pilot study Sector No.12 'Other' has the most patents (ignoring the SME with 65 patents held in the healthcare industry (No.11)). The 7.4% of respondents from the Rubber and Plastic Products sector have a similar number of patents to the Healthcare Sector (ignoring the 65 patents) with its 12.8% response count i.e. the patent count is spread amongst more SMEs. The Fabricated Metal Products sector (No.7) with 15% of respondents has fewer patents than the Healthcare sector. The Manufacture of Machinery sector (12.8% response rate) had one patent in the pilot and how has 6 patents between 3 companies i.e. one with 3, one with 2 and one with 1. These three SMEs are 3% of the respondents and therefore the expectation that responses to questions Q21.0, Q22.1, Q22.2, Q22.3 and Q23.0 show low values and Q22.4 higher values i.e. signing of confidential agreements with outsiders should not affect the overall analysis. Figure 5.1 shows

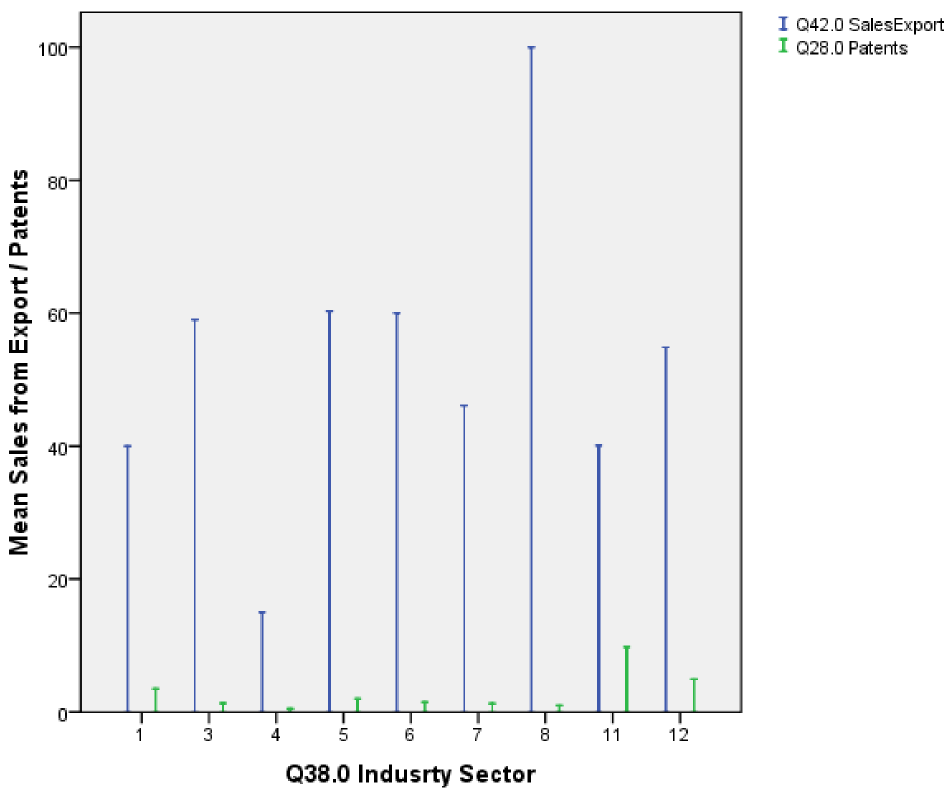

Figure 5.1 Mean Sales from Export and Mean Patents Held by Industry Sector

that the Electronic Components sector has the highest sales from exports (100% - although this is only one respondent) whereas the SPM sector has the lowest sales from export (12.8% of respondents), implying that these SMEs are servicing Irish businesses.

The highest mean number of patents held is in the Healthcare sector (however, this includes the 65 patents held by one SME) which is joint third with SPM for response count. Figure 5.1 also implies that the ‘Other’ sector (No.12) is an innovative sector. The Fabricated Metal Products sector (No.7) has approximately 50% mean sales from export. According to Figure 5.2 the Electronics Components sector suffers from a high percentage of products delayed/cancelled due to both a lack of funding and resources – again, this is only one respondent. Sectors 3, 6, 7, 11 and 12 all have a higher number of products delayed/cancelled due to a lack of resources rather than funding. This was also reported for Sector No.11 and No.12 in the pilot (no responses from sectors 3 and 6 for the pilot). This could be a skills issue as a comment from a respondent in the survey stated that if the funding can be made available the resources can be recruited. Lack of funding is a bigger issue than a lack of resources for the SPM (No.4), Rubber and Plastic Products (No. 1) and Manufacture of Electrical Machinery and Equipment (No. 5) sectors. The sector with the highest number of patent applications is the Healthcare sector – when this is considered along with its number of patents held it is an innovative sector. Sector 10 does not show up on this graph (it only has one respondent and its influence would be minimal).

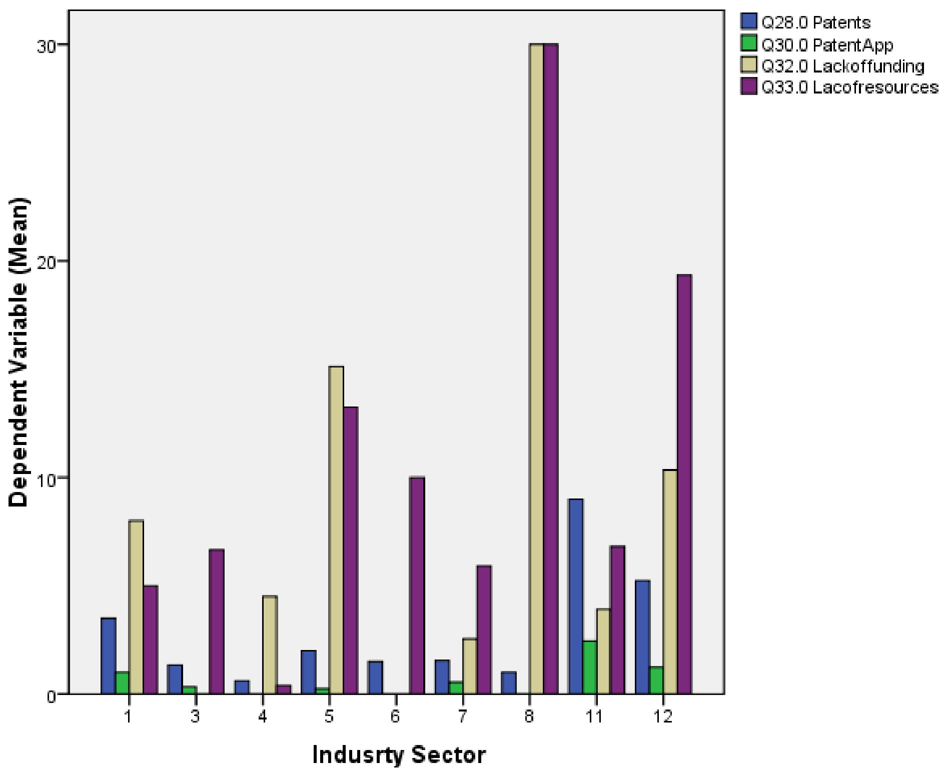

Figure 5.2 Mean Dependent Variables by Industry Sector

From Figure 5.3 it can be seen that the Healthcare sector (No.11) had the largest number of new product ideas and product enhancements evaluated in the last year and the least number of design changes in the same year resulting from customer complaints. The 'Other' sector has a higher number of design changes in comparison to new product ideas and the highest number overall (same in the pilot). Interestingly the SPM sector has the second highest number of new product ideas evaluated in the past year despite having fewer respondents than the 'Other' sector which is third. The Fabricated Metal Products sector (No.7, 15% response) had very few design changes from customer complaints relative to mean number of patents held. All the sectors had more ideas than patents – this allows for failed ideas.

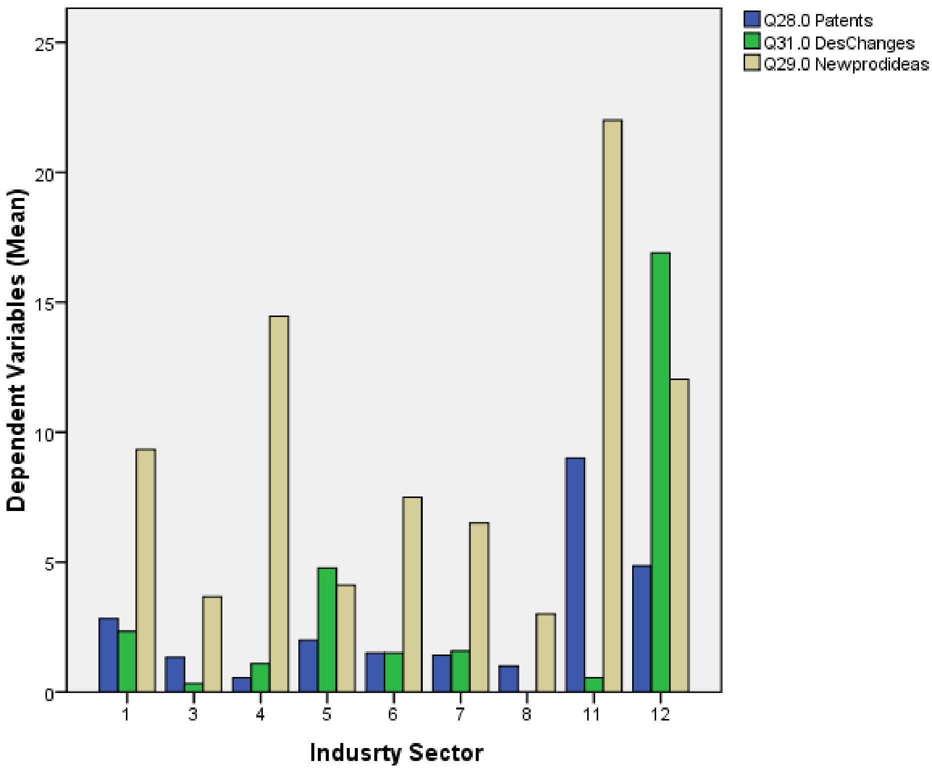

Figure 5.3 Dependent Variable (Mean) by Industry Sector

From Figure 5.4 the highest number of significant design changes resulting from customer complaints in the last year is in the 101 to 250 range (No. 6, as it was in the pilot) although it also has the highest number of patents. As discussed in reference [24] patenting is a measure of new technology knowledge and it tends to increase as company size decreases – comparing No.1 to No.6 it is not the case here – this supports A.13.8 (larger companies patent more). However, the 1 to 5 employee range

(No. 1), 14.7% of responses, is high on new product ideas/enhancements evaluated in the last year with a relatively low number of design changes from customer complaints. The highest number of new product ideas/enhancements evaluated in the last year is in the 21 to 50 employee range (No. 4). The 11 to 20 range (No.3) has a nice spread of new product ideas to design changes to patents. Range No. 2 (6 to 10) has more patents granted and new ideas/product enhancements in last year than design changes resulting from customer complaints.

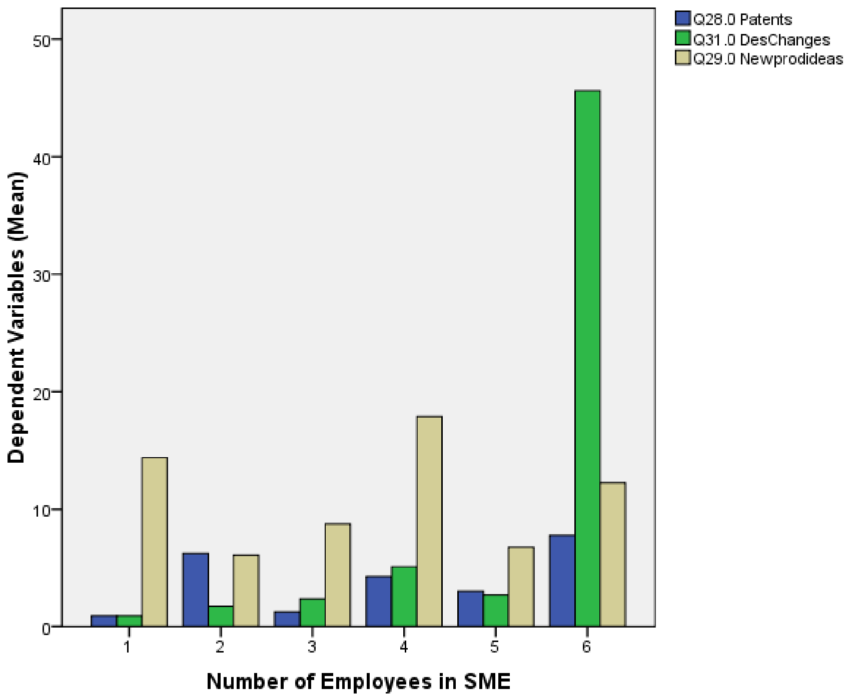

Figure 5.4 Dependent Variables (Mean) by Number of Employees

In relation to the SME quality culture (99% of respondents answered this question) the vast majority (66%) chose ISO as at least one of their quality environments. Only 5% chose Six Sigma (zero in the pilot) with 12% choosing Lean and 25% choosing 'Other'. From the 'Other' comments some used no quality system (e.g. each product is designed for its purpose) whereas some stated they are audited by their customers.

Table 5.4 Quality Culture

	N
Q27.1 ISO	63
Q27.2 Six Sigma	5
Q27.3 Lean	12
Q27.4 TQM	0
Q27.5 Hybrid	7
Q27.6 Other	24
Valid N (listwise)	0

Three SMEs used ISO, Six Sigma and Lean with two only using Six Sigma. Table 5.5 shows the descriptive statistics of Q26.0. As can be seen 85% of respondents chose Knowledge Based Development as their product development environment (88% in the pilot). This is a learning environment (A.5.21) with a non-repetitive PD process (A.5.20, A.7.20) and an organisational structure of SMEC 2c (flexible with information flow). A.7.19 is also a characteristic of this choice where formalisation of jobs is low with less behaviour guided by rules and procedures. In contrast 15% chose the structured based environment which is based on responsibility avoidance, controlling the process and reducing procedure neglect (A.5.13). This finding goes towards supports the hypothesis that SMEs use a KBD environment. However, this will be further tested in Chapter 6.

Table 5.5 Product Development Environment

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	14	14.7	14.9	14.9
	2	80	84.2	85.1	100.0
	Total	94	98.9	100.0	
Missing	System	1	1.1		
Total		95	100.0		

Table 5.6 shows that 49% of SMEs produce their own products (Q34.0, 54% in the pilot) whereas 9.5% (8.3 in the pilot) are 100% manufactured and sold as part of someone else's product (Q34.0, the smaller percentages in-between were deleted).

Table 5.6 Percentages of Products Sold as Part of Others Products

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	0	41	43.2	48.8	48.8
	100	8	8.4	9.5	100.0
	Total	84	88.4	100.0	
Missing	System	11	11.6		
Total		95	100.0		

Figure 5.6 shows that Rubber and Plastic Products (No. 1, 7.8% of respondents), Healthcare (No.11, 12.8% of respondents) and 'Other' (No.12, 33% of respondents) sectors develop more breakthrough than incremental products (only No.1 and No.11 in the pilot) – this is 54% of respondents. Sectors 4, 5, 7, 8, 10 are all developing more incremental products than breakthrough (roughly twice as much). Transport and Transport Equipment Sector (No.6, 2.1% of respondents) develop considerably more incremental than breakthrough products.

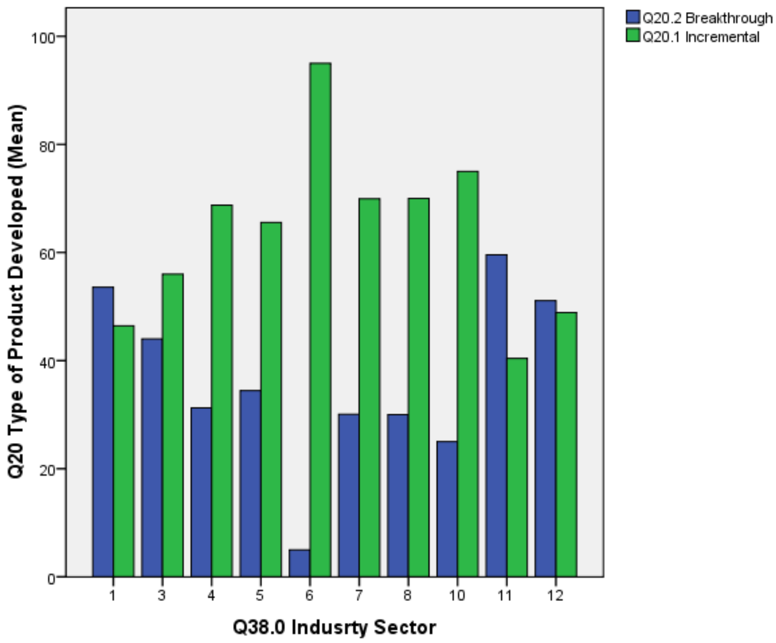

Figure 5.6 Type of Product Developed by Industry Sector

Figure 5.7 shows that the 14.7% of respondents in the 1 – 5 employee size range (No.1) develop twice as many breakthrough products as incremental products and are the only SME size range to develop more breakthrough than incremental products.

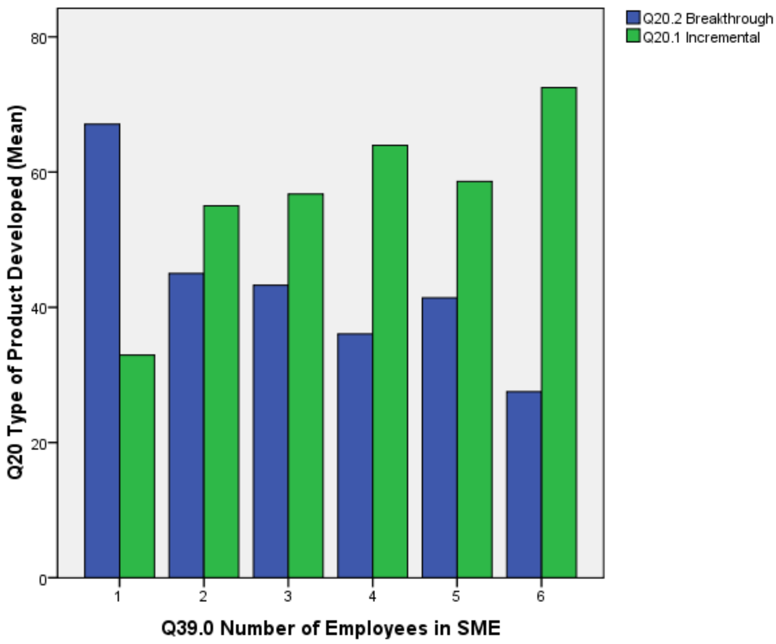

Figure 5.7 Type of Product Developed by SME size

In contrast the 101 to 250 employee range (No.6) is close to the complete opposite. 54% of sectors are developing more breakthrough than incremental products with small SMEs (72.6% of respondents which range between 1 and 50 employees) developing more incremental products than breakthrough (No.1 to No.4). As discussed in Section 2.3.2.7 reference [14] stated that Irish SMEs are focusing on breakthrough rather than incremental products – here this appears to be 50:50 in terms of sectors with smaller companies developing incremental products. According to A.8.2 SMEs are unable to develop technology offline (Q19.2) and merge with new products and it is safer to develop incremental products of current offerings. As can be seen in Table 5.7, 79% of respondents develop products off line and merge with new products to some extent or less whereas 84% develop products within their PDP to some extent or more (Q19.4, Table 5.8).

Table 5.7 Technology is Developed Offline

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	15	15.8	15.8	15.8
	2	22	23.2	23.2	38.9
	3	38	40.0	40.0	78.9
	4	15	15.8	15.8	94.7
	5	5	5.3	5.3	100.0
	Total	95	100.0	100.0	

Table 5.8 Technology is developed within the PDP

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	6	6.3	6.3	6.3
	2	9	9.5	9.5	15.8
	3	27	28.4	28.4	44.2
	4	26	27.4	27.4	71.6
	5	27	28.4	28.4	100.0
	Total	95	100.0	100.0	

Thus, the SMEs from the sample frame are developing incremental products within their PDP. However, it is also suggested (A.22.25, A.8.1) that bursts of radical or breakthrough innovation are carried out through ideation. Table 5.9 shows that 62% of respondents carry out ideation using tools and methodologies (Q19.1) to a very little extent or less, although 21% responded to a great extent or more.

Table 5.9 Ideation using Tools and Methodologies

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	19	20.0	20.0	20.0
	2	21	22.1	22.1	42.1
	3	35	36.8	36.8	78.9
	4	14	14.7	14.7	93.7
	5	6	6.3	6.3	100.0
	Total	95	100.0	100.0	

5.2.1 Descriptive Statistics Conclusion

The majority of respondents (36.8%) were from the East (including Dublin) of Ireland (68% in the pilot) with a relatively even spread of responses in terms of SME size. 36.8% have no patents (the pilot value was 36%) with 13.7% having one, 97.6% of SMEs have 20 patents or less and 29.6% have between 2 and 5. Sectors 12, 7, 11 and 4 represent 74% of respondents, therefore:

- Sector No. 12 'Other' (33% of respondents) – Similar to the pilot study this sector has the most patents and a higher number of products delayed/cancelled due to a lack of resources rather than funding.
- Sector No. 7 Fabricated Metal Products (15% of respondents) – Higher number of products delayed/cancelled due to a lack of resources rather than funding. This sector has approximately 50 mean sales from export.
- Sector No. 11 Healthcare (12.8% of respondents) - Higher number of products delayed/cancelled due to a lack of resources rather than funding. Had the largest number of new product ideas and product enhancements evaluated in the last year and the least number of design changes in the same year resulting from customer complaints.
- Sector No. 4 Special Purpose Machines (12.8% of respondents) – Lack of funding is a bigger issue than a lack of resources for SPM. Has the lowest sales from export (12.8% of respondents), implying that these SMEs are servicing Irish businesses. Interestingly the SPM sector has the second highest number of new product ideas/enhancements evaluated in the past year but has a greater issue with funding than with resources.

Sectors 3 and 6 also have a higher number of products delayed/cancelled due to a lack of resources rather than funding. Lack of funding is also a bigger issue than a lack of resources for the Rubber and Plastic Products (No. 1) and Manufacture of Electrical Machinery and Equipment (No. 5) sectors. All the sectors had more ideas than patents which allows for failed ideas. The highest number of new product ideas/enhancements evaluated in the last year is in the 21 to 50 employee range (No. 4). From Figure 5.4 the highest number of significant design changes resulting from customer complaints in the last year is in the 101 to 250 range. In relation to SME quality culture (99% of respondents answered this question) the vast majority (63) chose ISO as at least one of their quality environments. Only 5 chose Six Sigma (zero in the pilot) with 12 choosing Lean and 24 choosing 'Other' i.e. none of the other options. 85% of respondents chose Knowledge Based Development as their product development environment (88% in the pilot). This finding supports the hypothesis that SMEs use a KBD environment. 49% of SMEs produce their own products with 54% of sectors developing more breakthrough than incremental products but small SMEs (73% of respondents which range between 1 and 50 employees) developing more incremental products than breakthrough (No.1 to No.4). The sample frame is developing incremental products within their PDP with a high 62% of respondents carrying out ideation using tools and methodologies to a very little extent or less.

5.3 Exploration of Normality

As in Section 4.4.2.2 this section examines central tendency, dispersion and distribution i.e. it is looking from normality. Table 5.10 shows the exceptions to normality and highlights in 'yellow' the common exceptions between the final data and the pilot. Again, positively skewed (to the right) means skewed towards lower values and a leptokurtic kurtosis means statistical values are positive and distributions have higher peaks around the mean. The letter 'N' is used to denote the number of responses. Item Q1.1 is skewed towards higher values (80% to some extent or more) which proves A.7.12 and is a positive sign as described in A.7.8.

Table 5.10 Exploration of Normality (Final Study compared to Pilot)

Final Study						Pilot					
Item	Skewness	Kurtosis	Mean	Median	Mode	Item	Skewness	Kurtosis	Mean	Median	Mode
Q1.1	Negatively	No	3.4	4	4						
Q2.0	Negatively	No	3.88	4	4						
Q3.1	Negatively	No	2.81	3	3	Q3.3	No	No	2.76	3	2*
Q5.5	Negatively	No	3.55	4	4	Q5.5	No	No	3.18	3	3*
Q5.8	Negatively	No	3.52	4	4	Q5.9	Positively	No	2.86	3	2*
Q7.2	Negatively	Leptokurtic	3.8	4	4	Q7.1	No	No	3.5	3.5	3*
Q8.1	Negatively	No	3.2	3	3						
Q8.2	Negatively	Leptokurtic	3.77	4	4						
Q8.3	Negatively	Leptokurtic	3.88	4	4						
Q9.0	No	No	3.37	3	3*						
Q11.3	Positively	Leptokurtic	1.79	2	1	Q11.3	No	No	1.56	2	1*
Q11.4	Positively	No	2.32	2	2	Q11.4	No	No	2.48	2	1*
Q15.0	Negatively	No	3.93	4	4						
Q16.2	Negatively	Leptokurtic	3.72	4	4	Q16.1	Negatively	No	3.88	4	4
Q16.3	Negatively	No	3.67	4	4						
Q16.4	Negatively	No	3.68	4	4						
Q16.6	Negatively	No	3.66	4	4						
Q16.7	Negatively	No	3.32	3	4						
Q17.1	Positively	Platykurtic	2	1	1						
Q17.2	Positively	Leptokurtic	1.26	1	1	Q17.2	Positively	Leptokurtic	1.24	1	1
Q17.3	Positively	No	1.84	1	1						
Q17.4	Positively	No	1.42	1	1	Q17.4	Positively	No	1.48	1	1
Q17.5	No	Platykurtic	2.61	3	1						
Q17.6	Positively	No	1.53	1	1						
Q17.7	Positively	Leptokurtic	1.52	1	1	Q17.7	Positively	No	1.56	1	1
Q17.8	Positively	Leptokurtic	1.27	1	1	Q17.8	Positively	Leptokurtic	1.32	1	1

Q17.9	Positively	Leptokurtic	1.28	1	1	Q17.9	Positively	Leptokurtic	1.24	1	1
Q17.10	No	Platykurtic	2.72	3	1*						
Q17.11	No	Platykurtic	2.45	2	1	Q17.11	No	No	2.64	3	1*
Q17.12	Negatively	Platykurtic	3.2	4	4	Q17.12	Negatively	No	2.56	4	4
Q17.13	Positively	No	2	2	1						
Q19.3	Negatively	No	3.82	4	5	Q19.2	No	No	2.72	3	2*
Q19.4	Negatively	No	3.62	4	3*	Q19.4	No	No	3.6	4	3*
Q19.5	Negatively	Leptokurtic	4.28	5	5	Q19.5	Negatively	Leptokurtic	4.4	5	5
Q19.6	No	Platykurtic	2.82	2	1						
Q19.7	Positively	Platykurtic	1.83	1	1	Q19.7	Positively	No	2.08	2	1
Q19.8	Positively	Platykurtic	2.47	2	1						
Q19.9	Positively	Platykurtic	2.06	1	1						
Q19.10	Positively	Platykurtic	2.09	1	1						
Q19.11	No	Platykurtic	2.47	2	1	Q19.11	No	No	2.8	3	2*
Q19.13	Positively	Platykurtic	1.98	1	1	Q19.13	Positively	No	1.92	2	1
Q21.1	No	Platykurtic	2.97	3	1	Q21.3	No	No	3.08	3	3*
Q22.1	No	Platykurtic	3.06	3	5						
Q22.2	Positively	No	2.36	2	1						
Q22.3	Positively	No	2.15	2	1						
Q22.4	Negatively	No	3.61	4	5	Q22.4	Negatively	Leptokurtic	4.16	5	5
Q23.1	No	Platykurtic	2.73	3	3						
Q23.2	Positively	Platykurtic	2.47	2	1						
Q24.4	Negatively	No	3.63	4	4	Q24.4	Negatively	No	3.72	4	4
Q24.8	Negatively	No	3.67	4	4	Q24.8	Negatively	Leptokurtic	3.96	4	4
Q24.9	Negatively	No	3.79	4	4	Q24.9	Negatively	Leptokurtic	3.88	4	4
Q24.10	No	Platykurtic	2.61	2	1						
Q24.11	Negatively	No	3.38	4	4	Q24.13	No	No	3.28	3	3*
Q25.0	Positively	No	2.2	2	1						
Q26.0	Negatively	Leptokurtic	1	2	2	Q26.0	Negatively	Leptokurtic	1.88	2	2
Q35.0	Negatively	No	3.9	4	4	Q35.0	Negatively	Leptokurtic	4.16	5	5

Q2.0 is also skewed towards higher values in line with Q1.1 for forming task forces and integrating departments for a two way flow of work, resources and information (A.7.20). Q3.1 is also skewed towards higher values in this case indicating that the SMEs do not have a lack of communication in their organisation.

Q5.5 is skewed towards higher values (it was multimodal in the pilot with 68% using platforms to some extent or more, now 59%) which means that these SMEs use product platforms (A.1.15) and therefore have product components, modules or assets across a family of products. According to A.15.14 this is an alternative strategy to the four business types or the five strategy types (See Chapter 6).

The negative skewness of Q5.8 implies that SMEs that identify the factors which make competitors profitable and successful (81% of respondents replied to some extent or more to Q5.7) also identify solution to these factors for their customers (median and mode are 'great extent'). This also supports the use of a performance audit or SWOT (A.15.5) which is part of the FFE (A.1.4). Q7.2 is skewed towards higher values with 95% of respondents choosing a marketing driven strategy to some extent or more (51% to a great extent). This was 84% for Q7.1, 86% for Q7.3 and 73% for Q7.4 with N83 (See Chapter 6).

Q8.1, Q8.2 and Q8.3 are all skewed towards higher values with 85%, 94% and 94% respectively choosing some extent or more to three elements of product portfolio usage. Both Q8.2 and Q8.3 had 54% for great extent with N83. Although these are all high the items do not specifically mention product portfolios but it does imply SMEs carry out these activities in some manner (this is one of the hypothesis in Section 3.2.1.2). If carried out correctly they should get the benefit (A.1.14). This finding also implies that SMEs have a strategic focus and an innovative process (SMEC 3d, 3f).

Q9.0 is multimodal with 37% response rate to both some and great extent or 84% stating that they map future technology against current customer and technology requirements to some extent or more (N83). Again, A.15.27 via strategic characteristic A.1.16 implies that this 84% use Technology Roadmapping or would if they were aware of it. Q11.3 and Q11.4 were both multimodal in the pilot and are now skewed towards lower values with 85% and 60% having a guaranteed business and reliance on one customer to 'a very little extent' or 'not at all' (N95). When the response to Q11.3 and Q11.4 are considered along with the responses to Q7.2 it implies that SMEs should use a strong marking pull PDP – which this thesis is based on (See Section 2.11). This implies that responses to Q1.0, Q5.0, Q6.0, Q8.0, Q9.0 and Q10.1 (containing Q7.1, Q7.2 and Q7.3) or Q10.2 should all be high on the rating scale i.e. great extent or more.

For Q15.0 (N95), 93% of respondents have chosen to a great extent or more for the owner/manager assuming the role of facilitator during development activity (43% choosing 'great extent'). One respondent commented that "everyone is involved in innovation and it is driven by the owner/manager". Considering Q1.1 (80% to some extent or more) and Q15.0 (A.9.3) organisational decision making is decentralised. This gives the advantages of A.7.18 and means the Owner/Manager is delegating and possibly focusing on strategic issues (A.9.1). One of the influences of this is size (A.21.2) and as stated 73% of respondents range between 1 and 50 employees. This implies SMEs with the following positive characteristics - 3b, 3c, 4g, 5f with a reduced amount of 5i and 5j (Table 2.1).

Some of the Q16.0 items and Q17.0 items in Table 5.10 are related – Q16.0 and Q18.0 are the key characteristics of Q17.0 items explained in words. Table 5.11 shows these items in their own table with their percentage responses (N95). As can be seen all Q16.0 items have responses which are high on the rating scale while Q17.0 items are low (Q17.2, Q17.8 and Q17.9 were also leptokurtic in the pilot). This goes towards proving one of the hypotheses in Section 3.2.1.2 i.e. SMEs are using T&M such as Q16.0 items but are not aware of them.

Table 5.11 Comparison of Q16.0 to Q17.0

Item	**Skewness**	**Kurtosis**	**Some extent or more (%)**	**Great Extent (%)**	**Item**	**Skewness**	**Kurtosis**	**Very Little Extent or less (%)**	**Not At All (%)**
Q16.2	Negatively	Leptokurtic	93	59	Q17.2	Positively	Leptokurtic	94	80
Q16.3	Negatively	No	90.5	53	Q17.3	Positively	No	69	57
Q16.4	Negatively	No	94	58	Q17.3	Positively	No	69	57
Q16.6	Negatively	No	89	47	Q17.5	No	Platykurtic	44	35
Q16.7	Negatively	No	80	39	Q17.6	Positively	No	84	66

This is also supported by comments from this section of the survey i.e. "We could well use many of these methodologies, but not by name!" and "While some of us have a little training in some of these methodologies, we apply them in an informal way (keeping certain things in mind) rather than going through a formal numerical/form-based process". It is suggested in this thesis that these T&M are not used due to time constraints and that if they were 'simplified' they would be used. Another comment supports this stance "Most of the time our turn around time for a customised product is two weeks. We have created our own short form documents to clearly define in short terse manner the requirements of our product". This is in line with A.5.2. The exception to this is Q17.5 which is FMEA. This is one of the better known and used methodologies with 56% of responses in the some extent or more range. In fact all of the Q17.0 items are showing as non-normal. Table 5.12 shows the remaining item Q17.0 and their corresponding Q16.0 and Q18.0 items (N95).

Table 5.12 Comparison of Q17.0 to Q16.0 and Q18.0 Frequencies

Item	Skewness	Kurtosis	Some extent or more (%)	Some Extent (%)	Item	Skewness	Kurtosis	Very Little Extent or less (%)	Not At All (%)
N/A	N/A	N/A	N/A	N/A	Q17.1	Positively	Platykurtic	61	52
Q16.5	No	No	73	35	Q17.4	Positively	No	87.5	70.5
Q18.1	No	No	88.5	35	Q17.7	Positively	Leptokurtic	83	69.5
Q18.2	No	No	90.5	36	Q17.8	Positively	Leptokurtic	95	79
Q18.3	No	No	76	38	Q17.8	Positively	Leptokurtic	95	79
Q18.1	No	No	88.5	35	Q17.9	Positively	Leptokurtic	94	78
Q18.5	No	No	59	29.5	Q17.10	No	Platykurtic	38	29.5
Q18.7	No	No	69.5	36	Q17.11	No	Platykurtic	52	35
N/A	N/A	N/A	N/A	N/A	Q17.12	Negatively	Platykurtic	26	23
Q18.7	No	No	69.5	36	Q17.13	Positively	No	66	46

Again, Q16.0 and Q18.0 items have high responses whereas their corresponding T&M in Q17.0 have low response usage (Q18.1 and Q18.2 have a 40% and 41% response to 'great extent'). The exceptions to this are Q17.10 (Robust Design), Q17.11 (DOE) and Q17.12 (DFMA). Considering that only 5% stated they have a Six Sigma quality environment this is surprising for Q17.10 and Q17.11. Q17.12, like Q17.5 is a well known methodology hence 74% chose some extent or more. It was anticipated that this would be a well know methodology which is why there is no corresponding Q16.0 or Q18.0 (reduction of questionnaire items). These relationships are further examined in Chapter 6.

Table 5.13 shows Q19.0 items from Table 5.10 and their frequencies (Q19.5 was also leptokurtic in the pilot, N95). As can be seem Q19.3, Q19.4 (see Table 5.8) and Q19.5 are all high responses with Q19.5 having a 59% response to very great extent. It is expected that SMEs involved in design and development have a high usage of CAD (Q19.5). It is interesting to see a high usage of CAE (Q19.3) with a 39% usage reported to a very great extent. Also, 49% of respondents use simulation software to evaluate multiple design alternatives (Q24.10, Table 5.16) – this is high considering the high range of SMEs in the 1 to 50 employee range (73%) – the expectation would be that larger SMEs use simulation software more than small, although it is also industry dependent. Figure 5.8 shows that employee range No.3 and No.4 use simulation software the most (more respondents – case labels), through the range 'not at all' to 'very great extent'. So there is a high usage among small companies. Although there are 94 respondents to Q24.10 some are missing from Figure 5.8 as data labels, in this case the case numbers, can overlap [320] – however, the missing labels do not affect the conclusion. The SPM sector No.4 and Section No.12 'Other' also use simulation more than the remaining sectors. There are a few responses in the healthcare sector (No. 11) although there usage is mostly in the some extent or less range (3 and below).

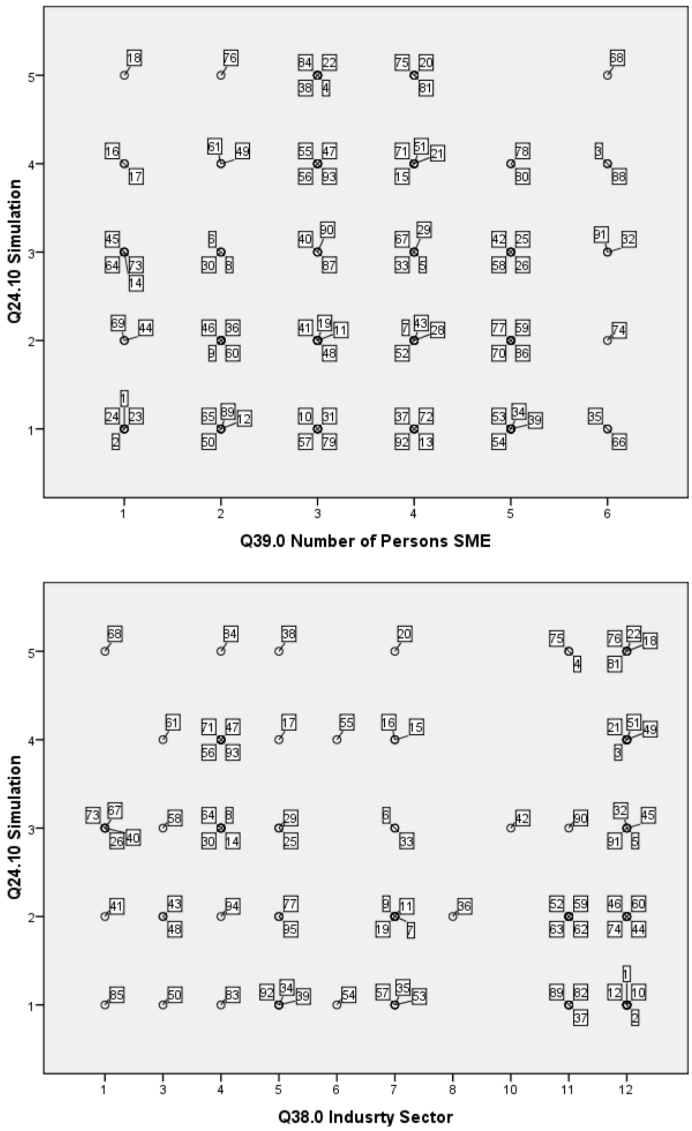

Figure 5.8 Simulation Software Usage by Number of Persons in SME and Industry Sector

Items Q19.6 to Q19.11 and Q19.13 are all skewed towards lower values and in fact are platykurtic as can be seen from the high ‘Not at all’ responses.

Table 5.13 Q19 Item Frequencies

Item	Skewness	Kurtosis	Some extent or more (%)	Not At All (%)
Q19.3	Negatively	No	84	8
Q19.4	Negatively	No	84	6
Q19.5	Negatively	Leptokurtic	91.5	7
Q19.6	No	Platykurtic	51.6	34
Q19.7	Positively	Platykurtic	26	57
Q19.8	Positively	Platykurtic	45	42
Q19.9	Positively	Platykurtic	34	53
Q19.10	Positively	Platykurtic	34	52
Q19.11	No	Platykurtic	48.5	40
Q19.13	Positively	Platykurtic	27	52

Q19.6 and Q19.8 are related to CAD/CAM integration – IGES and STEP. The usage of these technologies reduces errors and they speed up the development process, see A.18.17 – however, they would not apply to SMEs who outsource their manufacturing. Figure 5.9 shows the responses to the STEP214 (Q19.8) usage against the industry sector. Sector No.4 (SPM) and Sector No.12 (Other) have a similar number of respondents. Sector No.4 with 12.8% response rate (the same as Healthcare No.11) has a higher usage than Healthcare and the other sectors. However, SPM companies are more likely to design and manufacture in their own facility allowing CAD/CAM integration.

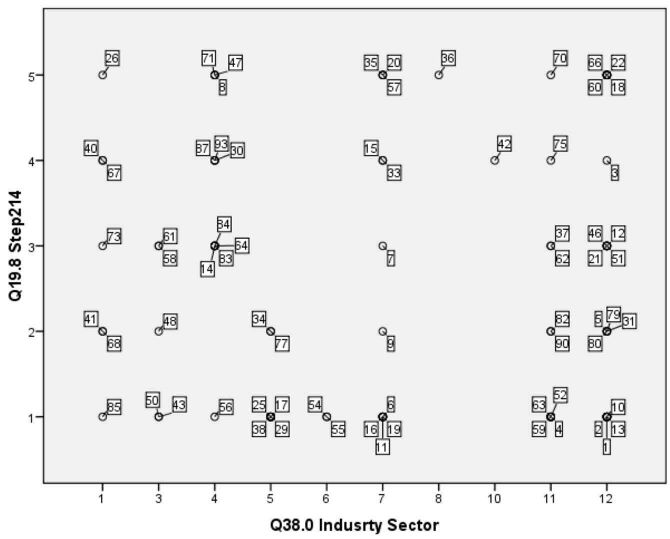

Figure 5.9 Step 214 usage by Industry Sector

Netmeeting and WebEx are collaboration technologies (Q19.7) – their low usage is not surprising considering the 73% employee range i.e. the need for these technologies would be more in larger or multiple site companies. However, they could also be used to work with international companies bringing the advantages of A.18.22. Q19.9 and Q19.10 are related to rapid tooling while Q19.11 is checking for usage of rapid prototyping (RP) – all report low usage and a high 'not at all' response. RP usage is however higher than RT usage – it would be a better known technology and there is the possibility of SME developing vast amounts of prototypes to have purchased their own RP machine (A.8.26). The requirement for these technologies would be dependent on the product under development i.e. the industry. Figure 5.10 shows the responses to the RP (Q19.11) usage against the industry sector. Sector No.1 Rubber and Plastic Products, Sector No. 11 (Healthcare) and Sector No.12 (Other) all have a high number of respondents and usage. Of these Sector No. 12 has both a high response and usage (4 respondents using RP to a very great extent).

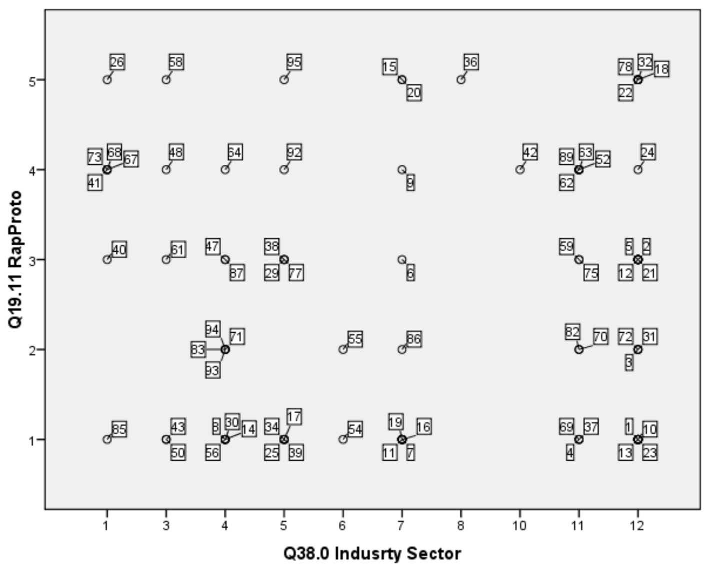

Figure 5.10 Rapid Prototyping by Industry Sector

Q19.13 is related to CAPP usage and implies a low usage of VPP and GPP (A.22.8 and A.22.9). This is a similar situation to Q19.6 and Q19.8 (IGES and STEP214). IPP using patents (Q21.1, N95) is shown in Figure 5.11. As can be seen it is used at extremes with 29 SMEs not using it at all and 28 SMEs using it to a very great extent.

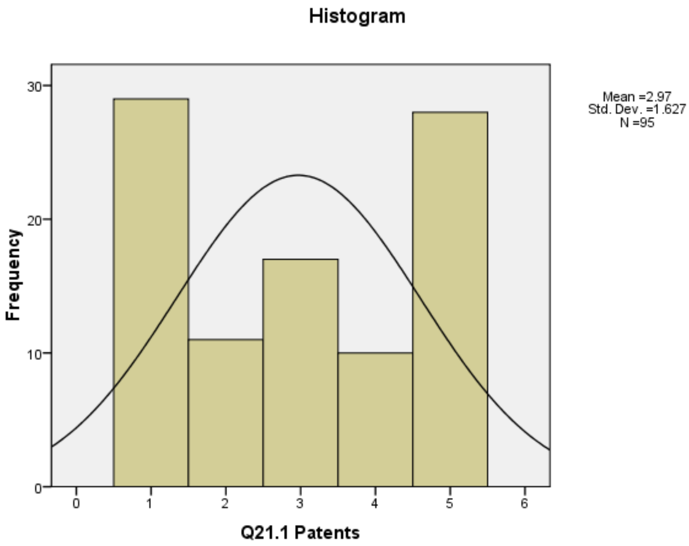

Figure 5.11 Patent Usage Frequencies

Figure 5.12 shows the spread of this patent usage over the industry sector. The 'Other' sector (No.12) and the Healthcare sector (No.11) have the highest usage of patents. This is in line with earlier findings on most patents held (See Figure 5.0). It is clear that sectors No.12 (33%), No.11 (12.8% response rate) and No.7 (15%) cause the high response on Figure 5.11 whereas No.1 (7.4%) and No.4 (12.8%) account for the middle range. The remaining sectors account for the lower range.

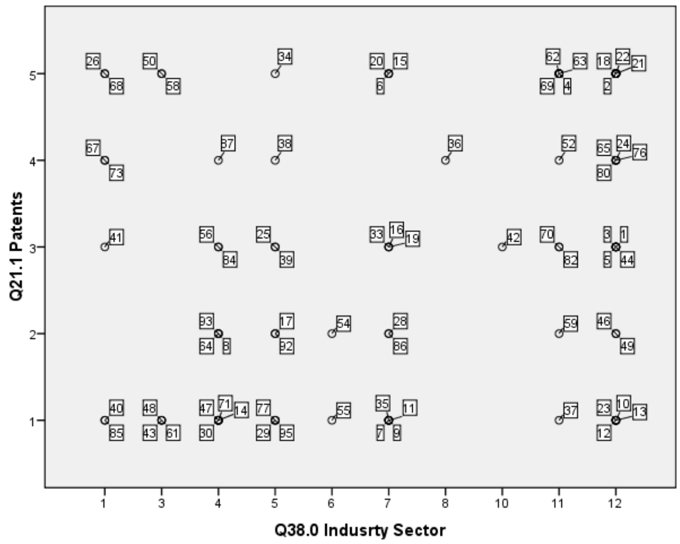

Figure 5.12 Patent Usage by Industry Sector

Table 5.14 shows the IPP policy items (N95). As can be seen the most used IPP policy is confidential agreements or NDA's (non disclosure agreements). 40% of respondents to Q22.4 stated 'very great extent' to this item.

Table 5.14 IPP Policy Item Frequencies

Item	Skewness	Kurtosis	Some extent or Less (%)	Not At All (%)
Q22.1	No	Platykurtic	53	33
Q22.2	Positively	No	80	35
Q22.3	Positively	No	82	49.5
Q22.4	Negatively	No	44	14

As can be seen in Figure 5.13 the main sectors having NDA's signed with outsiders are the SPM sector (No.4, 12.8% response), 'Other' sector (No.12, 33% response) and the Healthcare Sector (No.11, 12.8% response). The SPM sector would mostly sign NDA's with outsiders to design and develop equipment for their customers i.e. it would be a customer NDA they are signing – although they have fewer respondents than Sector No.12 they have a high usage of NDA's.

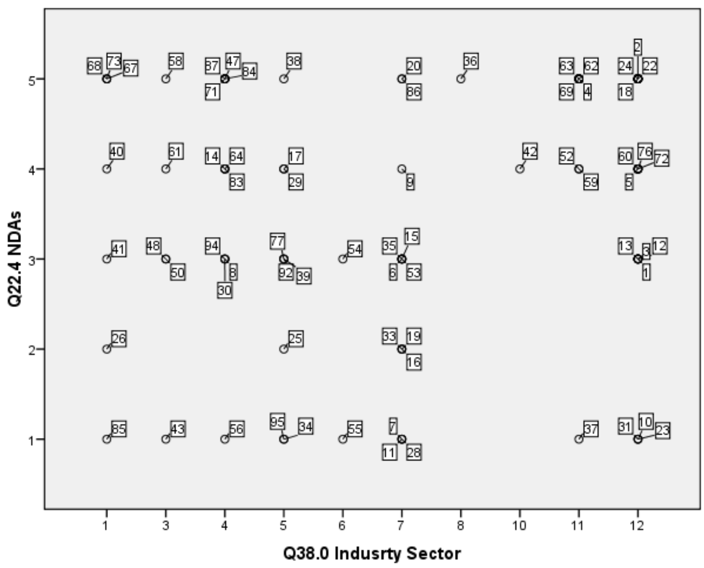

Figure 5.13 NDA's by Industry Sector

It would appear from Q22.1 and Q22.3 that SMEs trust their employees to protect their IP. It would also appear that SME respondents do not have their own specific methods of IP protection – Q22.2 (such as Q22.1 and Q22.3). According to Q23.1 and Q23.2 SMEs are not adapting IP Portfolios or an IP Strategy (Table 5.15). Although one comment from a respondent stated that they were "Working with Enterprise Ireland to develop an IP strategy".

Table 5.15 IP Portfolio and Strategy Item Frequencies

Item	Skewness	Kurtosis	Some extent or less (%)	Not At All (%)
Q23.1	No	Platykurtic	72	24
Q23.2	Positively	Platykurtic	77	36

According to A.13.12 IPP should be explained in company policy and company budgets. These activities, both Q22.0 and Q23.0 should be made part of the company strategy or New Product Strategy (NPS) as patent awareness improves information flow and knowledge sharing (A.13.13) and creates value for the SME (A.13.14). Q24.4 is skewed to a high degree with half the respondents choosing 'great extent' for using data from live prototypes for decision making (Table 5.16, N94). This is a characteristic of KBD (85% chose the KBD environment – Table 5.5) or the evolutionary prototyping process (A.19.6) and supports A.5.14. In relation to KBD A.19.9 proves this further and it is worth investigating the use of trade off curves in SMEs. Q24.8 is the KBD characteristic of 'responsibility based planning and control' (A.5.24) which asks about the practicality of the design review management process (A.5.13). This is reporting high with an 89.5% usage to some extent or more and a high great extent usage. This shows that management design reviews have the right personnel reviewing the right information – in the KBD world this would be the live data from the prototypes (Q24.4). Q24.9, Q24.10 and Q24.11 all relate to specific characteristics of Concurrent Engineering (CE) practices (A.19.17). As can be seen design and manufacturing issues are considered at the beginning of the PDP (Q24.9) and milestones are set throughout the PDP (Q24.11). Q24.10 was examined above.

Table 5.16 Q24 PDP Item Frequencies

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q24.4	Negatively	No	86	49
Q24.8	Negatively	No	89.5	43
Q24.9	Negatively	No	90	46
Q24.10	No	Platykurtic	49	17
Q24.11	Negatively	No	77	39

Q25.0 is related to the most used PDP in the USA (A.5.16), the stage gate process (N94). 88% chose some extent or less with 38% choosing 'not at all'. Considering some of the findings around high KBD and CE usage this is an interesting finding. It could be related to A.5.17; however, the type of PDP used by SMEs will need to be understood further in Chapter 6 as PDP characteristics like A.5.2, A.5.4, A.5.8, A.5.9, A.5.10 and A.5.3/14 will need to be examined. Q35.0 can be seen in the table below:

Table 5.17 Q35 Frequency

		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	1	3	3.2	3.2	3.2
	2	4	4.2	4.3	7.4
	3	23	24.2	24.5	31.9
	4	33	34.7	35.1	67.0
	5	31	32.6	33.0	100.0
	Total	94	98.9	100.0	
Missing	System	1	1.1		
Total		95	100.0		

As can be seen market share in the SMEs industry in the past three years is reported at 35% for increased for a small amount and 33% for increased significantly.

Although all of these items are statistically non-normal they are mostly expected findings.

5.4 Reliability/Consistency Analysis

As explained in Section 4.4.2.3 single item constructs are not as reliable as summated multi-item scales for drawing conclusions (inferences). Correlation analysis is used to describe the relationship between two or more variables. Figure 5.18 shows Cronbach's Alpha values for the final questionnaire with yellow highlighting the common results with the pilot.

Table 5.18 Cronbach's Alpha for Scaled Items (Final Study compared to Pilot)

Final				Pilot			
Question	Cronbach's Alpha	No. of Items	Consistency	Question	Cronbach's Alpha	No. of Items	Consistency
Q1.0	0.579	4	No	Q1	0.522	4	No
Q3.0	0.875	5	Yes	Q3	0.878	5	Yes
Q5.0	0.883	9	Yes	Q5	0.903	9	Yes
Q7.0	0.635	4	No	Q7	0.478	4	No
Q8.0	0.534	3	No	Q8	0.458	3	No
Q11.0	0.173	5	No	Q11	0.142	5	No
Q12.0	0.802	3	Yes	Q12	0.795	3	Yes
Q16.0	0.83	7	Yes	Q16	0.763	7	Yes
Q17.0	0.892	13	Yes	Q17	0.791	13	Yes
Q18.0	0.796	7	Yes	Q18	0.791	7	Yes
Q19.0	0.859	13	Yes	Q19	0.772	13	Yes
Q21.0	0.69	3	No	Q21	0.784	3	Yes
Q22.0	0.811	4	Yes	Q22	0.835	4	Yes
Q23.0	0.932	2	Yes	Q23	0.902	2	Yes
Q24.0	0.895	13	Yes	Q24	0.865	13	Yes

From Table 5.18, Q21.0 is now a 'No' to consistency although it is 0.69 which is very close to 0.7 and will be assumed a reliable one dimensional scale. As can be seen, of the 'No' findings in the pilot the final data 'No' are all closer to 0.7. The conclusion from this table is that the final sample frame is consistent to the pilot and that the survey is also internally valid. Therefore PCA was conducted on Q1, Q8 and Q11 as it was in the pilot. PCA was also conducted on Q7.0. As described in Section 4.4.2.3 Kaiser's criterion is the default for SPSS. However, according to reference [326] it is a matter of how many small factors to retain. The default setting of >1 was used to produce the principal components initially; however, scree plots and the percentage variance were examined to decide if enough of the variables were represented.

5.4.1 PCA for Q1.0 items:

Table 5.19 PCA of items Q1.0

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.794	44.846	44.846
2	1.014	25.357	70.203
3	.662	16.550	86.753

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.794	44.846	44.846
2	1.014	25.357	70.203
3	.662	16.550	86.753
4	.530	13.247	100.000

Extraction Method: Principal Component Analysis.

Figure 5.14 shows the scree plot of variance associated with each factor [320]. It can be used to decide how many factors should be kept. Rather than keeping only the factors greater than one (>1) it is recommended to keep the components after the 'break' in the plot where the steep slope of the large factors turns into the gradual trailing of the rest (the scree).

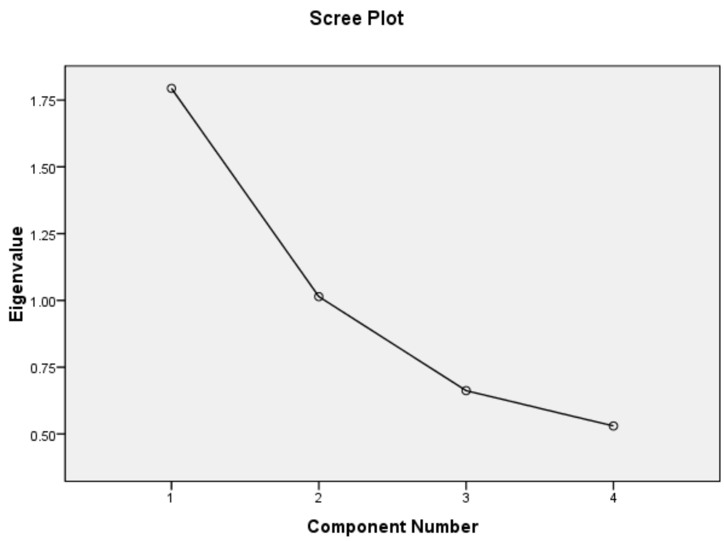

Figure 5.14 Scree Plot of Variance for Q1.0

From Table 5.20 and the scree plot it can be seen that Q1.1, Q1.2 and Q1.3 do not measure the same latent construct as Q1.4.

Table 5.20 Q1PC1 and Q1PC2

	Component	
	1	2
Q1.1 CFT	.578	.512
Q1.2 Invite	.866	-.172
Q1.3 Desfeed	.699	.283

Q1.4 Compeval	.007	.929
Extraction Method: Principal Component Analysis. Rotation Method: Varimax with Kaiser Normalization.		
a. Rotation converged in 3 iterations.		

These two rotated components account for 70% of the variance.

5.4.2 PCA for Q7.0 items:

The first three items on Q7.0 should be correlated to Q10.1 (A.15.13). Therefore, a PCA will be conducted on Q7.1, Q7.2 and Q7.3.

Table 5.21 PCA for Q7.1, Q7.2 and Q7.3

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.663	55.423	55.423
2	.832	27.734	83.157
3	.505	16.843	100.000

Extraction Method: Principal Component Analysis.

Figure 5.15 shows the scree plot.

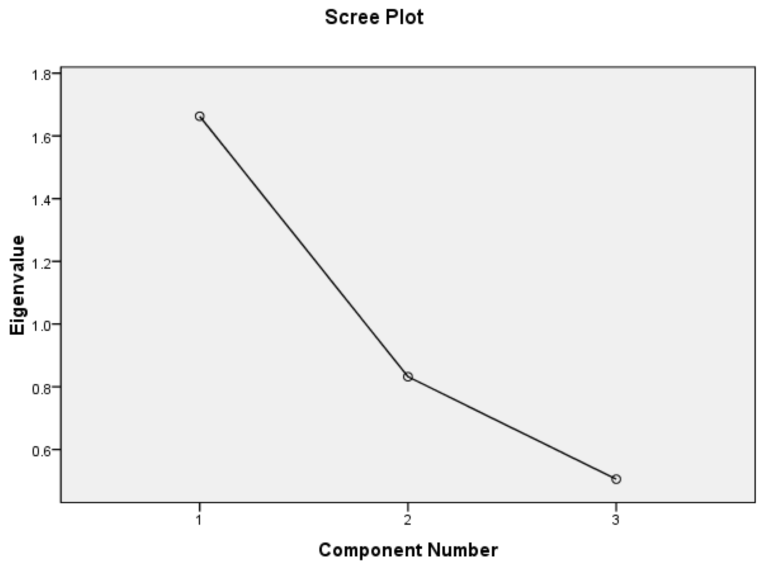

Figure 5.15 Scree Plot of Variance for Q7.0

Table 5.22 shows the PCA for Q7.1, Q7.2 and Q7.3.

Table 5.22 Q7PC1

Component Matrix[a]

	Component
	1
Q7.1 Techstrat	.698
Q7.2 Markstrat	.843
Q7.3 Focusedstrat	.681

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

As can be seen one component was extracted which based on the scree plot (no obvious 'break' point) and Table 5.21 accounts for 55% of the variance. PCA was conducted again with the extraction value of Eigenvalues set to >0.8 rather than >1. Table 5.23 shows the rotated component matrix. As can be see there are now two components which account for 83% of the variance.

Table 5.23 Q7PC1 and Q7PC2

Rotated Component Matrix[a]

	Component	
	1	2
Q7.1 Techstrat	.939	.018
Q7.2 Markstrat	.625	.566
Q7.3 Focusedstrat	.047	.948

Extraction Method: Principal Component Analysis.

Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

5.4.3 PCA for Q8.0 items:

Table 5.24 PCA for Q8.0

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.574	52.454	52.454
2	.963	32.101	84.555
3	.463	15.445	100.000

Extraction Method: Principal Component Analysis.

Figure 5.16 shows the scree plot of the variance for the three items in Q8.0. As can be seen there is no obvious 'break'.

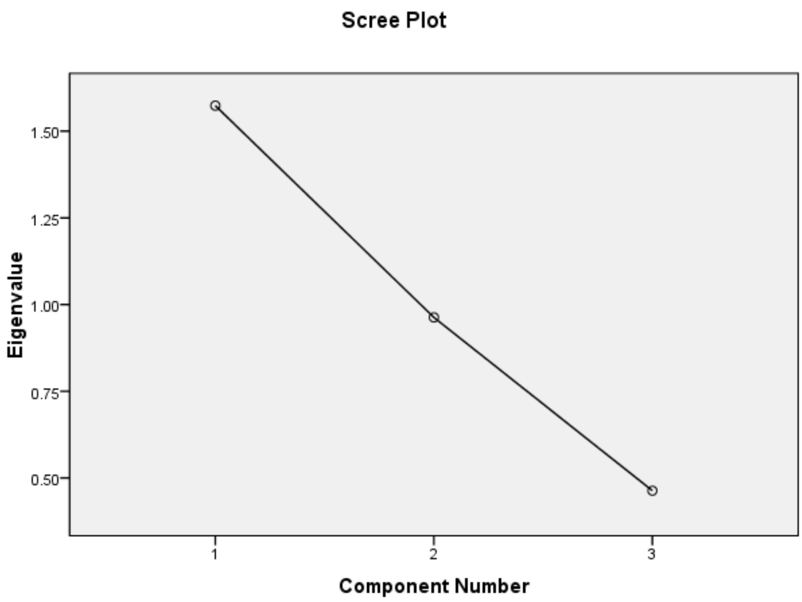

Figure 5.16 Scree Plot of Variance for Q8

Table 5.25 shows the table of PC for Q8.0 which produced one component representing 52% of the variance.

Table 5.25 Q8PC1

Component Matrix[a]

	Component
	1
Q8.1 Balanced	.610
Q8.2 Aligned	.872

Q8.3 Prioritised	.664
Extraction Method: Principal Component Analysis.	
a. 1 components extracted.	

PCA was conducted again with the extraction value of Eigenvalues set to >0.9 rather than >1. Table 5.26 shows the rotated component matrix.

Table 5.26 Q8PC1 and Q8PC2

Rotated Component Matrix[a]

	Component	
	1	2
Q8.1 Balanced	-.010	.949
Q8.2 Aligned	.666	.563
Q8.3 Prioritised	.933	-.068

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

As can be seen this has produced two components which together account for 85% of the variance.

5.4.4 PCA for Q11.0 items:

Table 5.27 shows the variance accounted for by each component.

Table 5.27 PCA for Q11.0

Total Variance Explained

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.535	30.698	30.698
2	1.353	27.053	57.751
3	.816	16.317	74.069
4	.669	13.375	87.444
5	.628	12.556	100.000

Component	Initial Eigenvalues		
	Total	% of Variance	Cumulative %
1	1.535	30.698	30.698
2	1.353	27.053	57.751
3	.816	16.317	74.069
4	.669	13.375	87.444

Extraction Method: Principal Component Analysis.

Figure 5.17 shows the scree plot for Q11.0. As can be seen there is a large variance between component 2 and 3 although again there is no obvious ‘break’ point.

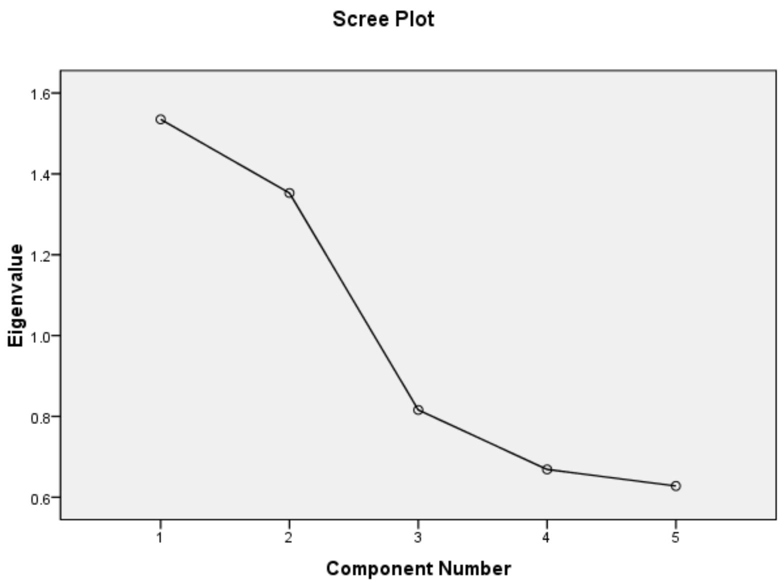

Figure 5.17 Scree Plot of Variance for Q11

Table 5.28 shows the rotated component matrix for Q11.0. As can be see two components resulted which account for 58% of variance (Table 5.27).

Table 5.28 Q11PC1 and Q11PC2

Rotated Component Matrix[a]

	Component	
	1	2
Q11.1 Veryimportant	.728	-.011
Q11.2 Pricemphasis	.104	.788
Q11.3 Guaranbus	-.763	.230

Q11.4 Relianonecust	-.229	.689
Q11.5 Networking	.599	.452

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 3 iterations.

PCA was conducted again with the extraction value of Eigenvalues set to >0.8 rather than >1. As can be seen from Table 5.29 this resulted in their components accounting for 74% of the variance.

Table 5.29 Q11PC1, Q11PC2 and Q11PC3

Rotated Component Matrix[a]

	Component		
	1	2	3
Q11.1 Veryimportant	.859	.022	.151
Q11.2 Pricemphasis	-.145	.769	.301
Q11.3 Guaranbus	-.736	-.099	.296
Q11.4 Relianonecust	-.037	.095	.934
Q11.5 Networking	.286	.787	-.132

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 5 iterations.

Table 5.30 shows the new factors resulting from the PCA on Q1.0, Q7.0 (Q7.1, Q7.2, Q7.3), Q8.0 and Q11.0. These factors can therefore be used to draw conclusions (inferences) from the survey in Chapter 6.

Table 5.30 Principal Components

Original Question	Number of Items	Factor 1	Name	Factor 2	Name	Factor 3	Name
Q1.0	4	Q1PC1	Teamwork, probing, paths	Q1PC2	Eval Comp Prod	N/A	N/A
Q7.0	3	Q7PC1	Techstrat	Q7PC2	Marketing / Focus	N/A	N/A
Q8.0	3	Q8PC1	Balanced, aligned	Q8PC2	Prioritised	N/A	N/A
Q11.0	5	Q11PC1	veryimport, Networking	Q11PC2	Priceemphasis, guaranbus	Q11PC3	Reliano necust

5.5 Conclusion

In this chapter the final data analysis was analysed from the perspective of descriptive statistics, exploration of normality and reliability/consistency analysis. In general all of these were in line with the pilot findings, also 93% of respondents answered ‘Yes’ to a report from the survey findings (Q44.0). Table 5.30 shows the principal components for Q1.0, Q8.0, Q7.0 and Q11.0 which were shown to be multi-dimensional scales and will be used in Chapter 6 to further analyse the data.

Chapter 6

Regression Analysis/Hypothesis Testing

6.1 Introduction

Chapter 5 covered descriptive statistics, exploration of normality and reliability/consistency analysis of the final data. Table 5.30 shows the principal components for Q1.0, Q8.0, Q7.0 and Q11.0 which were shown to be multi-dimensional scales. Appendix C.4 (Final Analysis plan) will be used to carry out hypothesis testing and further understand the results of this survey. Section 6.4 will draw conclusions from Chapter 5 and Section 6.3, which will in turn form the basis for the overall conclusions and recommendations in Chapter 7.

6.2 Regression Assumptions

Some of the assumptions of regression were discussed in Section 4.4.2.4. In addition the following are considered:

- Correct specification of the model – Relevant variables should not be omitted and irrelevant variables included.
- Linearity – This can be checked via the rule of thumb: Standard Deviation (SD) of dependent is more than the Standard Deviation of the residuals. If this is the case linearity is acceptable.
- Same underlying distribution – Bimodal vs. Normal and Multivariate normality. Univariate normality of each independent is acceptable – as applied in this thesis (Section 5.3).
- No outliers – Outliers are checked by using the leverage statistic ‘h’.

PCA components are normally distributed (mean of 0 and SD of 1) and are interval data. All items are considered interval data (Section 4.4.2.4). However, according to references [327-329] ‘moderate violations of parametric assumptions have little or no effect on substantive conclusions in most instances – the F test remains robust’. In addition, the central limit theorem states that ‘even when error is not normally distributed, when sample size is large (greater than 30), the sampling distribution of the b coefficient will still be normal’. Again, ‘violations of this assumption usually have little or no impact on substantive conclusions for large samples' [329]. For the following sub-hypotheses it is possible to have the below combinations of dependent and independent variables (Table 6.0):

Table 6.0 Type of Variables

Dependent	Independent
Principal Component	Principal Component
Principal Component	Individual Items (say 2 to 6)
One Item e.g. Q24.5	Principal Component
One Item e.g. Q11.2	Individual Items (say 2 to 6)

For principal components of dependent and independent variables the percentage of variance needs to be considered as this represents the amount of error around the fitted line. There are some advantages/disadvantages of using principal components over items. Principal components are normally distributed and are better than individual items for drawing conclusions (Section 4.4.2.3). They also have no covariance as the Eigenvectors are perpendicular to each other. However, most of the principal components used in this thesis are created from specific items which represent a product development characteristic under investigation e.g. for the Knowledge Based Development (KBD) PDP characteristic items Q24.4, Q24.5, Q24.6, Q24.7 and Q24.8 could be used to create a PC. But these items could also be used as independent variables in multiple regression. This brings the advantage of examining the significance of each item on the dependent. Although, items may not be normal (whereas principal components are normal) this may not be an issue for larger samples. Therefore, tables are created for each hypothesis which show the following values:

- F-significant value – The smaller the F-sig the more significant the result. The hypotheses below are either significant at the 0.05 (5%) level or the 0.01 (1%). A 0.05 level implies that the result has a 5% chance of not being true, 95% chance of being true.
- Pearson's r – correlation check.
- R-squ for independent variables explains a proportion of the variance in a dependent variable at a significant level.
- The prediction equation for the model – Section 4.4.2.4. The coefficient 'Beta' and the intercept 'B'.

- Linearity – SD of dependent is more than the SD of the residuals then linearity is acceptable.
- Outliers – The rule of thumb is that under 0.2 is not a problem (maximum leverage) but over 0.5 there is undue leverage.

Section 3.2.1.2 discussed the hypothesis of this thesis. Appendix C.4 shows the individual sub-hypotheses of this hypothesis. Most of the following sub-hypotheses take the form of a linear relationship with a dependent and one or more independents. Depending on the Sub-Hypotheses, the null hypothesis (Ho) is either that no linear relationship or a linear relationship exists between the dependent and independent variables. H1 is the opposite depending on which stance is taken – there is/is not a linear relationship between the dependent and one of the independents. For the below sub-hypotheses a question arises as to what is the independent and what is the dependent variable. First used in time is independent or it is the variable that can be manipulated. The dependent is fixed and dependent on the input of the independent. In Appendix C.4 (e.g. Sub-Hypothesis No.5, use of reverse engineering) the same variable can appear in both the dependent and independent variable columns. This is a reflection on the interrelationship of product development and also can be an indication that a relationship exists between the questionnaire items. In relation to Pearson's r a rule of thumb states that 0.19 and below is a very low correlation, between 0.2 and 0.39 is low; 0.4 to 0.69 is modest; 0.7 to 0.89 is high and 0.9 to 1.0 is very high [326].

6.3 Sub-Hypothesis Testing

Appendix C.4 (Final Analysis plan) will be used to carry out hypothesis testing and further understand the results of this survey. Appendix C.4 shows each of the below Sub-hypothesis and the dependent 'Y' and independent 'X' axis along with their corresponding variables. Also shown in C.4 are the questionnaire table appendices and their corresponding 'relevant' product development process elements which are used to analysis the findings as shown in Figure 2.0. The questionnaire table appendices are shown in the following format (e.g. Sub-Hypothesis No.1):

Q1.1 has both A.21.9 and A.18.3, this is then split from Q1.2 by a '/'. The dependent variables are split from the independent variables using a '//'.

6.3.1 Sub-Hypothesis No.1

Ho states that no linear relationship exists between Q1PC1 (dependent – Table 5.19) and Q5.4 (independent variable).

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.672	55.735	55.735	1.672	55.735	55.735
2	.685	22.845	78.580			
3	.643	21.420	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
Q1.1 CFT	.730
Q1.2 Invite	.753
Q1.3 Desfeed	.756

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Figure 6.0 Principal Component Q1PC1

The decision on team working, probing and creating new paths is dependent (it changes in response to the independent) on an open strategy (this can be manipulated) where utilization of external knowledge through the creation of a path should take place. As one item for the dependent variable is required the Q1PC1 from Table 5.19 was not used as it accounted for only 45% of variance.

Figure 6.0 shows the Q1PC1 component used in this hypothesis which accounts for 58% of the variance and therefore represents the three Q1.0 items better (only one component was extracted so it was not rotated). Table 6.1 shows the regression results.

Table 6.1 Regression Results for Q1PC1 and Q5.4

F-Sig	Pearson's r	Correlation Coefficients R-squ	Unstandardized Coefficients		Standardized Coefficients	Linearity	h <0.2, <0.5
			B	Std. Error	Beta		
0.001	0.373	0.128	-1.456	0.956	0.373	Yes	0.096

As can be seen in Table 6.1 this is a significant relationship at the 0.05 level or better, Pearson’s r is 0.373 which is low (0.2 to 0.39 is low) and the R-squ value is only 13%. The reported R-squ in the pilot was 32% (Table 4.17). The regression equation states that:

Q1PC1 = 0.373 * utknowledge – 1.456 + e1 (where e1 is the error term)

This means that team working, probing and paths changes 0.373 units when the dependent changes one unit. Therefore, for the final data this independent variable Q5.4 explains 13% of the dependent variable Q1PC1. However, Q1.1 was 80% and Q1.3 had 92% to some extent or more with Q5.4 having an 89% response to some extent or more (37% to a great extent). Q1.2 was 78% to some extent or less in relation to inviting customers to their premises to discuss products with a cross section of employees. One of the key aspects of this linear relationship is A.7.13 where working with customers in the manner of Q1.2 is a 'path' to gaining new market and technology knowledge. In addition the Q1PC1 captures 58% of the variance leaving 42% unexplained. Although Q5.4 has a high response it cannot be understood from this item where SMEs are utilizing knowledge from. SMEC 1e (SMEs may have difficulty building credibility with a potential partner – partner may have more knowledge to lose than gain) suggests that SMEs may work with external organisations (e.g. universities or companies in similar markets) less than larger companies (SMEC 3h). It is critical that these types of activity are carried out, therefore, Ho is true.

6.3.2 Sub-Hypothesis No.2

Ho states that no linear relationship exists between Q1PC1 (dependent) and items Q16.2, Q16.3 and Q16.4 (independent variables). This sub-hypothesis compares the Q16.0 independent items which ask about customer requirements (VOC information) with the dependent variables of using teams and gathering customer information. Q7.2 is skewed towards higher values with 95% of respondents choosing a marketing driven strategy to some extent or more (51% to a great extent) – marketing pull, so customer information is required to develop products.

Table 6.2 Regression Results for Q1PC1 and Q16.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.513	0.263	Yes	0.218

Although 'h' is over 0.2 implying outliers it is not over 0.5 which would imply undue leverage. This model is significant at the 0.01 level with a modest correlation (0.4 to 0.69 is modest) and an R-squ of 0.263. Therefore 26% of Q1PC1 is explained by the three items.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-3.142	.564		-5.575	.000
	Q16.2 KanoMod	.214	.128	.167	1.670	.098
	Q16.3 VOCT1	.246	.121	.208	2.038	.044
	Q16.4 VOCT2	.392	.151	.282	2.603	.011

a. Dependent Variable: Q1PC1

Figure 6.1 Coefficients for Q1PC1 and Q16 items

From Figure 6.1 it can be seen that two items, Q16.3 and Q16.4, are significant. Q16.2 does not contribute much to the model. The regression equation was re-calculated with just Q16.3 and Q16.4 included in order to ensure that the original model was correct i.e. the re-calculated values should not change significantly from the original. Based on this the re-calculated regression equation reads:

Q1PC1 = 0.225 * VOCT1 + .345 * VOCT2 – 2.747 + e1

Q16.3, Q16.4 and Q1PC1 are basically about gathering information from the customer (voice of the customer (VOC)) where Q16.3 and Q16.4 describes what a VOC Table would ask for and Q1PC1 is about the team working, probing/paths and understanding customer requirements. Based on this there should be some correlation. Examining the individual responses to the items, Q16.2 was 93%, Q16.3 was 90.5%, Q16.4 was 94% (Table 5.11), Q1.1 was 80% and Q1.3 had 92% to some extent or more. As stated, Q1.2 was 77% to some extent or less in relation to inviting customers to their premises to discuss products with a cross section of employees – this may account for some of the variance (along with the 42% PC variance not accounted for). T&M characteristic A.4.2 (See Appendix C.4) states that new products are not positioned along the perceived mindset of customers – this is often missed in cases where customer 'wants' are thought to be known i.e. in the case of existing products. Overall, the fact that 73% of the respondents are in the small SME range producing mostly incremental products (which are based on existing products), and based on item Q1.2 responses this could explain the model findings. Q16.2 should also be a predictor of the model as it is a key characteristic to understand about the customers' requirements i.e. customer satisfaction based on product attributes and customer usage requirements. Therefore from the perspective of the model the VOC aspect of A.4.23 is true. The disadvantage of not understanding the customer requirements can be seen in A.5.8. The advantages include A.7.13 and A.7.14. However, in relation to the regression model H1 is true.

6.3.3 Sub-Hypothesis No.3

Ho states that no linear relationship exists between Q24PCce (dependent) and item Q1.1, Q1.2, Q1.3 and Q1.4 (independent variables). This sub-hypothesis compares items used in a Concurrent Engineering based PDP to the items from the fuzzy front end (FFE) i.e. Q1.0 items. In a time sequence the FFE must happen before the PDP characteristics therefore making the PDP dependent on Q1.0 items (the design is based on the VOC activity). Figure 6.2 shows the PC analysis for Q24.0 CE items.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.516	62.911	62.911	2.516	62.911	62.911
2	.596	14.905	77.816			
3	.506	12.650	90.465			
4	.381	9.535	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
Q24.9 CEDesign	.827
Q24.10 Simulation	.740
Q24.11 Milestones	.829
Q24.12 Parallel	.773

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Figure 6.2 Principal Component for Q24PCce

As can be seen Q24PCce accounts for 63% of the variance. Table 6.3 shows that this model is significant at the 0.01 level with a high modest correlation and an R-squ of 0.362. Therefore 36% of Q24PC1 is explained by the four items.

Table 6.3 Regression Results for Q24PCce and Q1.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.602	0.362	Yes	0.164

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-2.953	.443		-6.658	.000
	Q1.1 CFT	-.023	.086	-.026	-.270	.788
	Q1.2 Invite	.298	.088	.317	3.382	.001
	Q1.3 Desfeed	.254	.102	.235	2.494	.014
	Q1.4 Compeval	.372	.092	.369	4.055	.000

a. Dependent Variable: Q24PCce1

Figure 6.3 Coefficients for Q24PCce and Q1.0 items

However, from Figure 6.3 it can be seen that item Q1.1 has a significance value of 0.788. This is very surprising as the basis and most critical element of a concurrent engineering environment is the use of CFT (A.19.17, A.7.12 and Section 2.6.5). Based on this the re-calculated regression equation reads:

Q24PCce = 0.310 * Invite + 0.230 * Desfeed + 0.362 * Compeval – 2.971 + e1

As can be seen item Q1.4 on evaluating competitor products strengths and weaknesses has the highest relative importance of the three predictors with Q1.2 next and Q1.3 with the least significance and standardised coefficient. From frequency analysis it was shown that there is a high usage of CFT among the respondents (80% some extent or more). What this implies is that considering design and manufacturing issues at the beginning of the PDP (Q24.9), evaluating multiple design alternatives with simulation software rather than actual prototypes (Q24.10), setting milestones (Q24.11) and designing products/processes in parallel (Q24.12) can be predicted by the variables in the above model. This could imply that SMEs are not operating in a CE environment. Sub-Hypothesis No.4 tests this.

6.3.4 Sub-Hypothesis No.4

Ho states that no linear relationship exists between Q24PCkbd (dependent) and item Q1.1, Q1.2, 1.3 and Q1.4 (independent variables). Based on the finding of No.3 this Sub-Hypothesis is comparing the independent variable of Knowledge Based Development (items Q24.4, Q24.5, Q24.6, Q24.7 and Q24.8) using Q24PCkbd as shown in Figure 6.4 with the dependent variables Q1.1, Q1.2, Q1.3 and Q1.4. These characteristics represent a KBD environment. Q24PCkbd accounts for 59.5% of fitted variance.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.973	59.452	59.452	2.973	59.452	59.452
2	.811	16.217	75.670			
3	.466	9.317	84.986			
4	.393	7.864	92.851			
5	.357	7.149	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
Q24.4 Liveknow	.776
Q24.5 Knowbase	.733
Q24.6 MultipleSets	.758
Q24.7 Redundency	.763
Q24.8 Techreviews	.823

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Figure 6.4 Principal Component Q24PCkbd

Table 6.4 shows that this model is significant at the 0.01 level with a high modest correlation and an R-squ of 0.413. Therefore 41% of Q24PC1 is explained by the four items.

Table 6.4 Regression Results for Q24PCkbd and Q1 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.642	0.413	Yes	0.164

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-3.223	.426		-7.573	.000
	Q1.1 CFT	.165	.082	.185	2.003	.048
	Q1.2 Invite	.178	.085	.188	2.096	.039
	Q1.3 Desfeed	.237	.098	.219	2.425	.017
	Q1.4 Compeval	.379	.088	.376	4.306	.000

a. Dependent Variable: Q24PCkbd

Figure 6.5 Coefficients for Q24PCkbd and Q1 items

From Figure 6.5, the regression equation reads:

Q24PCkbd = 0.185*CFT + 0.188*Invite + 0.219*desfeed + 0.376*Compeval – 3.223 + e1

From the regression model it can be seen that all the Q1 items are significant including the CFT predictor (unlike Sub-Hypothesis No.3). It is known that the sample frame have a high usage of the items in Q1.0 and it is now known that the FFE Q1.0 items share a better relationship to the KBD PDP characteristic than CE PDP characteristics according to the SME respondents. This is another finding in favour of KBD. H1 is true.

6.3.5 Sub-Hypothesis No.5

Ho states that no linear relationship exists between Q19.12 (reverse engineering) and Q1.4 (evaluation of competitor products). Q1.4 is independent as it comes before the use of reverse engineering. The evaluation of competitor products could be aided by the use of reverse engineering. According to the descriptive statistics analysis both variables were normal. Table 6.5 show the regression results.

Table 6.5 Regression Results for Q24PCkbd and Q1 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.655	0.046	0.002	Yes	0.06

As can be seen the null hypothesis is supported as this is not significant. Section 2.8.8 lists reasons to carry out reverse engineering (A.8.30) one of which is relevant to this regression – to analyse the good and bad, or discover new ways to improve a competitor's product performance and features. However A.8.31 states that knowledge of patent law is required for this activity. According to a frequency analysis of Q19.12, 79% of respondents are using reverse engineering to some extent or less. A.8.30 also lists other reasons not affected by patent law to carry out reverse engineering. Again, Ho is true.

6.6.6 Sub-Hypothesis No.6

Ho states that no linear relationship exists between Q26.1 (product development environment) and Q2.0 (reciprocal interdependence). Table 5.5 showed that only 15% of respondents chose Q26.1.

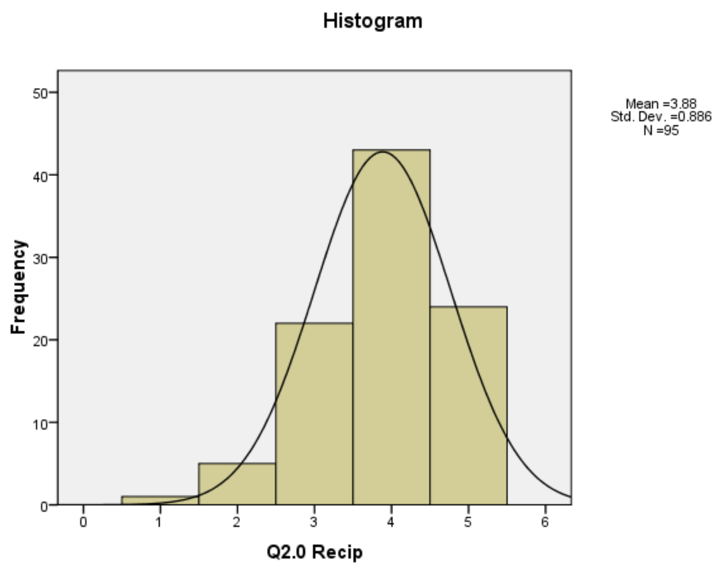

Figure 6.6 Histogram of Q2.0

From Figure 6.6 it can be seen that 45 respondents chose great extent (94% choosing some extent or more) which implies that the coordination of activities is based on reciprocal interdependence i.e. the forming of task forces and a two way flow of work, resources and information (A.7.20). Q26.2 is also in line with A.7.20 with an 85% response rate. The skewed values of Q2.0, and an 80% response to Q1.1 (the formation of cross functional teams) in the great extent or higher range (as mentioned in Section 5.3 and 6.3.2 above) also supports Q26.2. Section 5.3 also discusses Q15.0 (decentralisation of the organisation) which further aids A.7.20 via A.7.18. This further points to a preference for KBD. However, a 15% response to a Q26.1 type PD environment supports A.7.19 where jobs are standardised and guided by rules and procedures. The disadvantage of high usage of Q2.0 and Q26.2 is the possibility of A.5.13. However, A.5.20 states that reciprocal interdependence is a necessity in a PD environment. Therefore Ho is true in this case.

6.3.7 Sub-Hypothesis No.7

Ho states that a linear relationship exists between Q4.0 and Q3.0 items. This sub-hypothesis compares organisational change issues from Q3.0 with the requirement for using organisation change management processes (Q4.0) to see if there is a relationship. None of the five Q3.0 items were significant and as can be seen from Table 6.6 the model is not significant.

Table 6.6 Regression Results for Q4.0 and Q3.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.679	0.185	0.034	Yes	0.14

Q3.1 to Q3.5 are the common issues with change in an organisation identified by the references (A.24.1). As can be seen the regression analysis is backed up by Table 6.7. The Q3 issues are not seen as a problem by the majority of the SMEs and the use of change management processes is 87% to some extent or less.

Table 6.7 Frequency Analysis of Q3.0 and Q4.0 (N95)

Item	Skewness	Kurtosis	Some extent or less (%)
Q3.1	Negatively	No	82
Q3.2	No	No	83
Q3.3	No	No	80
Q3.4	No	No	92
Q3.5	No	No	81
Q4.0	No	No	87

This can be explained by the fact that 73% of the respondents are in the small SME range (1 to 50 employees). The comments section on the survey support this H1 finding where a respondent stated “Small size so no need for change management processes”. Other SMEs states that “Weekly/monthly meeting are used to bring change across” and that “Dynamic driven individuals bring across change”. Another respondent stated there are issues with “Long term promoted employees with no formal education can not communicate to newly hired educated employees”.

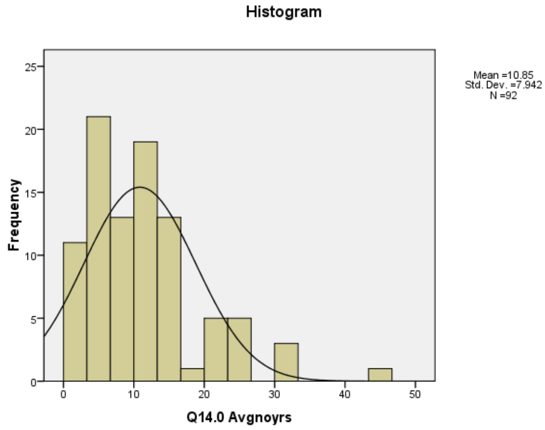

Figure 6.7 Histogram of Q14.0

Figure 6.7 shows the histogram of the average number of year’s management staff are with their SME. As can be seen this is 11 years which implies that this could be an issue in some SMEs. This could also explain the respondent that stated there was an element of ‘this is how we always did it’ among long term staff. Figure 6.7 does support the leadership characteristic that they should be in the company a considerable number of years (A.9.6). Change can be an issue for SMEs with more than one site. H1 is also supported by the fact that 63 respondents’ chose ISO as at least one of their quality environments with one respondent commenting their “ISO9000 quality system requires two way meetings”. Finally, another respondent pointed out that as a design company “change is what we do”.

6.3.8 Sub-Hypothesis No.8

Ho states that no linear relationship exists between Q5.2 and associated Q5 items and Q6. This hypothesis is based on A.15.9 i.e. the link between business strategy or strategic planning and new product strategy is of critical importance. Business strategy is created first so the New Product Strategy (NPS) is dependent on the business or independent items Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0 which are all part of carrying out strategic planning.

Table 6.8 Regression Results for Q5.2 and Q5.0 items and Q6.0

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.729	0.531	Yes	0.269

Table 6.8 shows that this model is significant at the 0.01 level with a high (0.7 to 0.89) correlation and an R-squ of 0.531. Therefore 53% of Q5.2 is explained by the Q5.0 items and Q6.0.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	.198	.364		.544	.588
	Q5.6 Missionstate	.175	.095	.174	1.842	.069
	Q5.7 IDcompfact	-.043	.122	-.039	-.353	.725
	Q5.8 IDsolutions	.257	.113	.244	2.283	.025
	Q5.9 Trendanalysis	.144	.112	.132	1.286	.202
	Q6.0 Compare	.472	.131	.406	3.599	.001

a. Dependent Variable: Q5.2 NewProdStrat

Figure 6.8 Coefficients for Q5.2 and Q5 items and Q6

Although the R-squ value is high it can be seen from Figure 6.8 that item Q5.6, Q5.7 and Q5.9 are not significant and add nothing to the predictive model. Based on this the re-calculated regression equation reads:

Q5.2 = 0.295 * IDsolutions + 0.518 * Compare + e1

In both Figure 6.8 and the re-calculated regression equation the constant or intercept was not significant i.e. 0.588 and now 0.290, it was therefore not included in the equation.

In order to understand this further Table 6.9 shows the frequency analysis of these items and Q5.1 and Q5.3. As can be seen 94% of respondents carry out strategic planning (Q5.1) to some extent or more with 41% doing this activity to a great extent.

Table 6.9 Frequency Analysis of Q5.2, Q5.0 items and Q6.0 (N83)

Item	Skewness	Kurtosis	Some extent or More (%)	Some Extent (%)	Great Extent (%)
Q5.1	No	No	94	42	41
Q5.2	No	No	78	31	30
Q5.3	No	No	78	26.5	35
Q5.6	No	No	67.5	39	20.5
Q5.7	No	No	81	40	29
Q5.8	Negatively	No	85.5	26.5	45
Q5.9	No	No	60	39	14.5
Q6.0	No	No	78	42	30

The NPS (Q5.2) is based on business trusts and strategies and starts with a SWOT (Strengths, Weaknesses, Opportunities and Threats, Q5.7, Q5.8 and Q5.9 are all elements of a SWOT carried out during strategic planning) – as discovered Q7.2 is the chosen strategy by 95% (choosing some extent or more) i.e. NPD is based on market needs and wants and therefore this activity is important. Q5.3 states that 78% of respondents link their business strategy to their NPS with the same percentage carrying out an NPS (Q5.2). As Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0 are characteristics of strategic planning (Q5.1) they all should be correlated to Q5.2. From the regression equation Q5.6, Q5.7 and Q5.9 are missing. 94% are carrying out strategic planning (Q5.1) whereas 67.5% are forming a mission statement (Q5.6). Assuming SMEs are following the A.15.3 steps to form a mission statement then Q5.6 should be one of the predictors and would also imply A.1.13 i.e. that SMEs are looking towards the future. In addition, Q5.9 related to Q5.1 is 60% versus 94% and this is an area worth further investigation. Q5.8 is identifying solutions to the factors from Q5.7 and both are around 80% although the ‘some’ or ‘great’ extent percentages should also be the same or reversed. Q5.7 is a missing predictor in the above regression equation so the identified Q5.8 solutions are to unidentified factors. From the perspective of the regression mode, H1 is true as correlation is high and R-squ is 53%, however there are important characteristics of strategic planning missing from the model.

6.3.9 Sub-Hypothesis No.9

Ho states that no linear relationship exists between Q12PCbackend and certain Q5.0 items (Figure 6.10) and Q6.0 (A.26.2). This sub-hypothesis compares the items from the strategy section to the items from the backend marketing section to see if there is any relationship. Figure 6.9 shows the PC created from items Q12.1, Q12.2 and Q12.3 which represents 72% of the variance.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	2.158	71.921	71.921	2.158	71.921	71.921
2	.480	15.999	87.920			
3	.362	12.080	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
Q12.1 Marketmix	.840
Q12.2 Branding	.829
Q12.3 Manchange	.875

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Figure 6.9 Principal Components for Q12PCbackend

Table 6.10 shows that this model is significant at the 0.01 level with a high modest correlation (0.4 to 0.69 is modest) and an R-squ of 0.367. Therefore 37% of Q12PCbackend is explained by the Q5.0 items and Q6.0.

Table 6.10 Regression Results for Q12PCbackend and Q5.0 items and Q6.0

F-Sig	**Pearson's r**	**Correlation Coefficients R-squ**	**Linearity**	**h <0.2, <0.5**
0.0005	0.606	0.367	Yes	0.352

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.523	.482		-3.163	.002
	Q5.1 Stratplanning	-.233	.162	-.185	-1.440	.154
	Q5.2 NewProdStrat	.352	.166	.392	2.118	.038
	Q5.3 LinkNewProdStrat	-.130	.170	-.146	-.765	.447
	Q5.6 Missionstate	.441	.107	.488	4.141	.000
	Q5.7 IDcompfact	.053	.132	.054	.405	.686
	Q5.8 IDsolutions	.007	.128	.007	.052	.958
	Q5.9 Trendanalysis	.130	.122	.133	1.064	.291
	Q6.0 Compare	-.070	.154	-.067	-.454	.651

a. Dependent Variable: Q12PCbackend

Figure 6.10 Coefficients for Q12PCbackend and Q5.0 items and Q6.0

However, from Figure 6.10 it can be seen that item Q5.1, Q5.3, Q5.7, Q5.8, Q5.9 and Q6 are not significant and add nothing to the predictive model. Based on this the re-calculated regression equation reads:

Q12PCbackend = 0.227 * NewProdStrat + 0.430 * Missionstate – 1.799 + e1

As standardized coefficients are used, the influence of forming a mission statement is 0.430/0.227 = 1.89 times (not accounting for error) more than that of forming a new product strategy [292]. Table 6.11 shows a frequency analysis of Q12.0 and the relevant Q5.0 items and Q6.0 are shown in Table 6.9 above.

Table 6.11 Frequency Analysis of Q12.0 (N95)

Item	Skewness	Kurtosis	Some extent or More (%)	Some Extent (%)	Great Extent (%)
Q12.1	No	No	85	32	43
Q12.2	No	No	76	30.5	36
Q12.3	No	No	73	43	24

The average 'some extent or more' for the combined Q5.0 and Q6.0 above is 78% and also 78% for the Q12.0 items. Assuming SMEs are following the A.15.3 steps to form a mission statement then the high coefficient and significance of Q5.6 in this predictor is correct. As stated Q5.7, Q5.8, Q5.9 and Q6.0 are also part of the strategic planning process i.e. performance audit or SWOT analysis. According to A.26.2 – the positioning strategy or attack plan is translated into a reality by assembling an appropriate 4Ps mix. Therefore Q5.7, Q5.8, Q5.9 and Q6.0 should be significant predictors for backend marketing. The NPS (Q5.2) is based on business trusts and strategies and starts with a SWOT and as discovered Q7.2 is the chosen strategy by 95% (choosing some extent or more) i.e. NPD is based on market needs and wants. These marketing needs and wants are used to design the product – features, price and branding should be considered at this stage (branding (Q12.2) is also part of the marketing mix – A.12.4). Q12.3 is about managing this process. Q5.3 which is about linking new product strategy to the business strategy and should also be a predictor as it is related to backend marketing via the SWOT analysis and as was shown in Section 6.3.8 is significant although missing some predictors. Although Q5.2 and

Q5.6 are predictors, Q5.0, Q6.0 and Q12.0 are all high on responses and should also be linked, so Ho is upheld.

6.3.10 Sub-Hypothesis No.10

Ho states that no linear relationship exists between Q35.0, Q36.0 and Q37.0 and associated Q5.0 items and Q6.0. This sub-hypothesis compares the individual items from the strategy section (Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.7, Q5.8, Q5.9 and Q6) as independent variables to each item from the performance section i.e. Q35.0, Q36.0 and Q37.0 (separately as dependent variables) to see if there is any relationship between use of strategy and performance. As can be seen in Table 6.12 all three models were not significant.

Table 6.12 Regression Model Significance Values for Performance v Strategy

	Q5.0 items and Q6.0
Q35.0	0.966
Q36.0	0.437
Q37.0	0.799

However, as can be seen from Table 6.9 there is a relatively high usage of these Q5.0 and Q6.0 strategy items. Q35.0 (Table 5.17), Q36.0 and Q37.0 can be seen in Figure 6.19 below. For Q35.0 market share in the SMEs industry in the past three years is reported at 35% for ‘increased by a small amount’ and 33% for ‘increased significantly’. Q36.0, sales from new products in the last three years had a response of 72% to ‘met expectations’ or below and for Q37.0, on a scale of 0 to 6 (0, lowest and 6, highest) 71% chose 4 or below. Although market share is good and overall success is reasonable, sales from new products is weak (A.28.98) and this could explain the lack of a relationship in addition to the finding of Sections 6.3.8 and 6.3.9. Ho is true.

6.3.11 Sub-Hypothesis No.11

Ho states that no linear relationship exists between Q10.1 and Q7.0 items. This sub-hypothesis compares item Q10.1 to items Q7.1, Q7.2 and Q7.3 as Q10.1 should contain elements of all these items i.e. there should be a relationship (A.15.13). Q10.1 was binned to create an interval scale as it did not have uniform intervals, from this; 1 = 0 to 19%, 2 = 20 to 39%, 3 = 40 to 59%, 4 = 60 to 79% and 5 = 80 to 100% choosing a differentiated strategy.

Table 6.13 Regression Results for Q10.1 and Q7.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.173	0.247	0.061	Yes	0.179

As can be seen from Table 6.13 this model is not significant – none of the three Q7.0 items predict the ‘Y’ variable Q10.1. The mean response is 30% allocation to Q10.1 and Table 6.14 shows the frequency response to Q7.1, Q7.2 and Q7.3 (Q7.4 shown for another purpose).

Table 6.14 Frequency responses to Q7.0 (N83)

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q7.1	No	No	84	36
Q7.2	Positively	Leptokurtic	95	51
Q7.3	No	No	85.5	40
Q7.4	No	No	73	32

The Q7.0 items all have a high usage response however it would appear that SMEs choosing Q10.1 are not including the three Q7.0 items. A.15.13 in Section 2.5.2.1.3.2 states that Q10.1, which is a Type A strategy, has an excellent balance between technological sophistication with aggressiveness and a strong market orientation and is better than Q10.2, Q10.3, Q10.4 and Q10.5 from the perspective of NPD success, Ho is true.

6.3.12 Sub-Hypothesis No.12

Ho states that no linear relationship exists between Q5Q6PCstrategy and Q7.2. This sub-hypothesis compares strategic planning to Q7.2 to see if there is a relationship between respondents choosing a marketing driven strategy (Q7.2, first decision) and carrying out strategic planning (Q5Q6PCstrategy). Q5Q6PCstrategy is not regressed against Q7.1 as it is a technology driven strategy or Q7.3 as it is platform based (Q7.4 is No.13 below). Figure 6.11 shows the Q5Q6PCstrategy component which accounts for 58% of the variance.

Total Variance Explained

Component	Initial Eigenvalues Total	Initial Eigenvalues % of Variance	Initial Eigenvalues Cumulative %	Extraction Sums of Squared Loadings Total	Extraction Sums of Squared Loadings % of Variance	Extraction Sums of Squared Loadings Cumulative %
1	4.608	57.600	57.600	4.608	57.600	57.600
2	.918	11.470	69.070			
3	.808	10.103	79.172			
4	.509	6.366	85.538			
5	.401	5.009	90.547			
6	.334	4.171	94.718			
7	.273	3.418	98.137			
8	.149	1.863	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component 1
Q5.1 Stratplanning	.709
Q5.2 NewProdStrat	.860
Q5.3 LinkNewProdStrat	.886
Q5.6 Missionstate	.627
Q5.7 IDcompfact	.723
Q5.8 IDsolutions	.725
Q5.9 Trendanalysis	.670
Q6.0 Compare	.832

Extraction Method: Principal Component Analysis.

a. 1 components extracted.

Figure 6.11 Principal Component Q5Q6PCstrategy

Table 6.15 shows the regression model results.

Table 6.15 Regression Results for Q5Q6PCstrategy and Q7.2

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.594	0.353	Yes	0.131

As can be seen this model is significant at the 0.01 level with a modest correlation and an R-squ of 0.353. Therefore 35% of Q5Q6strategy is explained by Q7.2.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	-2.647	.408		-6.491	.000
	Q7.2 Markstrat	.698	.105	.594	6.651	.000

a. Dependent Variable: Q5Q6PCstrategy

Figure 6.12 Coefficients for Q5Q6PCstrategy and Q7.2

Based on Figure 6.12 the regression equation reads:

Q5Q6PCstrategy = 0.594 * Markstrat – 2.647 + e1

Given the relatively high use of strategic planning (Table 6.9), the necessity to use a 58% of variance PC, and the fact that 95% of respondents chose Q7.2 (Table 6.14) to some extent or more H1 is true.

6.3.13 Sub-Hypothesis No.13

Ho states that no linear relationship exists between Q5Q6PCstrategy and Q7.4. This sub-hypothesis compares strategic planning to Q7.4 to see if there is a relationship between respondents choosing an offensive strategy (Q7.4, first decision) and carrying out strategic planning (Q5Q6PCstrategy).

Table 6.16 Regression Results for Q5Q6PCstrategy and Q7.4

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.0005	0.347	0.12	Yes	0.054

As can be seen this model is significant at the 0.01 level with low (0.2 and .39 is low) correlation and an R-squ of 0.12. Therefore 12% of Q5Q6strategy is explained by Q7.4.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	-1.064	.336		-3.167	.002
	Q7.4 Offensivestrat	.333	.100	.347	3.329	.001

a. Dependent Variable: Q5Q6PCstrategy

Figure 6.13 Coefficients for Q5Q6PCstrategy and Q7.4

Based on Figure 6.13 the regression equation reads:

Q5Q6PCstrategy = 0.347 * Offensivestrat – 1.064 + e1

Considering there is a relatively high use of strategic planning (Table 6.9), that the PC accounts for 58% of the variance of strategic planning and it has the least number of respondents (73% chose Q7.4 (Table 6.14) to some extent or more) this is not as good a predictor as Q7.2 due to the smaller beta value, lower correlation and lower R-squ than Sub-Hypothesis No.12. However, it is still significant – H1 is true.

6.3.14 Sub-Hypothesis No.14

Ho states that no linear relationship exists between Q5.5 and Q7.3. This sub-hypothesis compares the use of platform technology (Q5.5) to Q7.3 which also implies platform usage.

Table 6.17 Regression Results for Q5.5 and Q7.3

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.001	0.353	0.124	No	0.089

As can be seen this model is significant at the 0.05 level with low (0.2 and .39 is low) correlation and an R-squ of 0.124. Therefore only 12.4% of Q5.5 is explained by Q7.3.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients		
		B	Std. Error	Beta	t	Sig.
1	(Constant)	1.915	.499		3.834	.000
	Q7.3 Focusedstrat	.486	.143	.353	3.390	.001

a. Dependent Variable: Q5.5 Platforms

Figure 6.14 Coefficients for Q5.5 and Q7.3

Based on Figure 6.14 the regression equation reads:

Q5.5 = 0.353 * Focusedstrat + 1.925 + e1

Q5.5 was shown to be non-normal in Table 5.10 with 83% choosing some extent or more (34% choosing great extent). As stated in Section 5.3 it implies SMEs are using platforms. According to Table 6.14, 85% of SMEs are using a focused strategy (Q7.3). Therefore, use of platforms and use of a strategic platform approach is high. Q5.5 is only explained by 12.4% of Q7.3 and vice versa, with a low correlation. Platforms can be based on markets, technologies and or manufacturing processes but is high on the evolutionary path (A.15.22). One of the pre-requisites for platform usage is portfolio management. As discussed in Section 5.3 the use of Q8.1, Q8.2 and Q8.3 is high implying portfolio usage. The high apparent usage of platforms is surprising considering the issues discussed in Section 2.5.4.3 and these issues could explain the fact that Ho is true. Also, this regression is based on two items due to survey data reduction and priority requirements – A.15.22 and A.15.23 are examples of questions that were going to be included i.e. items worth further investigation.

6.3.15 Sub-Hypothesis No.15

Ho states that SMEs do not use a Type A differentiated strategy (A.15.13). Figure 6.15 and 6.16 show the five strategy types by industry sector and by number of employees. These describe the SMEs' business strategy.

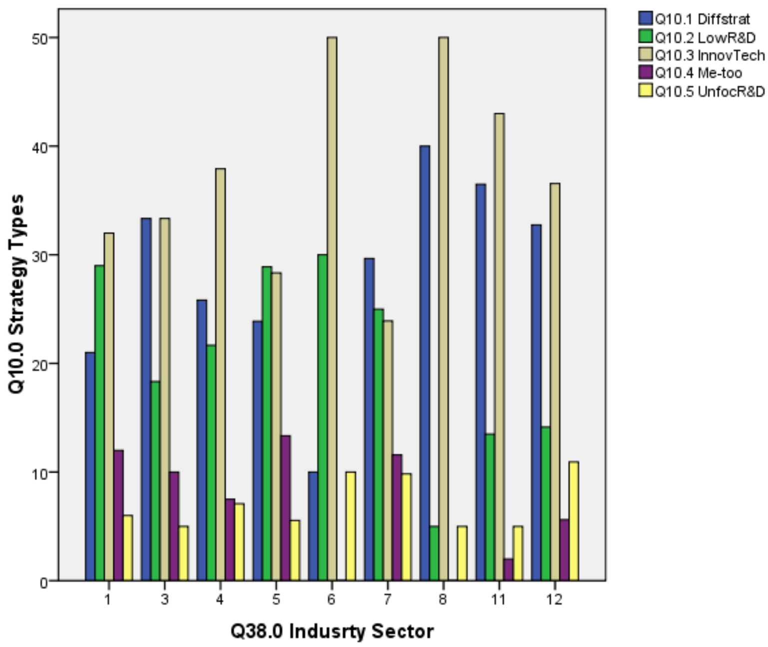

Figure 6.15 Q10.0 Strategy Types by Industry Sector

As can be seen the dominant approach across all sectors in an innovative technology driven approach (technology push strategy). This is in contrast to the business thrusts considered by SMEs when developing their strategy i.e. Q7.2 (marketing driven strategy) was the dominant choice (95% to some extent or greater) and not Q7.1 which is a technolgy driven strategy or technology push strategy (although this was 84%, Table 6.14). A technology push strategy does not require knowledge of the market to develop the product. It is also in contrast to the high use of up front strategic planning carried out by SMEs (Table 6.9) which is in line with a marketing driven strategy. From Section 5.2, 54% of sectors are developing more breakthrough than incremental products which does imply an innovation technology driven approach for half the sectors but not all as shown in Figure 6.15 (Q10.1). The top four sectors from a response rate standpoint are No.12, No.7, No.11 and No.4 respectively (Section 5.2.1). According to Figure 5.6 sector No.12 (Other) develops 50% incremental and breakthrough products (in line with Figure 6.15) while Sector No. 7 develops more incremental (in line with Figure 6.15). Sector No. 11 (Healthcare) develops more breakthrough in line with Figure 6.15 whereas No.4 (special purpose machines) develops more incremental which is in contrast to their Q10.3 approach – Section 4.4.2.1 also found that SPM companies develop incremental products/technologies with their customers and should therefore be using a differentiated strategy (Q10.1). With the exception of Sector No.6 (2.1% of respondents) there is a relatively even balance of Q10.1 and Q10.3 across all sectors however the responses to Q5.0, Q7.0 and Q20.0 are stating that the approach taken by the SMEs should be Q10.1 i.e. Type A differentiated strategy. This could also help explain why Ho was true in Section 6.3.11.

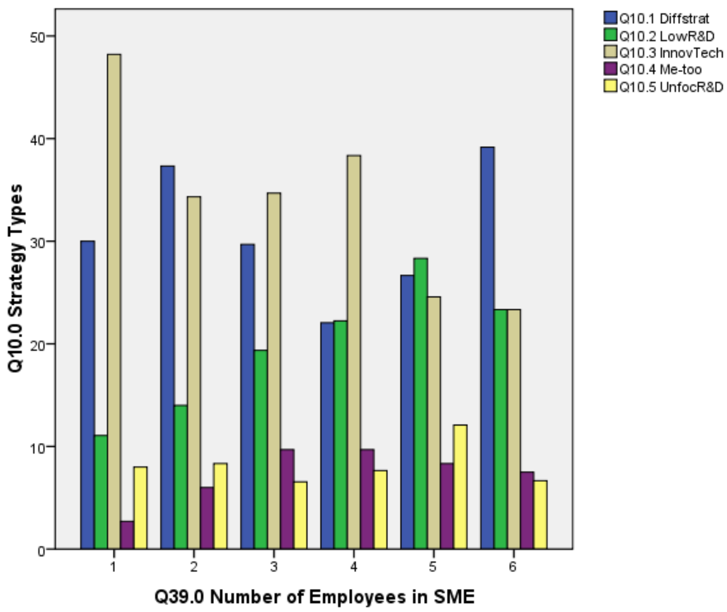

Figure 6.16 Q10.0 Strategy Types by No. of Employees

Small SMEs (73% - 1 to 50 employees, No.1 to No.4) are developing more incremental than breakthrough products (Section 5.2) and this is thus in contrast to

Figure 6.16 which is mostly an innovative technology driven strategy (Q10.3 rather than Q10.1). However, the larger SMEs (51 to 250) are using strategy Q10.1 or a differentiated strategy. Type B - Low R&D (Q10.2) spending and me-too new products are normally developed by smaller SMEs who stay close to their core markets (SMEC 1a and 1b) but according to Figure 6.16 as SME size increases so too does the use of Type B strategy – this could be further indication that Irish SMEs are developing strongly inclined marketing based products, also from Figure 5.1 most SMEs sectors have sales from export in the average 40 to 60% range (mean). The strategy Type E - unfocused R&D spending (Q10.5) is not surprisingly low in both figures. The null hypothesis is rejected although all the findings suggest that SMEs have the basis of this Type A strategy.

6.3.16 Sub-Hypothesis No.16

Ho states that SMEs are not marketing led organisations (MLO, A.12.11). Table 6.18 shows the frequency analysis for Q11.0 (See A.12.10). As can be seen Q11.3 confirms that these SMEs do not have a guaranteed business and Q11.1 that marketing is very important to company success (MLO). Q11.4 does indicate that some SMEs have a heavy reliance on one customer which implies a marketing independent organisation (MIO) - 40% to some extent or more, this could also explain the high response to Q11.1. There is a strong emphasis on price rather than product attributes (Q11.2) which implies a sales orientation and a marketing weak organisation (MWO).

Table 6.18 Frequency Analysis for Q11 (N92)

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q11.1	No	No	95	36
Q11.2	No	No	80	24
Q11.3	Positively	Leptokurtic	5	4
Q11.4	Positively	No	40	10
Q11.5	No	No	87	36

Based on using the role and relevance model to understand the marketing environment in SMEs (A.12.10) these responses imply a mixture of marketing organisations (A.12.8). However, Table 6.9, 6.11 and Section 6.3.1 showed a high response to the strategy, backend marketing and VOC/FFE questions (Q5.0, Q12.0 and Q1.0). Therefore H1 is true.

The response to Q11.4 (reliance on one customer) could mean trouble for the SMEs from international markets (A.12.9) or if that customer were to close down. Q11.5 is also high implying that networking is important to company success (A.12.17). As 73% of the SMEs are small this is not surprising. Also based on this 73% statistic, marketing is being used by these SMEs so the stages/growth effect (marketing only started when the SMEs reached a certain size or level of turnover, A.12.12 - Section 2.11.1.5) is not an issue. A.12.15 (younger SMEs are more aware of marketing than older SMEs) does not apply as the average number of years employees are with the company was eleven – Section 2.11.1.5 (Q14.0). A.12.16 probably does not apply based on the responses to Q5 and Q12. However, marketing led organisations perform better and invest more in marketing (A.12.11).

6.3.17 Sub-Hypothesis No.17

Ho states that SME employees are seen in a negative light if errors are made. Figure 6.17 shows the histogram for Q13.0. As can be seen 57% of responses were ‘’very little extent’ or less (No. 2 and 1) with 36% saying to ‘some extent’.

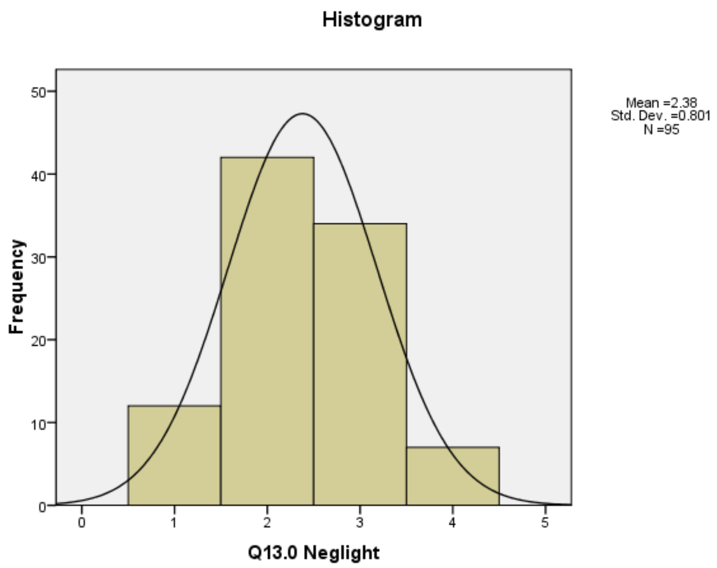

Figure 6.17 Histogram of Q13.0

According to A.17.1 mistakes must be tolerated to enable innovation (gain knowledge and create new value). H1 is supported.

6.3.18 Sub-Hypothesis No.18

Ho states that SMEs are using elements of T&M and are not aware of the actual methodologies. A frequency analysis on Q16.0, Q17.0 and Q18.0 was conducted in Section 5.3 which compared the explained 'practices' of these T&M with the actual T&M (Table 5.11 and 5.12). A regression analysis on these items will also show no significance (e.g. Q16.2 (Kano Model) was regressed with Q17.2 (Kano Model 2) resulting in a significance of 0.474). This supported this hypothesis – Ho is true. Q16.1 Q18.4 and Q18.6 are shown in Table 6.19.

Table 6.19 Frequency Analysis for Q16.1, Q18.4 and Q18.6 (N95)

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q16.1	No	No	86	41
Q18.4	No	No	49	18
Q18.6	No	No	75	35

According to Table 6.19 SMEs are translating CTQ into CTP (Q16.1, A.18.4) which is a key part of the design phase of DFSS. However, use of Six Sigma as a quality environment (Q27.2) was very low and knowledge of other DFSS approaches was minimal. The use of SPSD (Q18.4) is reported as 49% to some extent or more and as a world wide concern and the next step from Design for the Environment (DOE) sustainable product and/or service development is something to be improved upon (A.18.26). Use of industrial design (Q18.6) is reported high (A.6.1, A.6.3, A.6.4, A.6.6) although it is not known if this is in-house or external. These respondents do not see industrial design as strategically unimportant (A.6.2).

6.3.19 Sub-Hypothesis No.19

Ho states that SMEs are using QFD techniques in practice and not realising that they are doing so. A relationship should exist between Q17.1 and Q16.2, Q16.3, Q16.4 and Q16.5 as Q17.1 is QFD which contains Q16.2, Q16.3, Q16.4 and Q16.5. Table 6.20 is extracted from Table 5.11 and 5.12.

Table 6.20 QFD Comparison

Item	Skewness	Kurtosis	Some extent or more (%)	Great Extent (%)
Q16.2	Negatively	Leptokurtic	93	59
Q16.3	Negatively	No	90.5	53
Q16.4	Negatively	No	94	58
Q16.5	No	No	73	35
Item	**Skewness**	**Kurtosis**	**Some extent or less (%)**	**Not At All (%)**
Q17.1	Positively	Platykurtic	61	52

As can be seem the use of the Kano Model (Q16.2), VOCT 1 (Q16.3), VOCT 2 (Q16.4) and Affinity diagram (Q16.5) all report high whereas when respondents were asked if they used QFD (Q17.1), 61% said to some extent or less with a large 52% saying not at all. A linear regression was modelled for this with the dependent Q17.1 and the other items independent – not surprising the model was not significant (0.228). Therefore, Ho is true.

6.3.20 Sub-Hypothesis No.20

Ho states that SMEs are using KBD techniques in practice. Based on responses to Q24.1, only 15% (great extent or more) are using a traditional sequential 'over the wall' development process (N94, A.19.1) – these 15% of respondents support A.5.4 (SMEs have a lack of interest in systematic PD and creating a learning environment). Also, a PDP should consider all aspects of an innovation process (A.5.10) and communicate the need for innovation through a PDP (A.5.12). These SMEs should be trained on a more systematic approach (A.5.9). From Q24.2, 73% are using an 'evolutionary prototyping PDP' or iteration to some extent or more, 37% to some extent (N94, A.19.2/A.19.6). This is part of the traditional sequential process (Section 2.12.1). So although only 15% said they were using this process 73% are experiencing or using iteration (either with simulation or through prototypes – although based on Q24.4 (using prototypes) and Q24.10 (using simulation) in Table 6.21 mostly prototypes, See Section 5.3 for further discussion on Q24.10 to develop their products – this supports learning in the organisation (A.2.11). According to A.5.23 loop-backs are expensive (Figure 2.9 and 2.10) – especially if they are prototype based (as found). For Q24.3 (a budget or schedule limit is set for prototype iterations), 20% responded to a great extent or more (A.19.7) – according to A.5.14 this is better than no process at all. Although this can be used to control the budget or schedule, the technical risks are higher (A.5.19). This can be used in conjunction with a stage gate process where Q24.3 starts at the development and test stage. However, as discussed in Section 5.3, 88% chose some extent or less with 38% choosing not at all to the stage gate process (Q25), the most used PDP in the USA (A.5.16). Table 6.21 shows the PDP characteristics of a Knowledge Based Development process.

Table 6.21 KBD (N94)

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q24.4	Negatively	No	86	49
Q24.5	No	No	59	19
Q24.6	No	No	64	20
Q24.7	No	No	80	35
Q24.8	Negatively	No	89.5	43

As can be seem there is a high usage of using live knowledge from actual prototypes to make decisions (Q24.4) which makes sense when considered along side the fact that Q24.8 is 90% (hands on design review with technical people). Q24.8 implies the use of responsibility based planning (A.5.24) resulting in reduced procedure neglect, responsibility avoidance, lack or process control and management deficiencies (A.5.13). Also, Q24.7 (always have one working prototype when milestones are reached) implies the use of redundancy (A.19.12). However, as established this could be achieved through iteration (Q24.2) whereas A.5.23 (Set-Based CE) should be considered – based on Q24.6 (development of multiple sets of concepts which are systematically eliminated or combined), 64% of respondents are already using a form of this approach (A.19.11) thus possibly achieving more knowledge (A.5.22). This approach is further supported by the responses to Q16.7 and Q18.1 (80% and 88.5% to some extent or more, Table 5.12) – A.18.14 and A.18.15 i.e. the use of a concept classification tree and combination table to systematically examine/narrow and combine concepts. This can be done with or without the T&M associated (the T&M Q17.6 and Q17.7 currently not used by SMEs, Table 5.11 and 5.12). As Q24.7

(always have one working prototype when milestones are reached) is high it is surprising that Q24.5 (use of a knowledge) is not higher. According to A.19.10 concepts/ideas that are deemed too risky can be taken from the knowledge base and used again at the start of the next project – although 59% said they used a knowledge base to some extent or more. Table 6.22 shows the responses to the Concurrent Engineering PDP characteristics.

Table 6.22 CE (N94)

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q24.9	Negatively	No	90	46
Q24.10	No	Platykurtic	49	17
Q24.11	Negatively	No	77	39
Q24.12	No	No	75.5	25

The highest response in Table 6.21 and 6.22 is to Q24.9 (A.19.17). This means that fast cycle times, reduced design rework, reduced PD cost, improved communication and a product that meets customer needs (A.5.26) is a higher probability. Considering that product design and manufacturing issues are considered at the beginning of the PDP (Q24.9) these issues should be considered (designed) in parallel. However, Q24.12 (products and processes are designed in parallel) has a 75.5% response, which is a lower response than Q24.9. Q24.11 (milestone usage) although an aspect of CE is a general item and as can be seen 77% of respondents set milestones throughout the PDP. As can be seen from A.19.17 all of the CE activity starts with CFT (functional departments, customers and suppliers) and as shown in Section 6.3.3 CFT did not show up as a predictor of CE in the regression model. These CE characteristics are considered good PDP practice and could be used in conjunction with the KBD findings. The amount of CAD/CAM integration is also another factor in CE usage (A.19.17). As discussed in Section 5.3 (Table 5.13) there is a high usage of CAD (Q19.5) and CAE (Q19.3) although CAD/CAM (Q19.6, Q19.8) integration was 34% and 42% to 'not at all' while Q19.13 (CAPP) was also very low – this is explained further in Section 5.3. Therefore, Ho is true.

In relation to item Q24.13 40% answered some extent with 75.5% responding to some extent or more to speeding up their PDP to reduce lean times (A.19.18) – this can result in A.5.5 i.e. short-cuts, reduced product quality and reduction in team cooperation which in itself can result in increased resource and people costs. However, it may be related to intellectual property strategy (Section 6.3.26).

6.3.21 Sub-Hypothesis No.21

Ho states that SMEs are using TRIZ techniques in practice. Q19.1 (See Table 5.9) has a 79% response to some extent or less (37% to some extent) to ideation using tools and methodologies (T&M). According to A.8.1 T&M can be used to create breakthrough ideas which can then be developed incrementally (Section 5.2.1 – 73% are small SMEs developing products incrementally). A.18.16 states that creativity or ideation requires the problem solver to see the problem from many perspectives – TRIZ, section 2.7.3.4 is such as technique. From Table 5.12 TRIZ (Q17.8) received 79% response to 'not at all' yet two techniques in TRIZ Q18.2 and Q18.3 (A.18.17, A.18.20) were responded with 90.5% and 76% to some extent or more. Therefore, Ho is true. This hypothesis could equally apply to all the T&M and this will be discussed in the conclusion.

6.2.22 Sub-Hypothesis No.22

Ho states that no linear relationship exists between Q19.1 and Q16.0/Q18.0 T&M explained items (Figure 6.18). In this case Q19.1 (A.8.1) is dependent on Q16.0/Q18.0 as Q19.1 is a conscious decision to use T&M. However, Q17.0 items were not regressed against Q19.1 due to the amount of responses in lower range which is why the T&M explained Q16.0/Q18.0 items were used.

Table 6.23 Regression Results for Q9.1 and Q16.0/Q18.0

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.001	0.537	0.288	Yes	0.382

As can be seen this model is significant at the 0.05 level with modest (0.4 to 0.69 is modest) correlation and an R-squ of 0.288. Therefore 29% of Q19.1 is explained by Q16.0/Q18.0 items.

Coefficients[a]

Model		Unstandardized Coefficients B	Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	.401	.701		.572	.569
	Q16.2 KanoMod	.042	.177	.029	.236	.814
	Q16.3 VOCT1	-.046	.152	-.033	-.299	.765
	Q16.4 VOCT2	.052	.193	.033	.271	.787
	Q16.5 Affinity Diag	.039	.130	.035	.299	.766
	Q16.6 FMEA	-.190	.147	-.152	-1.291	.200
	Q16.7 ClassTree	.333	.155	.301	2.147	.035
	Q18.1 CombinTab	-.139	.160	-.112	-.872	.386
	Q18.2 IdealFinalResult	.385	.152	.301	2.538	.013
	Q18.3 Contradictions	.038	.147	.030	.257	.798
	Q18.7 OneFactor	.180	.124	.176	1.446	.152

a. Dependent Variable: Q19.1 Ideation

Figure 6.18 Coefficients for Q19.1 and Q16.0/18.0

Based on Figure 6.18 the re-calculated regression equation (with the constant still not significant) reads:

Q19.1 = 0.253 * ClassTree + 0.317 * IdealFinalResult + e1

Based on this model ideation is predicted by the Concept Classification Tree (A.18.14) and the TRIZ characteristic IFR (Ideal Final Result), with the influence of IFR 0.401/0.253 = 1.25 times (not accounting for error) more than that of Concept Classification Tree. Of all the T&M the IFR is one of the more powerful for ideation (Section 2.7.3.4.1.1) – the results from this IFR can be analyzed using a concept classification tree. However, the IFR is based on the VOC so items Q16.2, Q16.3, Q16.4 and Q16.5 could be used to gather and understand VOC information. H1 is true to a small extent.

6.3.23 Sub-Hypothesis No.23

Ho states that SMEs are not using 'best practice' CAD/CAM integration. This is investigated by comparing Q19.6 (IGES usage – A.22.5) to Q19.8 (STEP usage – A.22.6). Although neither usage is high (Table 5.13) the 'old' method is used more than the 'new' method i.e. IGES files are used more than STEP214 (See section 2.8.2.1.2). Therefore, Ho is true.

6.3.24 Sub-Hypothesis No.24

Ho states that a linear relationship exists between an SME developing incremental products (Q20.1) and the VOC/FFE activity (Q1.1, Q1.2, Q1.3 and Q1.4) but not for breakthrough products (Q20.2). SMEs developing incremental (products based on marketing pull, not radical technology push products) products should be using these Q1.0 items to gather customer requirements. Q20.0 was binned to create an interval scale as it did not have uniform intervals, from this; 1 = 0 to 19%, 2 = 20 to 39%, 3 = 40 to 59%, 4 = 60 to 79% and 5 = 80 to 100%. As can be seen from Table 6.24 and 6.25 neither models are significant, whereas Q20.1 should be and Q20.2 should not.

Table 6.24 Regression Results for Q20.1 and Q1.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.09	0.291	0.044	Yes	0.164

Table 6.25 Regression Results for Q20.2 and Q1.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.067	0.303	0.092	Yes	0.164

Q20.1 has less significance than Q20.2, although both R-squ values are very low. H1 is true.

6.3.25 Sub-Hypothesis No.25

Ho states that a linear relationship exists between an SME developing incremental products (Q20.1) and strategic planning (Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0) but not for breakthrough products (Q20.2). SMEs developing incremental (products based on marketing pull, not radical technology push products) products should be using these Q5.0/Q6.0 items to understand their markets and customers in order to develop products customers want. As can be seen from Table 6.26 and 6.27 neither models are significant, whereas Q20.1 should be and Q20.2 should not.

Table 6.26 Regression Results for Q20.1 and Q5.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.155	0.379	0.143	Yes	0.359

Table 6.27 Regression Results for Q20.2 and Q5.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.204	0.364	0.133	Yes	0.359

Q20.1 has more significance than Q20.2 – this is in line with 6.3.15, but the F-sig are high. H1 is true.

6.3.26 Sub-Hypothesis No.26

Ho states that SMEs are using secrecy for IPP. Figure 5.11 showed patent usage (Q21.1) frequencies and explained why it was multimodal. Table 6.28 shows Q21.1 (patents) along with Q21.2 (secrecy) and Q21.3 (lead time).

Table 6.28 Frequency responses for Q21.0

Item	Skewness	Kurtosis	Some extent or More (%)	Great Extent (%)
Q21.1	No	Platykurtic	58	32
Q21.2	No	No	73	32
Q21.3	No	No	67	30

As can be seen usage of all three techniques of intellectual property protection are similar in terms of their ‘great extent’ usage although secrecy appears to be the preferred option overall, supporting A.13.7 (secrecy was used more by SMEs). This could be due to A.13.4 (limitations of patents), A.13.6 (cost) and A.13.10 (type of product). Considering that secrecy is the preferred IPP method it is even more surprising that Q22.1 (employees sign protection agreements) is low (Table 5.14). As mentioned in Section 5.3 (Figure 5.4) large companies patent (A.13.8). Also, considering that these SMEs are developing physical products it is less likely that they are patenting processes – secrecy is more effective for processes (A.13.1). From Section 6.3.20, 40% answered ‘some extent’ with 75.5% responding to some extent or more to speeding up their PDP lead times (Q24.13) which may be due to their IPP approach. However, Section 6.3.20 explains the disadvantages of this. Ho is true.

6.3.27 Sub-Hypothesis No.27

Ho states that IP policy, strategy and Portfolios improve the SME sales from new products. As described above, and as can be seen in Figure 6.19, market share is good and overall success/performance is reasonable but sales from new products are weak. From Figure 5.4 the employee range 1 to 50 (No.1 to No.4, 73% of responses) has a high number of new product ideas/enhancements evaluated in the last year. These SMEs are using secrecy (Table 6.28, Figure 6.20– possibly for the reasons given in Section 6.3.26); do not use IP Strategy or Portfolios (Table 5.15) and employees are not trained on company IP policy (Q22.2) yet the use of Q5.0 strategic planning items and Q1.0 VOC/FFE items are high. In addition a regression model with Q36.0 (sales from new products) as dependent and Q21.1, Q21.2, Q21.3, Q23.1 and Q23.2 resulted in a model F-sig of 0.250. Therefore, Ho could be proved true with further investigation.

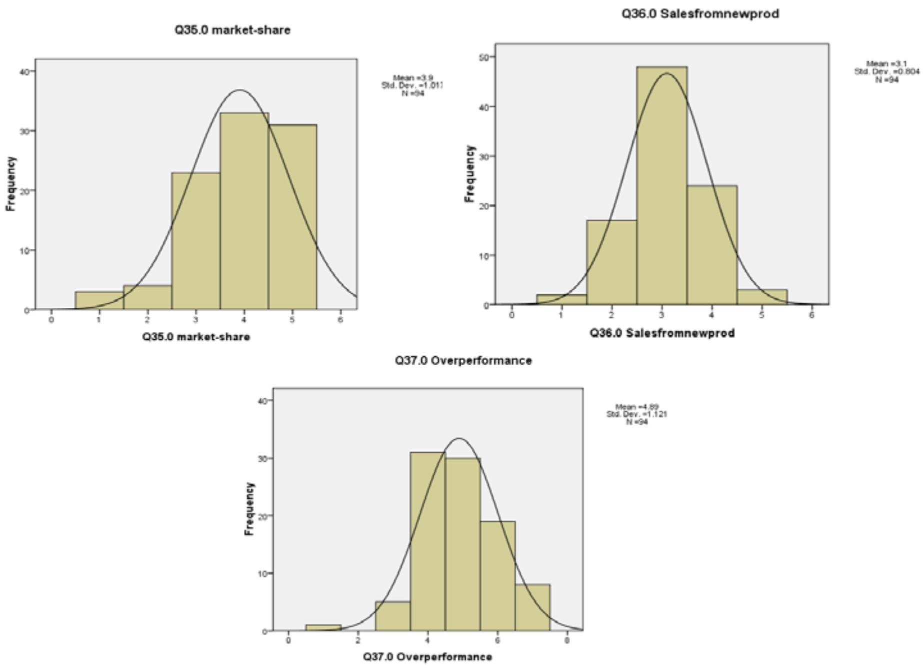

Figure 6.19 Q35, Q36 and Q37 Histograms

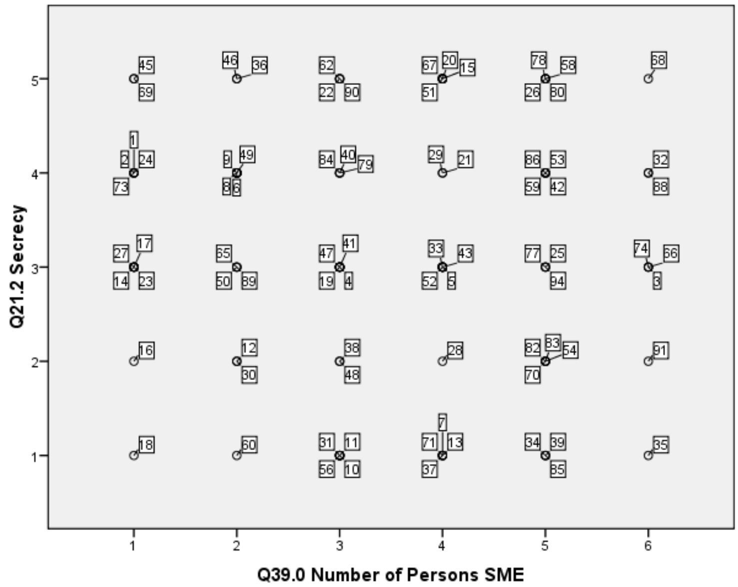

Figure 6.20 Secrecy by Number of Persons in SME

6.3.28 Sub-Hypothesis No.28

Ho states that a linear relationship exists between performance and one or all of the Q24.0 KBD items (Q24.4 to Q24.8), Q24.0 CE items (Q24.9 to Q24.12), Q5.0 items (Q5.1, Q5.2, Q5.3, Q5.6 to Q5.9) and Q6.0 and all Q1.0 items. A principal component was created from the performance indicators Q35.0, Q36.0 and Q37.0 (Figure 6.21). As can be seen 58% of the variance is accounted for by this component.

Total Variance Explained

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	1.738	57.924	57.924	1.738	57.924	57.924
2	.758	25.258	83.182			
3	.505	16.818	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix[a]

	Component
	1
Q35.0 market-share	.782
Q36.0 Salesfromnewprod	.826
Q37.0 Overperformance	.667

Extraction Method: Principal Component Analysis.
a. 1 components extracted.

Figure 6.21 Q353637PC

Table 6.29 shows that none of these regression models are significant.

Table 6.29 Regression Model Significance

	Q353637PC
Q24.0 - KBD Items	0.157
Q24.0 - CE Items	0.07
Q5.0 strategy Items and Q6.0	0.978
Q1.0 Items	0.277

Nevertheless, comparing the F-sig values does show that Q24.0 CE items have a better significance value than the other three predictors. This is due to Q24.9 (considering design and manufacturing issues at the beginning of the PDP) – See Section 6.3.29. However, H1 is true.

6.3.29 Sub-Hypothesis No.29

Ho states that a linear relationship exists between Q37.0 (overall performance/success) and one or all of the Q24.0 KBD items (Q24.4 to Q24.8), Q24.0 CE items (Q24.9 to Q24.12), Q5.0 items (Q5.1, Q5.2, Q5.3, Q5.6 to Q5.9) and Q6.0 and all Q1.0 items.

Table 6.30 Regression Model Significance

	Q37.0
Q24.0 - KBD Items	0.29
Q24.0 - CE Items	0.014
Q5.0 strategy Items and Q6.0	0.779
Q1.0 Items	0.006

As can be seem from Table 6.30 the regression model for the dependent Q37.0 and the predictor Q24.0 CE items and Q1.0 items was significant. Table 6.31 shows the regression results for Q24.0 CE items.

Table 6.31 Regression Results for Q37.0 and Q24.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.014	0.359	0.129	Yes	0.206

As can be seen this model is significant at the 0.05 level with a low (0.2 to .39 is low) correlation and an R-squ of 0.129. Therefore only 13% of Q37 is explained by Q24 CE items.

Coefficients[a]

Model		Unstandardized Coefficients B	Unstandardized Coefficients Std. Error	Standardized Coefficients Beta	t	Sig.
1	(Constant)	3.657	.477		7.661	.000
	Q24.9 CEDesign	.486	.158	.411	3.081	.003
	Q24.10 Simulation	.079	.100	.094	.787	.434
	Q24.11 Milestones	-.189	.126	-.201	-1.496	.138
	Q24.12 Parallel	-.053	.130	-.050	-.408	.685

a. Dependent Variable: Q37.0 Overperformance

Figure 6.22 Coefficients for Q37.0 and Q24.0 CE items

Based on Figure 6.22 the re-calculated regression equation reads:

Q37.0 = 0.312 * CEDesign + 3.497 + e1

Q24.9 is critical for any PD project. As shown in Table 6.22 it has a 90% response to 'some extent' or more and is therefore a characteristic of the PDP that SMEs are doing and consider important. Considering design and manufacturing issues at the beginning of PDP is superseded by ensuring the right product is designed. This is why Q1.0, Q5.0 and Q6.0 and Q9.0 (Section 5.3) are critical along with understanding Q7.0 and Q10.0.

Table 6.32 shows the regression results for Q1.0 items.

Table 6.32 Regression Results for Q37 and Q1.0 items

F-Sig	Pearson's r	Correlation Coefficients R-squ	Linearity	h <0.2, <0.5
0.006	0.385	0.148	Yes	0.164

As can be seen this model is significant at the 0.05 level with a low (0.2 to .39 is low) correlation, although it is close to a modest correlation, and an R-squ of 0.148. Therefore only 15% of Q37.0 is explained by Q1.0 items.

Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	4.191	.575		7.291	.000
	Q1.1 CFT	-.289	.111	-.289	-2.599	.011
	Q1.2 Invite	.300	.114	.284	2.623	.010
	Q1.3 Desfeed	.231	.132	.190	1.749	.084
	Q1.4 Compeval	-.004	.119	-.004	-.034	.973

a. Dependent Variable: Q37.0 Overperformance

Figure 6.23 Coefficients for Q37.0 and Q1.0 items

Based on Figure 6.23 the re-calculated regression equation reads:

Q37.0 = -0.244 * CFT + .333 * Invite + 4.765 + e1

As can be seen Q1.1 (cross functional teams) is negatively correlated with overall success/performance of SMEs. As stated, Q1.1 is 80% to some extent or more in terms of SME response and is critical in a marketing pull PDP strategy. As discovered in Section 6.3.3 (Q24.0 CE items relationship with Q1.0 items) the use of CFT was missing whereas for Section 6.3.4 (Q24.0 KBD items relationship with Q1.0 items) it was included and positive. Unlike in other regression models Q1.2 (invite customers to the SME to discuss strength/weaknesses of products with cross section of employees) is a predictor of success (Q37.0), as would be expected. Q1.2 also includes the use of cross functional teams. Therefore, Ho is true although the Q1.0 relationship is flawed from the perspective of CFT.

6.4 Sub-Hypothesis Conclusion

This section will summarise the above findings as per the structure of the thesis (Figure 1.16).

6.4.1 Strategy Usage/Understanding

The finding from Sub-Hypothesis No. 1 (SHNo.1) was that Ho was true – Q5.4 badly predicted the dependent variables Q1PC1 which consisted of Q1.1, Q1.2 and Q1.3 (R-squ was 13%). Although Q5.4 had a high response it was unknown where this knowledge was coming from i.e. customers, suppliers, competitors and/or universities – however SMEs generally appear to have an open strategy (A.1.5). SMEs are not creating paths through Q1.2 which could lead to new market and technology knowledge (A.7.13). However, due to the high responses to Q1.1, Q1.3, Q1.4 and Q5.4 SMEs are following best practice team working, probing and creating paths. The high reported use of CFT (Q1.1) results in innovation ideas travelling through the organisation (A.7.8) and similarly Q1.3 results in the best practice mitigation of no customer involvement (A.5.8).

SHNo.2 modelled Q1PC1 against three Q16.0 items. Q16.3 and Q16.4 were found to be a predictor of Q1PC1 (which includes Q1.2) which goes towards a relationship between forming teams and understanding customer requirements at two different sections of the questionnaire. It would appear from the responses to Q1.1, Q1.3, Q1.5 and Q16.2, Q16.3 and Q16.4 that SMEs are gathering customer requirements rejecting the possibility of lack of customer involvement (A.5.8, A.7.5) and supporting the understanding of user needs (A.5.10) and to a lesser extent probing the future with partners and creating paths (A.7.13 and A.7.14).

According to A.15.9 the link between business strategy and new product strategy is of critical importance for PD – having a formal and clear strategy is a key success factor (A.1.3). SHNo.8 tested this and was found to be true with Q5.8 and Q6.0 predictors. This shows that SMEs have a form of a Fuzzy Front End (A.1.4) which could be due to 40 to 60% (mean) of SMEs having sales from export (Figure 5.1, A.1.6). However, Q5.6, Q5.7 and Q5.9 were missing from the model and are also characteristics of a formal NPD screening method (A.1.4) – this could be due to the non exporting SMEs concerned with SMEC 3d (operational rather than strategic issues).

According to A.15.13 a Type A differentiated strategy (Q10.1) should contain Q7.1, Q7.2 and Q7.3. As stated in Section 2.5.2.1.3.2 strategy Type A is better than the others from the point of view of new product success, business unit sales (47% v 35%), and meeting the businesses stated new product aims. Based on SHNo.11 none of these three Q7.0 items predicted Q10.1 despite them having high usage responses. This again points to lack of a formal PDP process or a process excluding stages and a lack of a clear strategy (which helps create a competitive advantage), A.1.1 and A.1.3. Sub-Hypothesis No. 12 and 13 examined the relationship between the strategy Q5.0 items and Q6.0 (Q5Q6PCstrategy) and the Q7.2 and Q7.4 business thrusts (these should be considered when developing strategy). Both were significant and considered a true relationship, Q7.2 was a better predictor. This is as expected considering the high usage of Q7.4 as an SME strategy and shows that some form of a clear strategy (which helps create a competitive advantage) exists (A.1.3).

SHNo.14 examines the use of platform technology and although Ho is true Q5.5 and Q7.3 both have high responses. This finding is worth further investigation and the issues in Section 2.5.4.3 should be considered.

SHNo.15 states that SMEs do not use a Type A differentiated strategy. The finding here supports the finding in SHNo.11 that these SME responses point to a Type A differentiated strategy (marketing driven PD approach) but they are using a Type C Innovation Technology driven approach (technology push). This is further proof of SMEs not having a clear strategy (A.1.3) and implies confusion among SMEs about PD strategy.

Although neither model was significant for SHNo.25 the relationship (via the significance of the regression model) between Q20.1 and the Q5.0 items and Q6.0 was stronger than for Q20.2 which supports the findings from SHNo.11 and SHNo.15 – SMEs are developing incremental marketing driven products (gathering customer requirements). However, the finding from SHNo.24 was the opposite – again with insignificant models.

As mentioned in Section 5.3 all Q8.0 items (portfolio usage) had high responses implying portfolio usage – however the items make no reference to the fact that they are related to product portfolios, just projects. This is one of the stages of a PDP (A.1.1) and possibly contradicts A.1.10 which states that SMEs are unable to develop a portfolio of products. According to A.1.14 SMEs that use portfolio management processes out perform those that do not. Q8.1 (balancing long term projects) implies that SMEs are thinking long term which is key to success (A.1.12) although at 85% it is the lesser used of the Q8.0 items – it could also be argued that as the item reads it does not sound as generic as Q8.2 (project are aligned to business strategy) and Q8.3 (projects are prioritised). Q9.0, (Section 5.3) reported an 84% to some extent or more implying that SMEs map future technology against current customer and technology requirements. Like Q8.0 (portfolio management) this does not specifically say it was technology roadmapping. However, the use of Q8.0 and Q9.0 is 'best practice' and the basis of an evolutionary path as the roadmapping output is the input to a portfolio (Section 2.5.5.3).

6.4.2 Organisational Structure / PDP Environment

SHNo.6 (Section 6.3.6) found that the coordination of activities is based on reciprocal interdependence i.e. the forming of task forces and a two way flow of work, resources and information (Q2.0, A.7.20). Responses to Q1.1 (use of CFT's) supported the cross functional team environment (although comments in the survey from smaller SMEs stated that happens naturally). The extent to which the owner/manager assumes the role of facilitator during development activity (Q15.0) pointed to the SMEs working in a decentralised organisation. SHNo.17 (Section 6.3.17) found that employees are not seen in a negative light if mistakes are made (Q13.0). According to A.17.1 in order to innovative mistakes have to be made. The positive answer to this item implies the cultural openness to ideas and experimentation (A.3.2). The use of CFT's allows innovation to travel through the organisation (A.3.3). A no blame culture also ensures a high enrolment in the process of innovation (A.11.5) and these responses show that learning from failure may not be seen in a negative light (A.2.6). Also, managerial development and knowledge management are central to small company innovation strategy (A.3.11) – the knowledge based development environment (Q20.2) chosen by 85% of respondents supports this (See Section 6.4.8).

6.4.3 T&M usage/understanding

Section 2.7.1 highlights A.4.4 to A.4.14, A.4.16 and A.4.19 (although 66 SMEs chose ISO as a quality standard many SMEs do not have process management elements in place) as reasons for SMEs to use T&M whereas the size of the SME (SMEC 4a, 4b, 4c) and complexity of the T&M (A.4.15) are the main issues for T&M non-usage in SMEs. SHNo.18 makes reference to the frequency analysis in Section 5.3 (Table 5.11 and 5.12). It is clear the SMEs are using elements of T&M in practice without using the actual formal methodologies (this was supported by comments from respondents). However, Section 2.7.1 considered these T&M issues and examined T&M throughout the PDP to understand what the key aspects were. From this it was discovered that the House of Quality (an element of QFD) was too complicated (considering SME characteristics) but the Kano Model, VOCT and Affinity diagram could be easily used by SMEs (A.4.23). From Table 5.11 and 5.12, Q16.2 (Kano model) had very high usage whereas Q17.2 was very low, similarly for Q16.3 (VOCT1), Q16.4 (VOCT2) and Q16.5 (Affinity Diagram). This was also supported by SHNo.19 as these items are elements of QFD.

A similar approach was taken to TRIZ, where the requirements of fast success and minimum time spent training (A.4.24) were considered. Again, the key elements with the maximum to gain (in terms of innovation) and the simplest to implement were examined i.e. Q18.2 (the ideal final result) and Q18.3 (elimination of contradictions) – both of which had high 'some extent or more' responses. SHNo.21 also supported this finding as Q18.2 and Q18.3 are methods of ideation. SHNo.22 also considered Q18.2 as a predictor of ideation (Q19.1) along with Q16.7 (use of the classification tree, A.18.14), See Section 6.4.4 re radical bursts of innovation. These Q18.0 items along with Q18.1 (combination table, A.18.15) have a low response to their corresponding Q17.0 items on Table 5.11. In Section 2.7.3.6 DOE was recognised by 88% of SME respondents in Antony's [113] research whereas Q18.7, which describes DOE reported a 70% response to some extent or more. For Q17.11 (direct question on DOE usage) it was 48% 'to some extent or more' – again SMEs are carrying out the activity without recognising what it is. As mentioned in Section 5.3 the higher use of Q17.10, Q17.11 and Q18.1 (CTQ into CTP – see SHNO.18) is surprising considering the 5% response to Six Sigma (Q27.2). It was also stated in Section 2.7.4 that FMEA should be used by all SMEs – with an 89% to Q16.6 and 56% to Q17.12 it should be. According to Q18.5 (you are more likely to control noise factors than use DOE) 59% responded to some extent or more whereas for Q18.7, 70% responded to some extent or more – A.4.28, DOE can reduce cost, warranty, rejection and the overall cost of development. This implies that SMEs are more likely to use DOE than design out the problem. Q17.13 asks about the usage of a simple alternative technique to DOE called 'one-factor-at-a-time' which could be easily adopted by SMEs (A.18.34) rather than the more complicated DOE techniques. However, the fact that SMEs do not seem to 'design out' the need for using experiments (Q18.5) further reinforces the need for a simple alternative to

DOE such as Q17.13 – according to A.4.34, one-factor-at-a-time plans can be used in SMEs where budget and schedule changes affect ongoing experiments i.e. in dynamic PD environments. The high use of FMEA analysis (Q16.6, Q17.5), Q17.12 (DFMA) and Q18.6 (industrial design – See SHNo.18) are positive findings for SMEs future growth. However, as described in Section 6.3.18 the use of Q18.4 (SPSD) requires improvement.

6.4.4 Technology and Technology Development

SHNo.5 (Section 6.3.5) found that no linear relationship exists between Q19.12 and Q1.4. Although patent law is an issue there are numerous other reasons to carry out reverse engineering (Section 2.8.8) which SMEs could consider. According to SHNo.23 (Section 6.3.23) SMEs are not using 'best practice' CAD/CAM integration. STEP214 (Q19.8) eliminates the issues of data exchange, incompatible formatting and lack of interoperability and post-processing (A.8.16). Based on SHNo.20 (Section 6.3.20) and (Section 5.3) Table 5.13 there is a high usage of CAD (Q19.5) and CAE (Q19.3 – among small companies, Figure 5.8) with Q19.13 (CAPP) reporting a very low usage – as stated in A.8.17 CAPP is a link between CAD/CAM and this link between design and manufacturing can be used to increase productivity and potentially improve survival in competitive markets (depends on the industry – Figure 5.9). The low usage of Netmeeting and WebEx are understandable considering the high number of small SMEs (73%). Section 5.3 also discusses Q19.9 (use of rapid tooling), Q19.10 (use of direct rapid tooling) and Q19.11 (use of rapid prototyping, Figure 5.10) and explains how they are also industry dependent (based on the type of product developed).

In relation to industry sector it is 50:50 towards developing breakthrough and incremental products, however, small SMEs are developing incremental products (73% of respondents). According to Q19.2 (technology is developed offline, Table 5.7) and Q19.4 (technology is developed within the PDP, Table 5.8) these incremental products are being developed within the PDP. As mentioned this supports the stance that SMEs do not develop technology online and merge with new products but (A.8.2) develop it within the PDP which supports the finding that they are developing incremental products (which is safer) which can result in stronger market positions if this technology is being developed by new-to-market SMEs

(A.8.8). As stated in Section 2.3.2.7 this incremental development is a faster development process which allows SMEs to use their speed and flexibility (SMEC 2c, 3c, 3i). It is suggested that this be combined with 'bursts of radical change', possibly through ideation (A.8.1) – See Section 6.4.3.

6.4.5 IP Strategy and Portfolio Usage

In terms of intellectual property protection (IPP) SMEs are mainly using secrecy (SHNo.26 – Section 6.3.26) which may explain why SMEs are speeding up lead times through their PDP (Section 6.3.20). Also, secrecy is mainly used for protecting processes (A.13.1) whereas these SMEs are developing physical products – from A.13.2 these SMEs are open to reverse engineering and from A.13.3 they could be loosing out on a marketable asset. They are not using IP Strategy or Portfolios (SHNo.27 – Section 6.3.27). However, all SMEs should take basic steps to protect their work (A.13.11) which is why a higher usage of IP policy should be implemented and explained, preferably through an IP strategy (improving information flow and knowledge sharing – A.13.13) and increasing the chance of evaluated ideas becoming patented products. According to A.13.14, IPP, IP strategy and IP portfolios create value for SMEs and they, when used, should be linked to the New Product Strategy (NPS).

6.4.6 Issues with Change Management

SHNo.7 (Section 6.3.7) found that there is no need for organisation change management processes (Q4.0). However, this requirement would be expected to be necessary for larger SMEs whereas 73% of responses were from small SMEs (1 to 50), and for SMEs with more than one site. Also, responses to the O/M as a facilitator (Q15.0) support that SME management/owners are not dictators (A.9.3) and based on the fact that 40% to 60% of SMEs are exporting it would appear that they are outward looking in nature (A.9.4). According to Figure 6.7 they are also with their SMEs a considerable number of years (A.9.6); however where change is required and employees are lacking in decision making skills the O/M must lead the change (A.10.7).

6.4.7 Marketing Usage (Front and Backend)

According to the findings of SHNo.9 (Section 6.3.9) backend and front end marketing strategies are not linked in the SMEs due to Q5.1, Q5.3, Q5.7, Q5.8, Q5.9 and Q6.0 being missing from the predictive equation. Due to the high responses of Q5.0, Q6.0 and Q12.0 SMEs are carrying out the individual tasks required to link their activities. According to A.12.7 marketing processes are universal and the 4P's should be implementable by most SMEs. However, as Q5.0 and Q6.0 have high responses, the use of backend marketing only (A.12.5) i.e. no front end strategy is not seen as an issue. This finding does imply that SMEs are excluding a key stage of the PDP (A.1.1. A.1.3).

SHNo.16 (Section 6.3.16) found that the use of marketing led organisations (MLO) is strong in SMEs (A.12.11). As Q11.3 (you have a guaranteed business and do not need to carry out marketing to ensure survival) implied that SMEs do not have a guaranteed business it is the case that their competitive environment requires a strategic approach (A.12.8). However, there is an element of a reliance on one customer (Q11.4). Networking is also important to SMEs (Q11.5).

6.4.8 PDP Usage (Stage Gate, CE and KBD)

In a linear relationship between Q24.0 Concurrent Engineering items and Q1.0, item Q1.1 was the only non-significant item (SHNo.3, Section 6.3.3). As Q1.1 is the basis of a CE environment (A.19.17) this was a surprising finding. SHNo.4 examined the relationship between the same Q1.0 items and the Q24.0 Knowledge Based Development (KBD) items. As can be seen in Section 6.3.4 all of the Q1.0 items were significant and predictors of KBD. SHNo.4 (KBD) also has a higher correlation (Pearson's r) and R-squ value than SHNo.3 (CE). SHNo.20 (Section 6.3.20) found that SMEs are not aware of the stage gate process (Q25.0), the majority do not use the sequential PD process (Q24.1) although they do use iteration (Q24.2) and do not set budget or schedule limits for prototype iterations (Q24.3). As covered in Section 6.3.20 it could be argued that KBD is used by Irish SMEs. Also, 85% of respondents chose the definition of a KBD environment as their environment (Q26.2). It should be noted that although Section 6.3.20 talks about KBD in relation to prototyping (KBD is normally done through prototypes) it can also be conducted through simulation – either way the organisation is learning (A.2.11). In Section 2.4 it was suggested that formal NPD processes do not exist within the SME – Ledwith's [15] finding were that PDP formality is not sufficiently linked with NPD success. It was stated that this goes against the findings of A.1.1 and its corresponding SMEC. However, it does look as if the basis of a KBD process could exist and that SMEs should be trained on this type of process (A.5.9) to create a formal PDP based on the principles of KBD that works for SMEs. This would be a process that is not rigid or heavy on paper work (A.5.2). It is clear that SMEs do have a learning environment (A.5.4, A.2.2) and a KBD environment is an innovation and learning process (A.5.10, A.2.9). It can also remove any issues with data recording (A.5.15) and create more knowledge via Set Based CE (A.5.23). This process could also use the other elements of the CE process that SMEs are already using i.e. Q24.9, Q24.11 and Q24.12. It was also found in SHNo.20 that SMEs are speeding up their PDP to reduce lean times (A.19.18) – this can result in A.5.5 i.e. short-cuts, reduced product quality and reduction in team cooperation which in itself can result in increased resource and people costs.

6.4.9 Performance

Q35.0 (Table 5.17), Q36.0 and Q37.0 can be seen in Figure 6.19. For Q35.0 market share in the SMEs industry in the past three years is reported at 35% for 'increased by a small amount' and 33% for 'increased significantly'. Q36.0, sales from new products in the last three years had a response of 72% to 'met expectations' or below and for Q37.0, on a scale of 0 to 6 (0, lowest and 6, highest) 71% chose 4 or below. The weakest performance indicator is sales from new products.

SHNo.10 (Section 6.3.10) examined the relationship between use of strategy and performance. No relationship was found. SHNo.28 (Section 6.3.28) compared PC Q353637PC to Q24.0 KBD items (Q24.4 to Q24.8), Q24.0 CE items (Q24.9 to Q24.12), Q5.0 items (Q5.1, Q5.2, Q5.3, Q5.6 to Q5.9) and Q6.0 and all Q1.0 items none of the regression models were significant.

SHNo.29 (Section 6.3.29) compared Q37.0 (overall performance/success) to Q24.0 KBD items (Q24.4 to Q24.8), Q24.0 CE items (Q24.9 to Q24.12), Q5.0 items (Q5.1, Q5.2, Q5.3, Q5.6 to Q5.9) and Q6.0 and all Q1.0 items. From these linear regression models Q37.0 has a significant linear relationship with Q24.0 CE items and Q1.0 items. For Q24.0 CE this was predicted by Q24.9 i.e. design and manufacturing issues are considered at the beginning of the PDP process (this was also the reason Q24.0 CE items had the highest non-significant value in SHNo.28). It was also significant with Q1.0 items – Q1.1 and Q1.2. However, Q1.1 (cross functional teams) was negatively correlated with the overall success/performance of SMEs – this is surprising as the basis for all good PD activities is CFT.

6.5 Conclusion

This chapter covered the regression analysis and sub-hypothesis testing of 29 different hypotheses. In addition it discussed finding from Chapter 5. The Sub-Hypothesis conclusions will be used to form the conclusions and recommendations in Chapter 7.

Chapter 7
Conclusion and Recommendations

7.1 Conclusion

In Section 3.2.1.2 the following specific areas of 'best practice' were identified and each of these was analyzed in Chapter 5 and 6.

- Strategy usage/understanding
- Organisational Structure/PDP Environment/Culture
- T&M usage/understanding (e.g. SMEs use TRIZ without knowing)
- Technology and Technology Development
- IP Strategy and Portfolio Usage
- Issues with Change Management
- Marketing Usage (Front and Backend)
- PDP Usage (Stage Gate, CE and KBD)
- Performance

7.1.1 Strategy usage/understanding

SMEs generally have an open strategy, are using cross functional teams and are gathering customer requirements. However, they do need to create paths and probe the future more e.g. invite customer for cross functional team analysis of product strength/weaknesses (Q1.2). In addition, strategic planning (Q5.1) related to carrying out market and industry trend analysis (Q5.9) is 94% versus 60% and this is an area worth further investigation. However, this percentage difference could be related to SME Characteristics (Table 2.1) 1c and 1d i.e. SMEs have frequent and close contact with customers (especially for the non-exporting SMEs which would mostly have local and regional markets (SMEC 1b)). The link between their business strategy and their new product strategy appears to be missing and although responses point to a Type A differentiated strategy they appear to be using an innovative technology driven approach – there could be an issue in forming a clear strategy as stated in A.1.3. Generally, SMEs are following best practice, however it may be that these SMEs are trying to develop breakthrough products using incremental ‘organisational (innovation) processes’ e.g. gathering market requirements. Or SMEs think they are developing breakthrough products whereas they are in fact developing incremental products and the strategy and PDP needs to be aligned to this fully. Based on Section 2.4.1.6 it could be suggested that SMEs are good at single product development projects (strong on Q1.0, Q5.0, Q6.0, Q8.0 and Q9.0 – SMEC 3d and 3f do not apply i.e. there is a strategic rather than an operational focus and innovation processes are strong) and the next stage is probing the future and ultimately to have linked routines from one development to the next (evolution by learning) i.e. SMEs improve their core competencies and capabilities by linking and improving their organisational processes.

7.1.2 Organisational Structure/PDP Environment/Culture

SMEs are using reciprocal interdependence and working in a decentralised organisation. The owner/managers are working as facilitators and there is minimal blame culture. This all points to best practice development environments which are open to ideas and experimentation and therefore have potential for innovation. Based on this the dominant SMEC are 2b, 2c, 5a (flat structures with few layers of management, flexible with information flow and less bureaucratic) not 5j, 5k (dictatorial management style that is only results orientated).

7.1.3 T&M usage/understanding

SMEs are using T&M in practice but not the formal methodologies – at times not recognising what they are. The simplified methodologies identified and outlined in this thesis can be used to aid the product development process (PDP) within SMEs and introduce the visual aspects of the design for six sigma (DFSS) approach. They can also be used to increase ideation and therefore develop more innovative products – create evolutionary technology jumps. Considering that SMEs have a lack of resources (financial, human and time – SMEC 4a, 4b, and 4c) simplified tools and methodologies are relativity cheap to implement.

7.1.4 Technology and Technology Development

SMEs are not gaining some of the benefits of reverse engineering or CAD/CAM integration although CAD and CAE usage is high. SMEs are developing more incremental products than breakthrough which is why the findings of the strategy section 7.1.1 and T&M section 7.1.2 are important. Developing incremental products allows SMEC 3c and 3i (flexible and adaptable processes used to develop products in less time). Typically, SMEs are developing products within their PDP process – also implying safer incremental PDP development. SMEs routines can restrain their behaviour. Training on T&M methodologies and CAD/CAM integration could help create an evolutionary path (Section 2.4.1.6.).

7.1.5 IP Strategy and Portfolio Usage

The main intellectual property protection method used is secrecy. SMEs, especially ones developing physical products should be trying to patent products as they add value to the organisation. SMEs are not using IP strategy, IP portfolios or forming IP policy. In this case SMEs are not following best practice and need to implement these strategies. This would then be followed by linking the IP strategy to the new product strategy or business strategy and thus moving to the next evolutionary stage of this organisational (innovation) process.

7.1.6 Issues with Change Management

Respondent SMEs have no significant issues with change management and do not need to use change management processes.

7.1.7 Marketing Usage (Front and Backend)

Although SMEs are carrying out the individual tasks to link their backend and frontend activities this linkage is not happening. Again, SMEs are carrying out best practice in these individual areas and are positioned to move to the next stage of the evolutionary path (linking routines/organisational (innovation) processes).

7.1.8 PDP Usage (Stage Gate, CE and KBD)

SMEs are not aware of the stage gate process and do not use sequential processes but do use elements of the concurrent engineering process. They have product development processes focused on prototyping and experimentation as per A.5.14 and appear to use a knowledge based development (KBD) process for their PDP activities. Although, KBD is based on prototyping this approach can also be conducted through simulation. In addition, the generation of concepts and the narrowing and combining can be done using tools and methodologies (T&M) to get to a stage where prototypes are used – thus creating knowledge and learning. This learning can be from the perspective of the product under development and the organisation i.e. the repetition of the KBD process can be used to improve the overall organisational/product development process by facilitating learning between projects. As stated in A.2.2 – the first step to becoming an innovative organisation is becoming a learning organisation.

7.1.9 Performance

Although market share and overall success were good, sales from new products were weak. Also, from the perspective of conducting surveys, Q44.0 to Q47.0 (A.28.59, A.28.94 to A.28.96 – numerical financial questions) in the pre-test surveys were not answered by four of the five respondents because the question (performance indicator) was not measured or the information to the question was not available to the respondent. The Q35.0, Q36.0 and Q37.0 style of questions (general and using a scale) were all answered.

SMEs are following best practice in a lot of areas; however the recommendations below could be used to bring NPD sales to a higher level.

7.2 Recommendation

- Further training on strategy development and in particular new product strategies.
- Train SMEs on IP policy, strategy and portfolios. Carry out a longitudinal study with a sample of SMEs that are currently creating a high number of ideas but a low number of patents.
- Platforms strategy usage should be investigated further as they are costly and cause over designing in the product families lower end products. Also, platforms that are weak affect all products, platforms can hamper innovation due to the modular approach and they can cause organisational clashes (Section 2.5.4.3).
- Train SMEs on the knowledge based development approach (considering simulation alternatives to prototyping) and develop their current PDP around this approach where appropriate.

- Train SMEs on the key T&M approaches and integrate with aspects of knowledge based development. 'Whole scale change' which is a change management process (Section 2.10.2) could be used in larger SMEs for implementation.
- Develop a software package based on the findings of this research for SMEs to customise their PDP. This can lead to improved collaboration along with management of the process, project, product development tools, project schedule, portfolio management, resource management and PD strategy – See A.22.18.
- Take the findings of this study and investigate them in a longitudinal study – KBD usage and T&M usage of the simplified techniques recommended.
- Support the special purpose machine sector with more finance to help develop products (Figure 5.2).
- Investigate what computer aided engineering (CAE) usage is being undertaken by SMEs.
- Investigate the fact that the emphasis in strategy, fuzzy front end activity and voice of the customer activity should lead to an ability to link the strategy plan to a performance measurement system as mentioned in A.14.12.

In order to support SMEs the following recommendations are advanced:

- Develop a generic best practice product development process based on these findings for SMEs to use (could be paper or software based).
- Develop a training program on this generic best practice product development process.
- Train SMEs on this process (including the areas mentioned above).

In order to make this a reality these recommendations could be submitted to:

1. The Office of Science and Technology (OST) which has a direct link to the Department of Enterprise, Trade and Employment (See Figure 3.2).
2. Enterprise Irelands planning department which develops schemes and programs for Irish SMEs.
3. Enterprise Irelands Research and Innovate division who work directly with Irish SMEs on R&D/Product Development.

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Appendix A Elements and Questions

Appendix A.1 Strategy Element

A.1	SMEC	Strategy Characteristics	Thesis Section	Reference
1	2d,2e,3a,3d,3e,3f,3g,3L,3m,5g,5k	Some SMEs do not have a PDP and therefore must add this requirement as part as their strategy i.e. SMEs should follow a formal product development process which does not exclude key stages	2.1	[26],[30],[68],[35],[32]
2	3e,3f,5c,5f	Innovation should be part of company strategy	2.3	[31], [100],[103]
3	2d,2e,3d,3e,3f,5f,5g,5h,5k	Having a formal and clear strategy is a key success factor to PD success i.e. SMEs need to think strategically to create a competitive advantage and develop a culture of innovation	2.3.2.3 and 2.3.3	[24], [17], [8],[20],[39], [35]
4	3d,3e,3f,3L,5c	Failure to have a formal NPD screening method (trust their in house market knowledge) - All of the PD and design processes researched placed a major emphasis on pre-development activities (FFE) - FFE models contain strategic planning, identification of markets and technologies, idea generation and selection and concept definition, leadership, culture, knowledge management and performance and measurement	2.3.1.1.3, 2.3.2.1 and 2.3.2.8	[37], [42]
5	1a,1b,1c,1e,3L,,3h,4h	Open Strategy - Seeking cooperation and flexibility by utilizing knowledge from external resources/Partnerships with new customers, suppliers, competitors and/or universities (is best for company's developing new products with new technology and is essential to exploit new technology) - management of external linkages consume technical and managerial resources - Transferred Directly Across	2.3.2.1 and 2.4.1.3	[37], [33],[27]
6	1b,3h,5g	Exporting Strategy - High-tech companies have an externally orientated strategic view (planning process), leadership style and culture leading to greater performance	2.3.2.2	[40]
7	3d	The Miles and Snow typology is applicable to manufacturing SMEs (with short life cycles and changing technology (hi-tech SMEs)) i.e. strategic orientation must be considered during strategy formulation and deployment stage	2.3.2.5	[32]
8	3d,5h	The development of strategic plans also aids in measuring performance	2.3.2.8	[14]
9	1a,1b,1c	Product specialisation (technical based) with geographic diversification and a market niche (small companies avoid direct competition with large companies and stay close to their customers)	2.3.2.8	[24], [14]

A.1	SMEC	Strategy Characteristics	Thesis Section	Reference
10	3d,3e,3f	Portfolio Management requirement - Time constraints are also a result of attempting too many projects rather than the right project	2.4.1.1	[35]
11	3d,3e,3f	Unable to develop a portfolio of risk defined products i.e. low risk, medium risk and high risk	2.4.1.1	[42]
12	3d,3f,5k	Only SMEs with long-term strategies and long-term ambition and focus on PD can sustain PD performance	2.4.1.6	[33]
13	1b,3d,5k	Strategic Plan considers the Future, includes mission formulation.	2.5.1	[20]
14	3d,3e,3f,5k	Companies that have a systematic portfolio management process out-perform those that do not	2.5.3	[83]
15	1b,3f,3i,3L,4a	Product Platforms - If an SME has a large variety of products components, modules and other assets across a family of products	2.5.4.3	[87], [88]
16	3d,3e,3f	Roadmapping is the most common form of technology development planning	2.5.5	[89]

Appendix A.2 Learning Element

A.2	SMEC	Learning Characteristics	Thesis Section	Reference
1	3e,3L	In order to innovate, people must want to learn and gain knowledge	2.3.1.2	[41]
2	3e,3f,3L	The first step to becoming an innovative organisation is becoming a learning organisation as this will act as the means to becoming innovative	2.3.1.2	[41]
3	1a,b,c,3e,3f,3L,	SME learning orientation is required as SME marketing is from core customer's feedback and is therefore a narrow form of innovation.	2.3.1.2	[31]
4	2c,3b,3c,3L,4d,4e,4h	Continuous learning – requires enabling learning, competency development, training in team working, problem solving, knowledge management, exploratory dialogue and experimental initiatives	2.4.1.3	[27]
5	4d,4e,4h,5k	Knowledge-based intangible resources accumulate over time through learning (unique and hard to copy by other companies (inimitability))	2.4.1.4	[36]
6	5c,5k	Learning from failure seen as negative	2.4.1.5	[34]
7	1b,1c,1e,3l,4h,5k	Learning concurrently by experimenting with new technology within new markets - SMEs should move from adaptive learning (cost and operational efficiency) too a higher order learning (radical innovations, exploring new markets and technology).	2.4.1.6 and 2.3	[33], [31]
8	2c,3c,3i	SME flexibility and capability to learn and adapt offers a major competitive advantage over larger competitors.	2.4.1.6	[33]

A.2	SMEC	Learning Characteristics	Thesis Section	Reference
9	3L,5b,5c,5i,5j	The learning organisation is not a structural model or design, but rather a cultural model (mindset)	2.6.4.4	[100],[106]
10	3L	The five core disciplines for building a learning organisation are: Systems Thinking, Personal Mastery, Mental Models, Shared Vision, Team Learning	2.6.4.3	[100], [106]
11	3L,4h,5c	The organisation's learning methods are as follows: On the Job, Simulation, Prototyping, Vicarious Learning	2.6.4.3	[100],[106]

Appendix A.3 Innovation Element

A.3	SMEC	Innovation Characteristics	Thesis Section	Reference
1	5c	An employee is seen in a negative light if an error is made, to be an innovator mistakes must be made to gain knowledge and create new value	2.3.1.2	[41]
2	3e,3L,5f	Company innovativeness - the cultural openness to new ideas and experimentation	2.3.1.2	[31]
3	3ef,3f,5f	Innovation must travel through the organisation affecting every discipline, process and level. Innovation requires a co-evolution between technology and culture	2.4.1.3	[27]
4	3e,3L,4a,4b,4c,4d,4e,4h,5j	Necessary competencies to develop innovation capabilities e.g. financial resources, time, facilities, technology, skills, energy and support	2.4.1.3	[27]
5	5j	Innovation implementation – project management (T&M) and innovation initiatives are key	2.4.1.3	[27]
6	4a,4b,4c	Resources hinder the implementation of innovation	2.4.1.3	[27]
7	2c,3e,3f	Innovation process is communicated via job appraisals, information bulletins and informal discussions	2.4.1.3	[27]
8	4c,5f,5i,5j,5j	Innovation implementation - Management buy-in must be sought on all aspects.	2.4.1.3	[27]
9	3d,4a,4b,4c,5j,5k	Innovation implementation - The pressure of production causes problems with implementation i.e. management behaviour caused by production pressure is a huge threat to innovation implementation	2.4.1.3	[27]
10	3d,3e,3f,5k	Innovation as a strategic advantage – new technology, process and products	2.4.1.3	[27]
11	4d,4h,5i,5j	Managerial development and knowledge management should be central to small company innovation strategy	2.4.1.4	[36]

Appendix A.4 T&M Element

A.4	SMEC	Tools and Methodologies Characteristics	Thesis Section	Reference
1	1c,3d, 4a,4b,4c	Lack of use of Planning tools/techniques (maybe due to SMEC 1c and lack of resources) - lack of resources makes planning critical for SMEs	2.3.2.1 and 2.4.1.5	[37], [34]
2	1c,1d,3d	VOC - new products are not positioned along the perceived mindset of customers. In cases of standard products this is due to an existing knowledge of what they want	2.3.2.1	[37]
3	3d,3f,3m	No formal DFMA and no product platform planning. DFMA and weak technical performance or DFMA carried out without designing to customer requirements. Inability to estimate a product unit cost - Good design not carried out, use of tools and methodologies	2.4.1.1	[42], [35]
4	3b,3e,3f,3L,5c	T&M to aid knowledge capture - Problem framing and problem solving; issues with storing/retrieval decisions associated to past projects and their rationale (lack of a structured organisational memory)	2.4.1.5	[34]
5	2b,2c,3d,3f,5f,5g,5h,5i,5j	Strategic Planning as a T&M – provides a common vocabulary and perspective. Turn the O/M tacit views (vision and decision making) into explicit views and aid communication throughout the company avoiding communication problems and therefore issues with cost and time to market (See A.1.2)	2.4.1.5	[34]
6	3e,3f,5g,5h	Tools can guide action and be used to measure progress (where we are, where we are going) and aid communication (who is doing what)	2.4.1.5	[34]
7	3e,3f,3L,5g,5h	Tools can be used to acquire knowledge based on past experiences and capture the knowledge of employees gone from the company	2.4.1.5	[34]
8	3e,3f,3L,5g,5h	T&M prevent technical decision making based on the unknown. Reduce fire fighting	2.4.1.5	[34]
9	3e,3f,3L,5g,5h	In the unpredictable world of PD, process tools can be used to aid problem solving and determine possible outcomes of actions and choices e.g. DFSS	2.4.1.5	[34]
10	3e,3f,5g,5h	Project execution requires monitoring and control tools	2.4.1.5	[34]
11	3e,3f,3L,5k	Within the PD process tools can support before and after learning (learning is the internalisation of knowledge)	2.4.1.5	[34]
12	3e,3f,3L,5j	Ex-ante tools can be used to understand ideas and externalise tacit knowledge i.e. they are used for reasoning and communication	2.4.1.5	[34]
13	3e,3f,3L,5g,5h,5j	Using tools helps improve how things are done and industrialise	2.4.1.5	[34]
14	3e,3f,3L,5g,5h,5j	Ex-post tools can be used to collect the sources of problems, problem solving modes and best practices and thus learn from them. Even with innovation elementary tasks are repeated over	2.4.1.5	[34]

A.4	SMEC	Tools and Methodologies Characteristics	Thesis Section	Reference
		time		
15	4g,4j,4k,5a,5b	Adoption of T&M in companies is directly related to company size and the absorptive capacity (the more complex the T&M the less likely it is to be used) of the SME	2.7.1	[112]
16	3d,3e,3f	The use of T&M, combined with formal planning and training, can be used as a technology path for SMEs - formal planning is linked to T&M adoption	2.7.1	[112]
17	4a,4b,4c	T&M which outputted visual information, identified the root cause of problems and were easier to use were the most used methods	2.7.1	[113]
18	3f,5i	T&M evolution - Six sigma is the next evolutionary stage of TQM	2.7.1	[111]
19	3c,3f,5i	Many SMEs with ISO 9000 do not have process management elements in place - 74.5% of respondent's wanted improved control of the company e.g. documented procedures	2.7.1	[111]
20	3L,4a,4b,4c,4h	A short training programme should be used which concentrates on the main T&M - should be specific to the company with statistical methods minimised. Problem complexity is less in the SME	2.7.1	[111]
21	3d,3f,4a,4b,4c,4d,4e,4h,5j,5k	Six sigma projects should be tracked over 12 months - enough time to provide self financing and short enough to minimise tracking effort	2.7.1	[111]
22	3c,4g,4k	SME may not be willing to change - incentives should be used to encourage usage of the T&M.	2.7.1	[111]
23	4a,4b,4c	HOQ four phases is too complicated for SMEs - From the perspective of an SME the Kano Model, VOC and Affinity Diagram are the critical element at this stage of the PDP	2.7.3.1	[65], [127],[128]
24	4a,4b,4c,4d	TRIZ customers/beginners have four requirements; fast success, minimum time spent training, familiar terminology and 'ego protection'	2.7.3.4	[136]
25	3e,3f,3L,3m,4d,4e,4h	Robust Design - It aides the overall DFSS approach for creating knowledge as it helps increase engineering skills	2.7.3.6	[330]
26	4a,4b,4c	The response surface approach (dual and tolerance analysis) is mathematically complicated (requires a statistician or mathematician) and a consultant/expert should carry out this work - SMEs would not carry out this work themselves	2.7.3.6	[160],[162],[163],[164],[165]

A.4	SMEC	Tools and Methodologies Characteristics	Thesis Section	Reference
27	4a,4b,4c	Generally speaking robust design is complicated, however, basic robust design/design of experiments can be carried out using the Taguchi method or using 'One-Factor-at-a-Time' experimentation - Also, DOE and the Taguchi method were recognised by 88% and 81% of the SMEs in Antony's research	2.7.3.6	[113], [121], [167]
28	4a,4b,4c	DOE can reduce cost, warranty, rejection and the overall cost of the development	2.7.3.6.1.2	[171]
29	4a,4b,4c	According to Frey et al. research findings one-at-a-time plans are more effective than orthogonal arrays under certain conditions	2.7.3.6.2	[167]
30	1a,1b,1c,1d	PLM - However, some smaller companies also have to deal with time pressure, complexity of products, complex manufacturing processes, numerous product configurations, shortening product life cycles, changing suppliers and in some cases multi-location R&D (e.g. possibly exporting SMEs)	Deleted	[331]
31	3m	PLM used because for this? Manufacturing invested in information technology to automate the various processes in NPD leading to CAD/CAM/CAE software. The result of this was what is known as "Islands of Automation"	Deleted	[332]

Appendix A.5 PDP Element

A.5	SMEC	Typical PDP Characteristics	Thesis Section	Reference
1	3d,3e,3f,3L,	PDP usage - Owner/Manager has an implicit marketing/strategic plan which is reflected in day-to-day operations – by translating into a written marketing plan it becomes visible to the employees (improving organisational learning and company innovativeness)	2.3.1.2	[31]
2	3a,3b,3c, 3e,3f,4a,4b,4c	Rigid, top down practices are not appropriate for SMEs – however, structured design documentation can impose rigour without adding levels of inflexible bureaucracy e.g. the product design specification. The key is to have a process that is not laden down with paperwork and is therefore suited to the SME	2.4	[35] and A.1.1
3	1c,3b,3c, 3e,3f,3i,3L,3m,4g,4i,5a,5b,5e,5k	Iteration (for optimum design solution), evaluation and testing of ideas are necessary.		[35]
4	3e,3f,3L,5i,5j,5k	SMEs have a lack of interest in systematic PD and creating a 'learning' environment.	2.4.1.1	[35]

A.5	SMEC	Typical PDP Characteristics	Thesis Section	Reference
5	4a,4b,4c, 4i,5a,5d	Attempts at reduced lead times (speeding up the PDP) in SMEs result in short-cuts, reduced product quality (do not compromise quality), reduction in team cooperation. Knock on is increased resource and people costs	2.4.1.1	[35]
6	3d,3f	PDP failure from - Lack of design documentation e.g. market research reports, product design specifications, risk analysis (business and technical) and validation reports.	2.4.1.1	[35]
7	3d,3e,5h	Existing PDP can prevent development of riskier products e.g. marketing people working on 'sales support' rather than marketing research and competitive analysis	2.4.1.1	[42]
8	1c,3f,3g,3m	PDP failure - Lack of design approval from customer (product rejected) - There is insufficient user/customer involvement (SME companies said this was due to intellectual property and fear of rapid competitive response - however benefits of feedback generally outweigh these issues)	2.4.1.1	[42],[35]
9	3f,4d,5c,5f,5g,5h,5i,5k	PDP process usage - O/M should be trained on a more systematic/process driven development approach with the use of simple design tools e.g. product design specification.	2.4.1.1	[35], [34]
10	1b,3e,3f,3h,5a,5c	An innovation (PD) process must consider: products, technologies, processes, culture, creativity attitude, external focus, understanding of user needs, be incremental (through product/process improvement) and radical	2.4.1.3	[27]
11	3f,3g,5g,5h	PDP software - sound decision making from Investment in management information systems and innovation measures	2.4.1.3	[27]
12	2a,2b,2c, 3e	PDP usage - Communicate the need for innovation in a structured fashion	2.4.1.3	[27]
13	3f,4d,4e	Procedure neglect; responsibility avoidance; lack of process control; management deficiencies	2.4.1.5	[34]
14	1c,3f,3L	Rather than no process at all - SMEs should have fixed development processes focused on prototyping and experimentation with customers	2.4.1.6	[33]
15	3b,3c,3d, 3L,5h	PDP usage - Lack of data recording between projects can cause problems in PD (repeated mistakes) – lack of learning	2.4.1.6	[33]
16	3b,3c,3d, 3e,3f	Stage Gate is the most widely used process (it has been dominant in USA industry for 30 years) in NPD and is also called the waterfall, phase-gate, or life cycle	2.12.2	[252],[65]
17	1c,3i,4a,4b,4c	Stage Gate - process structure is good for well understood technologies and projects that are dominated by quality requirements rather than cost or schedule requirements. If speed and time to market are more important than extra functionality or total quality then it is not a good process - process documentation can be difficult and time consuming	2.12.2	[252],[254]

A.5	SMEC	Typical PDP Characteristics	Thesis Section	Reference
18	1c,3f,3i	Evolutionary Prototyping Process - used for vague requirements with early customer involvement, where speed is used to measure progress	2.12.3	[255], [256]
19	1c,3f,4a,4b,4c	Design to Schedule/Budget process - This process is based on the status of the schedule and/or budget by controlling project time and/or cost risk. Strict budget and schedule limits almost guarantee SME time and cost risks are controlled - technical risks are higher	2.12.4	[255], [256]
20	2c	Unlike manufacturing which is a repetitive process, product development is a non-repetitive process. PD information and communication flow is not in one direction	2.12.5	[261], [262]
21	3e,3f,3L,4h	KBD environment - can be looked at as a learning environment; KBD is supported in Toyota by the management philosophy that “management is learning”	2.12.5	[257]
22	3e,3f,3L,4h	By using a set-based rather than a point-based design process there is more knowledge available	2.12.5.2	[257]
23	3e,3f,3L,4a,4h,5k	Set-Based CE Design is a simple, repetitive development cycle that achieves high innovation in products and manufacturing systems without the risk by using redundancy, robustness, and knowledge capture - redundancy is cheaper than loop-backs	2.12.5.2	[257]
24	2c,3c,5f,5g,5h,5i,5j,5k	Responsibility based planning and control has accountability, ownership and rapid response flexibility	2.12.5.3	[257]
25	3e,3f	SE takes an uncertain and complex set of requirements and applies a structured NPD process	2.12.6	[269]
26	3e,3f	CE - Fast cycle time, reduced design rework, reduced PD cost, improved communications, and a product that meets customer’s requirements	2.12.7	[269], [271], [272]

Appendix A.6 Product Design Element

A.6	SMEC	Product Design Characteristics	Thesis Section	Reference
1	3m	Strong design capability is important in business success	2.4.1.1	[42]
2	3d,3f,3m, 4a,4b,4c,5f,5i,5j	Requirement for a product design process/strategy - can be seen as strategically unimportant	2.4.1.1	[35], [72]
3	3m	Aesthetics should not be compromised for function.	2.4.1.1	[35]
4	3d,3m	Product design which considers usefulness, ergonomics, novelty, appearance/aesthetics, technical and engineering quality and economics are key to differentiation in crowed markets - conventional means of product differentiation is not enough (cost and quality).	2.4.1.1 and 2.4.1.2	[42], [72]

A.6	SMEC	Product Design Characteristics	Thesis Section	Reference
5	4a,3h,3m	Use of industrial design - No use of external or hiring of internal industrial design - however, general understanding of the advantages of industrial design	2.4.1.1	[42]
6	2a,2b,2c,3f,3m	More product design focus - Management focus on TTM and 'stages and gates' resulting in less focus on the design itself. The need to deliver high quality product to market is more important	2.4.1.1	[42]

Appendix A.7 Organisational Structure Element

A.7	SMEC	Organisational Structure Characteristics	Thesis Section	Reference
1	2e,2f	Undefined responsibilities and job descriptions evolve over time	2.4.1.1	[35]
2	2a,2b,2c,3a,3b,3c,3e,3f,3h,3i,3j,3L,3m,4i,4j,4k,5a,5b	The organisational structure (some cases the O/M) must be designed to support innovation	2.4.1.3	[27]
3	2a,2b,2c,2e	Use of Team Leaders	2.4.1.3	[27]
4	1c,2c,4i,4j,4k	Created a panel of lead users – test new products/product improvements and provide in-depth feedback to the customer	2.4.1.3	[27]
5	1c,2c,4i,4j,4k	Invite users (customer) to the SME to discuss strengths/weaknesses of the products with a cross-section of employees	2.4.1.3	[27]
6	1c,2c,3m,4i,4j	Customer involvement in the design process and their feedback on provisional designs	2.4.1.3	[27]
7	3m,4e	Employees evaluate competitor products strengths and weaknesses	2.4.1.3	[27]
8	2a,2b,2c,3j,4j,4k	Team working and a flat structure – enable innovative ideas to travel up through the organisation and enables ad-hoc teams to form and manage innovation	2.4.1.3	[27]
9	3c,4g,4k	Use of organisational development methodologies e.g. used for the introduction of a night shift (could include change management)	2.4.1.3	[27]
10	1c,2a,2b,2c,3j,4j,4k	Teams of engineers and other functional groups sent to customers' premises to solve their problems by developing new products and gaining feedback on market potential of solutions. All employees systematically exposed to customers via meetings and visits	2.4.1.3	[33],[27], [24]
11	1a,1b,1c,3j,4i,4j,4k	Communication - Internal/External requires a structure. Consider the different 'world thoughts' between functional departments	2.4.1.5	Scozzi
12	2a,2b,2c,3j,4j,4k	Cross Functional Teams (CFT) are necessary and easily adopted by SMEs - should include technical and marketing personnel	2.4.1.6	[33], [24]
13	1a,1b,1e,3h,3L	The continual development of new networks of customers and suppliers (partners) should be viewed as a 'path' using a trial and error approach thus gaining new market and technological knowledge	2.4.1.6	[33]

A.7	SMEC	Organisational Structure Characteristics	Thesis Section	Reference
14	1a,1b,1e,3h, 3L	'Probing the future' (with partners) increased credibility as solution providers attracting new customers with novel problems and suppliers with novel technologies	2.4.1.6	[33]
15	2a,2b, 2c,3a,3b, 3c, 3L,5j	Rigid and formal reporting structure results in introspective and therefore incremental PD. Autonomy allows personnel to experiment and develop the learning processes necessary for new-to-market (type 2) product development	2.4.1.6	[33]
16	3d,3e,3f	Changes in strategy may require a new structure for successful implementation - structure should be reassessed. New strategies require different skills and key activities	2.6	[97, 99]
17	2a,2b,2c,3a, 3c,4i,5d	Flat structures make communication easier, faster, and more accurate which aids speedier decision making	2.6.2	[99], [100],[101]
18	3b,3c,4g,5j	Centralised v Decentralised - Adv of decentralisation are: an even distribution of control throughout the organisation, decision making is faster and the organisation is more flexible and responsive	2.6.2	[99], [105],[101]
19	3b,3f,3j	Formalisation is the level to which jobs within the organisation are standardised and the extent to which employee behaviour is guided by rules and procedures	2.6.2	[99],[100],[1 01]
20	2c,3c	Reciprocal interdependence with a high degree of coordination - forming task forces and integrating departments for two way flow of work, resources, or information	2.6.2	[99]
21	2a,2b,3b,3c, 3j,4g,4j,4k,5a ,5b,5e	Size affects structure at a decreasing rate i.e. the smaller the organisation the less structure required	2.6.2.1	[100, 105], [103]

Appendix A.8 Technology Element

A.8	SMEC	Technology/Technology Development Characteristics	Thesis Section	Reference
1	1c,3b,3c,3i,	Technology Development Strategy - Strategic Ideation, Ideation using tools and methodologies can lead to new breakthrough ideas and these technologies can then be developed incrementally	2.3.2.7	Myself
2	1c,3d,3e,3f,5k	Unable to develop technology offline and merge with new products. Develop incremental products of current offerings (safer) - See A.1.7	2.4.1.1	[42]
3	4a	SMEs have a lack of expenditure on technology	2.4.1.3	[27]
4	4d,4e,4h	SMEs have a lack of expertise to use technology to its maximum effect	2.4.1.3	[27]
5	1c,1b,3e,3f	SMEs that combine customer value innovation with technology innovation have sustainable growth and profit	2.4.1.3	[27]
6	3d,3e,3f,3m	Resolve the conflict between core products and more advanced products	2.4.1.3	[27]
7	3m	Reverse engineering through the use of competitor products	2.4.1.3	[27]

A.8	SMEC	Technology/Technology Development Characteristics	Thesis Section	Reference
8	3e,3f	For 'technology positions' new-to-market producers develop new technology within their PDP - results in strong market positions	2.4.1.6	[33]
9	3e,3f,3i,3L,3m,4a,4b,4c	CAD/CAM/CAPP/CAE is critical for design and development orientated SMEs as successful implementation of these should "positively influence the manufacturing parameters and ultimately establish the desired competitive priorities of SMEs in order to safeguard their position in the market place"	2.8	[173]
10	2c,3c,1c,4c,4a,4b,4c	SME benefits gained from integrating CIM technologies/elements are flexibility, speed, reduced cost, improved quality due to increased automation and reduced human error	2.8	[173], [176]
11	3d,4a,4d,5k	Investing in all the elements of CIM is expensive and SMEs must take a long term strategic view and understand enough of the CIM technology to gain an advantage without investing unnecessary time and money	2.8	[173], [174]
12	3c,3i,4a,4h	SMEs should identify the most suitable technologies for their business (which were typically MRP, CAD/CAM and the internet); concurrent engineering (CE) and CAPP were not seen as important – however this was considered to be based on the narrow view of CIM advantages taken by SMEs, flexibility was considered the main advantage from CIM implementation (affecting cost, price, quality and speed) and development and training for employees must be considered	2.8	[173]
13	3e,3f,3i,4c	Only 25% of the USA engineering community are using 3D CAD. Of 1,000 3D CAD users 95% had an increase in productivity, while 69% had faster time to market, and 90% reported one or more of the following:	2.8.1	[180]
14	3f,3m	CAE/CAM/CAPP processes have access to the feature definition of a part to increase process efficiency by not requiring users to specify information already captured	2.8.1	[181], [183]
15	4a	CAD Assembly - Society of Automotive Engineers state that 50% of a product's manufacturing cost is related to the assembly process.	2.8.1.3	[184]
16	3i, 4a,4b,4c	STEP - It is aimed at eliminating the issues of data exchange, incompatible formatting, lack of interoperability and post-processing	2.8.2.1.1	[186], [187], [188]

A.8	SMEC	Technology/Technology Development Characteristics	Thesis Section	Reference
17	3e,3f,3i,3L,3m,4a,4b,4c	Computerised process planning is essential for the integration of CAD/CAM as it is the link between design and manufacturing. Stronger integration of CAD and CAM is needed to increase productivity and ensure survival of SMEs in increasingly competitive global markets	2.8.2.3	[179], [192]
18	4a,4b,4c	CAD/CAM Integration - CAD feature-based information does not provide all the information necessary for process planning e.g. tolerance and materials information must be provided manually	2.8.2.3	[179], [192]
19	3e,3f,3i,3L,3m,4a,4b,4c,4e,4h,	CAE - Before a CAD model goes to CAM it can be analysed to predict product behaviour. The product behaviour is simulated in order to optimise the final product performance.	2.8.3	[197]
20	3i,3L,3m,4a,4b,4c,	Front End CAE - Product knowledge increases faster than cost as the test/redesign is carried out on the computer. This simulation allows more testing options and reduces development time on the overall product	2.8.3.1	[199]
21	4d,4e,4h	FEA is the most common CAE package	2.8.3.2	[197], [198]
22	1e,2c,3h,3i,3L,3m,4a,4b,4c	Collaboration Technology - A method for bringing teams/external people and their knowledge, experience and skills together and is therefore critical for an effective PDP - use of collaboration technology is of great importance	2.8.4	[208]
23	3d,3e,3f,3i,4a,4b,4c,4d,4h,5f,5g,5h5i,5j,5k	Paper based PD processes (see Section 2.12) can now be integrated using the web. This integration increases the project manager/team's ability to manage and track all levels of the project (task, step, phase, product, portfolio, cross portfolio, or enterprise level) at any stage of the PD process - combining them leads to a competitive advantage	2.8.4.3	[218]
24	3d,3e,3f3g,3h,3L,3m,4d,4h,5c,5g,5h,5i,5j,5k	The maturity of the organisation's PDP is often a factor in web-enabling the process	2.8.4.3	[219], [207]
25	2b,2c,3e,3j	The general rule is not to automate a bad process such as the unstructured process. However the purchase of an off-the-shelf solution would bring a structured web-enabled process straight to the company. Alternatively, if the process is structured than a flexible solution could be implemented capturing the requirements of the company. The current legacy systems and the corporate culture also have to be considered i.e. hierarchical organisations should use a highly structured tool while flat structures (SMEC 2b) should use a flexible tool (SMEC 2c), the company ability to	2.8.4.3	[219], [207]

A.8	SMEC	Technology/Technology Development Characteristics	Thesis Section	Reference
		react to change should also be considered		
26	3e,3f,3i,3L,3m	3D printers are the fastest growing RP machine type installed and are used for the early evaluation of product designs. Companies can buy a 3D system from $20,000 to $40,000 making these systems affordable for SMEs	2.8.5	[224]
27	3e,3f,3i,3L,3m	The main types of RP technology used are as follows; SLA (3D Systems, 44.7%), SLS (3D Printing, 13.7%) and 3D Printing (Stratasys,10.7%)	2.8.5	[222]
28	3e,3f,3i,3L,3m	The term Rapid Tooling (RT) is typically used to describe a process which either uses a Rapid Prototyping model as a pattern to create a mould quickly (Indirect RT Method, which is the most popular) or uses the Rapid Prototyping process directly to fabricate a tool for a limited volume of prototypes (Direct RT).	2.8.6	[226]
29	3e,3f,3i,3L,3m	It is believed that RM, which is growing rapidly, will eventually be bigger than RP and RT	2.8.7	[222]
30	3e,3i,3L,3m	Below is a list of reasons for reverse engineering a part or product	2.8.8	[227]
31	3g	Anyone involved in reverse engineering must be familiar with the patent and copyright laws	2.8.8	[229]

Appendix A.9 Leadership Element

A.9	SMEC	Leadership Characteristics	Thesis Section	Reference
1	3b,3d,5k	Ability to delegate - Lack of strategic focus from dealing with short term issues leading to delegation issues.	2.4.1.1	[35]
2	4d,5f,5k	Leaders must be competent and knowledgeable - PD is disadvantaged by O/M unrealistic expectations	2.4.1.1 and 2.4.1.3 and 2.4.1.5	[27], [34],[35]
3	5c,5f,5j,5i (from 4a,4b,4c)	O/M as facilitator - If O/M controls decisions on market research, design specifications, prototyping, pre-production tooling etc - repressive behaviour in PD i.e. O/M should assume the role of facilitator in encouraging employee participation (culture encourages empowerment), delegation of authority from O/M to CFT increases learning	2.4.1.1 and 2.4.1.3	[35], [27], [33]

A.9	SMEC	Leadership Characteristics	Thesis Section	Reference
4	5f,5g,5h	Visionary and committed leadership are required to overcome the resistance to change - leaders must be outward looking in nature (particularly as SMEs have less resources)	2.4.1.3	[27]
5	5f,5j	Leaders must inspire employees	2.4.1.3	[27]
6	4d,4e,5f	Leaders should be in the company a considerable number of years	2.4.1.3	[27]
7	5f,5g,5i,5j,5k	Actions of managers whether they are owners or not is important – provide resources and validity to NPD - lead and participate within all the processes	2.4.1.6	[33]

Appendix A.10 Change Management Element

A.10	SMEC	Change Management Characteristics	Thesis Section	Reference
1	3b,5f,5i,5j	Not Possible to Figure it out from the Top - It is no longer sufficient to have one person learning for the organisation. Top-Down Change or Command and Control methods of change i.e. focused but limited tasks for each worker, thinking/changes done by top management	2.3.1.2, 2.10, 2.10.1	[41], [236], [237],[238], [240]
2	4g,4j,4k,5a,5 b, 5j	Process based approaches to change implementation can be used in SMEs as well as MNC	2.4.1.3	[27]
3	3b,4g,4j,4k,5 a,5b,5i,5j	Use change management; conflict management methods	2.4.1.5	[34]
4	1a,1b,1c,1d, 3b,4k	Change is required as markets and customers advance, competition evolves and new legislation is required (change - strategy, organisational structure, introducing new tools and methodologies, implementing new technology such as CAD or CIM systems or the implementation of a new product development process for SMEs)	2.10	[236], [237]
5	3e,3f	Changes bring company innovativeness to the SME which must travel through the organisation	2.10	A.3.2, A.3.3.
6	3b,5f,5i,5j	Employees must be involved in the change process and pre-emptive communication is the best way to do this i.e. employees are engaged as early as possible in the change process	2.10.1	[237], [239]
7	3b,4d,4e,5a, 5f,5i,5j	In a work culture where employees do not have decision making skills the owner/manager must lead the change until the stage employees' can contribute	2.10.1	[237]

Appendix A.11 Culture Element

A.11	SMEC	Culture Characteristics	Thesis Section	Reference
1	3k,4g,4i,4j,5a,5b,5f,5i,5j	Changing a culture is difficult and requires time and effort. Behaviour change leads to changes in attitudes and values	2.4.1.3	[27]
2	3k,4g,4i,4j,5a,5b,5f,5i,5j	Culture and cultural fit are critical in the SME as the SME is engulfed in the culture of the company	2.4.1.3	[27]
3	5f,5i,5j	A quality culture is a key enabler to the development of a process of innovation management	2.4.1.3	[27]
4	2e,4d,4e,5j	Key employees must take ownership of their roles	2.4.1.3 and 2.4.1.5	[27],[34]
5	5c	No blame culture - High enrolment in the process of innovation - commitment to the company	2.4.1.3 and 2.4.1.5	[27], [34]
6	1c,3b,4h,5c	Training and tolerance towards prudent risk taking	2.4.1.3	[27]
7	4h	Need to watch for errors in recruitment - when recruited insure training on company innovation culture	2.4.1.3	[27]
8	3d,4a,4b,4c	Production pressure hinders the cultural development of a company	2.4.1.3	[27]
9	5i,5j,4a,4b,4c	Improve disciplines of PDP implementation	2.4.1.3	[27]
10	2d,3k	Employee of the year award	2.4.1.3	[27]
11	2a,2b,2c,3j,5f,5j	Communication Culture - Quarterly magazine, weekly team leader meetings, regular planning meetings, encourages informal communication	2.4.1.3	[27]
12	5k	Management must realise that there may be lack of early payback on PD projects	2.4.1.3	[27]
13	2a,2b,2c,3j	Allow corridor meetings	2.4.1.6	[33]

Appendix A.12 Marketing and Branding Element

A.12	SMEC	Marketing and Branding Characteristics	Thesis Section	Reference
1	1b,3d,5g	The pricing strategy is critical i.e. review, monitor and adapting pricing strategy to maintain competitive position in international markets	2.4.1.2	[72]
2	1b,3d,4d,5g,5h	The lack of study of marketing in SMEs has been an issue for over twenty years - insufficient knowledge about marketing in small business remains and an appropriate small business marketing theory is required	2.11	[241], [242]
3	1c,1e,3d	Marketing function, if executed well is a key critical success factor in new product development	2.11	[243]
4	1a,1b,1c,1d,3m,4d,5k	The back end (Development, Testing, and Product Launch) deals with the marketing mix or as it is also known, the 4Ps (Product-Price-Promotion-Placement). Branding is part of the	2.11, 2.11.2	[70], [246]

A.12	SMEC	Marketing and Branding Characteristics	Thesis Section	Reference
		marketing mix		
5	3d,3e,3f	The use of backend marketing only has been criticised in the literature - many o/m see marketing as only the 4Ps and do not see marketing as a means of solving every day issues	2.11	[242]
6	3d,5g,5h	The 'Contingency' approach considers the fact that strategy-performance relationships vary across different environments and company sizes. This approach lies between the extreme views that universal marketing principles exist and apply to all company sizes and each SME is unique and should be analyzed separately. Outcome approach and not a process model	2.11	[242]
7	3c,3f,3L,4i,4j,4k,5a,5b,5d,5e	Marketing processes (such as the 4Ps) are universal and transferable between SMEs (implementation processes are different)	2.11	[242]
8	3d,3e,3f,5h, 5k	The SME business environment is dynamic and can therefore lend itself to a variety of successful marketing approaches and strategies	2.11	[241]
9	1a,1b,1c,1d	In competitive or dynamic businesses, a big marketing effort would be required to maintain market share	2.11.1	[244]
10	3d,5g,5h,5k	The role and relevance model can be used as a diagnostic tool for the current marketing situation and for selecting strategies to achieve future goals	2.11.1	[244]
11	1e,3d,3e,3f, 4d,5f,5g,5h, 5k	Marketing Led Organisations (MLO) perform better and invest more in marketing	2.11.1.5	[241]
12	1a,1b,1c,1d	It was also concluded that the stages/growth approach had an effect as many SMEs only started using marketing when they reached a certain size or level of turnover	2.11.1.5	[241]
13	1a,1b,1c,1d, 4a,4b,4c	Marketing was only used when the competitive environment required a strategic approach and resources were available to implement	2.11.1.5	[241]
14	3d,3e,3f,4d,	MLO (with more than 50 employees) have a marketing database, an active business plan, marketing representation at board level and a marketing department	2.11.1.5	[241]
15	1a,1b,1c,1d	Younger SMEs were marketing orientated whereas older SMEs were less aware (could be related to networking)	2.11.1.5	[241]
16	3d,4a,4b,4c, 4d	Some were operational focused rather than marketing – Due to resources or due to the limited understanding of management	2.11.1.5	[241]

A.12	SMEC	Marketing and Branding Characteristics	Thesis Section	Reference
17	1a,1b,1c,1d	There is plenty of evidence in literature that SMEs are poor at e-commerce, e-business and internet marketing - this is not the case for networking	2.11.3	[241]

Appendix A.13 Intellectual Property Element

A.13	SMEC	Intellectual Property Characteristics	Thesis Section	Reference
1	3g, 3L,4a	Lead time, learning curve and secrecy were mostly used for protecting processes (these are easier to hide than products as they may not be seen)	2.9.2	[232]
2	3g, 3m	Patents were considered more effective for products as competitors' would be able to observe them and possibly reverse engineer them (a reason to patent – Section 2.8.8)	2.9.2	[232]
3	3g,4e	IP is increasingly more important - for technologically orientated SMEs patents could be their most marketable asset	2.9.2	[232]
4	3g,4a,4b,4c	Companies must also consider the limitations of effectiveness of patents such as their validity if challenged, non enforcement if challenged, competitors legally 'inventing around' patents, patent irrelevancy due to technology pace, disclosure of too much information in patent documents and cross-licensing agreements with competitors	2.9.2	[232], [233]
5	3g	SMEs in Europe, Canada and Japan are less likely to patent compared to larger companies	2.9.2	[233]
6	3g,4a,4b,4c	Cost of the Patent Process/Security, Fear and Cost of Litigation, Less likely to patent outside their own country, Bullying by larger companies (Hanel also found this in other studies (Bouju, Tager and von Witzlen))	2.9.2	[233], [231],[234], [235]
7	3g,4a	Secrecy was found to be valued more that patents by all companies, but especially SMEs (it was assumed due to cost issues)	2.9.2	[233]
8	1c,3e,3f,3g, 4a	Large companies patent more because they carry out more innovation and can spread the cost better via higher production runs, although SMEs are closer to the market reducing unnecessary expenditure	2.9.2	[234]
9	3g,3h	The propensity for SMEs to seek cooperative agreements or licence the commercialisation leads to IP protection as this secures their investment	2.9.2	[234]
10	3g,3m	They also discuss the relevance of the type of product (imitability/complexity) and size of SME in terms of which of the six methods of protection to use	2.9.2	[234]

A.13	SMEC	Intellectual Property Characteristics	Thesis Section	Reference
11	3g	All companies should take basic steps to protect their work and lessen the potential for loss of profit and market value	2.9.3	[235]
12	3g,4a,4b,4c	IPP should be explained in company policy and company budget	2.9.3	[235]
13	2c,3d,3e,3f, 3g,3L,4a,4b, 4c	Patent Awareness within the organisation will improve information flow and knowledge sharing between employees and the creation of an IP strategy should be considered	2.9.3	[230]
14	3d,3e,3f,3g, 3L,4a,4b,4c	The sole purpose of IP protection, IP strategies and IP portfolios is to create value for the SME. This is done by linking these to the overall PDP via the Innovation strategy or New Product Strategy and developing commercially successful products.	2.9.4	[230]

Appendix A.14 Performance Measurement Element

A.14	SMEC	Performance Measurement Characteristics	Thesis Section	Reference
1	3e,3f	SMEs do not use a performance measurement (PM) model, use a model incorrectly or use a model for MNC which is modified and therefore missing key elements or just not suitable for SMEs. SMEs must be able to compare the 'feedback reality' to the original strategic plan	2.11.2	[248],[277]
2	4a,4b,4c,3d	No resources and time to implement a PMS as operational rather than strategic focus. No PMS or implementation does not get finished	2.13	[277],[278],[28 1]
3	4d,4e	Technical rather than marketing experience – managerial and operational experience with emphasis on operational	2.13	[277]
4	4a	Lack of financial resources - specifically the affordability of management software (See A.5.11)	2.13	[277]
5	3d,5k	Short term planning	2.13	[277]
6	3e,3f	No formal PD process (tacit knowledge) making the PMS system difficult to implement	2.13	[277]
7	2c,4d,5g,5h, 5i,5k	No understanding of the advantages of a PMS – seen as a reducer of flexibility	2.13	[277]
8	3e,3f	SMEs with a quality culture can have managerial systems.	2.13	[277]
9	3e,3f	Very few PMS models have been developed for SMEs (some since 2001).	2.13	[277]
10	3d,3e,3m,4h ,5a,5b	PMS systems are not integrated i.e. they emphasize operational and financial measures excluding innovation, human resources, work atmosphere, R&D and training. Some use customer satisfaction, internal processes and training indicators.	2.13	[277]

A.14	SMEC	Performance Measurement Characteristics	Thesis Section	Reference
11	3d,3f	PM in SMEs is informal, not planned and not based on a predefined model. It is introduced to solve a specific problem. Therefore, there is a bad alignment between strategy and measures (unless the SME has quality management experience).	2.13	[277]
12	3d,5k	SMEs could use a PMS to implement strategic planning (closing the loop between the front end and back end as discussed in Section 2.11) with a link to operations.	2.13	[277], [278],[281],[248]
13	3d,5k	PM focuses on past activities i.e. gathering information to support the control activities and not for future planning.	2.13	[277]
14	4b,4c	Limited time for data analysis. Data is processed in an imprecise way and presented in a tabular format rather than graphically (unless they have a quality management system).	2.13	[277]
15	3d	PM reviews (tracking changes made to the PMS related to internal/external changes) not carried out correctly resulting in poor alignment to strategic objectives.	2.13	[277]
16	1c,1d,5g,5h	Are PMS's required in an SME as SME businesses are more visible such that an informal PMS systems emerges i.e. they hear about issues with customers, products and/or delays	2.13	[277]
17	4a,4b,4c	Measures should be both simple and practical	2.13	[281]
18	4a,4b,4c,3d	PMS implementation failed due to the implementation process being too resource intensive and too strategically orientated - this is a major issue for PMS in SMEs as they require strategic long-term thinking and to be strategically focused	2.13	[281]
19	1a	Reliance on small number of customers means tracking customer satisfaction is very important.	2.13	[281]
20	2b,3j	Flat organisational structure of SMEs means employees have a wider scope of job. Therefore, human resource dimension must be monitored (e.g. training)	2.13	[281]
21	5f,5j	Owner/Managers have a strong personal goal when formulating performance targets	2.13	[279]

Appendix A.15 Strategy Questions

A.15	Characteristics	Variables	Strategy Questions	Thesis Section	Reference
1	A.1.3	Use of a strategy	Strategic planning is carried out when: An organisation is in start up mode. The company is starting a new venture such as developing a new product, department, or division. To prepare for a new fiscal year. In order to update action plans	2.5.1	[75]
2	A.1.12, A.1.13	Strategic consideration of the future	Applied Strategic Planning – Similar to the Basic and Goal based processes only it helps the organisation to envision the future and therefore create its future	2.5.1	[76]
3	A.1.4	The use of pre-development activity i.e. Fuzzy Front End	The following questions are asked to formulate a mission statement: What function(s) does the organisation perform from the point of view of the customer? What percentage of the customer base is the primary target? How will the mission be achieved, what is the marketing strategy? Why does this organisation exist? How are the organisation's driving forces (e.g. products or services offered, market needs, technology, production capability, method of sale, method of distribution, natural resources, size and growth, and profit/return on investment) prioritised?	2.5.1.1.3	[76],[77]
4	A.1.8, A.1.13	Identification of markets, performance measurement, culture, consider the future	Strategic Business modelling process: Do you identify Lines of business (LOB) – allows planner to decide the mix of products. Identify critical success indicators (CSI) of LOB e.g. sales, ROI, VOC, employee morale. Use Future Planning (pre/pro active).	2.5.1.1.4	[76],[77]
5	A.1.4, A.1.6, A.1.7, A.1.12, A.1.13	Externally orientated strategic view, Use of Miles and Snow, consider the future	Use of a performance audit (SWOT) - Do you carry out the following tasks?	2.5.1.1.5	[65]
6	A.1.3, A.1.12	Use of a long-term strategy	Gap Analysis	2.5.1.1.6	[77]
7	A.1.3	Use of a strategy	Integrating Action Plans	2.5.1.1.7	[77]
8	A.1.1,A.1.3,A.1.4	Use of a PDP not excluding stages, use of a strategy, FFE usage	Do you use an NPS?	2.5.2.1	[65]

A.15	Characteristics	Variables	Strategy Questions	Thesis Section	Reference
9	A.1.1, A.1.3	Use of a PDP not excluding stages, use of a strategy	The link between the business strategy and the new product strategy is of critical importance	2.5.2	[79],[80],[68],[65],[81]
10	A.1.3, A.1.7	Use of a strategy, Use of Miles and Snow	NPS Goal Setting - Prospectors and defenders are the dominant business type used by SMEs (Based on Section 2.3.2.5)	2.5.2.1.1	[65]
11	A.1.1, A.1.3, A.1.4	Use of a PDP not excluding stages, use of a strategy, FEE usage	Do you define target arenas - assessing the identified opportunities - Leads to a company knowing its potentially hottest strategic arenas e.g. market arenas, technologies arenas and/or product arenas	2.5.2.1.2	[65]
12	A.1.1, A.1.3, A.1.4	Use of a PDP not excluding stages, use of a strategy, FEE usage	How do you define target arenas - Arena Strength v Business Strength	2.5.2.1.2.1	[65]
13	A.1.1, A.1.3, A.1.4	Use of a PDP not excluding stages, use of a strategy, FEE usage	Attack arenas (Develop attack plans) - Four Strategic trusts and Strategy type A (1,2,3 trusts) - specific questions on these	2.5.2.1.3.2	[65]
14	A.1.15,A.4.4	Use of product platforms, T&M to capture knowledge	Instead of the four business types or the five strategy types the attack plan could be based on product platforms - After identifying the strategic marketing arenas, product platforms could be developed to target the arenas (strategic trust 3)	2.5.2.3	[65]
15	A.1.1, A.1.10, A.1.11, A.1.14	Use of a strategy, use of a product portfolio	SMEs could use product portfolios	2.5.2.3	[65]
16	A.1.10, A.1.11, A.1.14	Use of a product portfolio	Projects are evaluated, selected and prioritized; existing projects may be accelerated, killed or de-prioritized; and resources are allocated and re-allocated to the active projects - do you carry out these tasks?	2.5.3	[65]
17	A.1.10, A.1.11, A.1.14	Use of a product portfolio	Ensure that the projects with the greatest commercial value are developed in line with their particular business objective	2.5.3	[65], [84], [85]
18	A.1.11, A.1.12,A.1.14	Use of a product portfolio, use of a long term strategy	Balancing of the project portfolio in relation to long term projects v short term projects, high risk projects v low risk projects. Also different markets, technologies, product categories, and project types	2.5.3	[65]

A.15	Characteristics	Variables	Strategy Questions	Thesis Section	Reference
19	A.1.10, A.1.11, A.1.14	Use of a product portfolio	Ensure that all projects are in line with the business strategy of the SME and that if a particular technology is the future of the SME that the projects are aligned to it	2.5.3	[65]
20	A.1.10, A.1.11, A.1.14	Use of a product portfolio	It is critical to balance the resources available for projects and the number of projects under development	2.5.3	[65]
21	A.1.10, A.1.11, A.1.14	Use of a product portfolio	Integrating into NPD - The portfolio gate (phase) or portfolio review approach (at idea stage), after this they are checks	2.5.3	[65]
22	A.1.1, A.1.15	Use of a PDP not excluding stages, use of product platforms	PD projects, to Portfolio Management to Product Platforms	2.5.4	[86]
23	A.1.15	Use of product platforms	The "common building blocks" are the influence behind the "product platforms" and therefore the products brought to market	2.5.4.1	[88]
24	A.1.16	Use of technology development planning	Do you use Road mapping?	2.5.5	[89]
25	A.1.16	Use of technology development planning	Product-Technology Roadmaps - These roadmaps help product teams link the business strategy, product plans, and technology development	2.5.5.2.1	[90],[92]
26	A.1.16	Use of technology development planning	Do you - Product drivers are mapped into quantitative target markets and to the architectural elements of the product (which ensures that the features of the product are related to the product drivers and hence customers needs)	2.5.5.2.1	[92], [94]
27	A.1.16	Use of technology development planning	They show the planned and future planned technology mapped against customer and technology requirements	2.5.5.2.1	[92], [94]
28	A.1.16	Use of technology development planning	Do you - If a company is using roadmaps, then they can be used to support the four goals of portfolio management	2.5.5.3	[92]
29	A.1.5,A.7.13	Utilization of knowledge from external sources (Open strategy), Creation of a 'path'	Question on Open Strategy	2.3.2.1 and 2.4.1.3	[15], [33],[27]

Appendix A.16 Learning Questions

A.16	Characteristics	Variables	Learning Questions	Thesis Section	Reference
1	A.2.1,A.2.2,A.2.4,A.2.6,A.2.9, A.2.10,A.7.8,A.7.17	The requirement for SMEs to learn, How they learn	The five core disciplines for building a learning organisation are: Systems Thinking, Personal Mastery, Mental Models, Shared Vision, Team Learning	2.6.4.3	[100],[106]
2	A.2.3,A.2.4,A.2.5,A.2.8,A.2.9, A.2.11	Learning is critical so what types of learning are used	The organisation's learning methods are as follows: On the Job, Simulation, Prototyping, Vicarious Learning	2.6.4.3	[100],[106]

Appendix A.17 Innovation Questions

A.17	Characteristics	Variables	Innovation Questions	Thesis Section	Reference
1	A.3.1,A.3.2,A.11.5,A.11.6,A.2.6	Perception of mistakes, Mistakes must be tolerated to enable innovation	An employee is seen in a negative light if an error is made, to be an innovator mistakes must be made to gain knowledge and create new value	2.3.1.3	[41]
2	A.3.3,A.3.4,A.3.6,A.3.7,A..11.11	Communication of innovation process, Communication Culture	Innovation process is communicated via job appraisals, information bulletins and informal discussions	2.4.1.3	[27]

Appendix A.18 T&M Questions

A.18	Characteristics	Variables	T&M Questions	Thesis Section	Reference
1	A.4.15,A.4.17,A.4.20,A.4.21,A.4.23,A.4.26, A.4.27	Reasons why SMEs would not use T&M	What T&M are you aware of and do not use, why?	2.7.1	A.4.15 to A.4.20 Ref
2	A.4.2,A.4.4,A.4.6 to A.4.14,A.4.16,A.4.21	Use of VOC, Knowledge capture, Why SMEs should use T&M, Use as a technology path, Sustained use of T&M	DFSS is a complex methodology of systems engineering analysis that uses statistical methods and balances cost, cycle time, schedule and quality	2.7.2	[115]
3	A.4.2,A.4.9	Use of VOC, Use of Problem Solving, Use of Risk	Identify Phase - This phase is concerned with selecting the best product or service concept based on the voice of the customer (VOC).	2.7.2.2	[116]

A.18	Characteristics	Variables	T&M Questions	Thesis Section	Reference
		Analysis			
4	A.4.4, A.4.6 to A.4.14	Knowledge capture, Measurement, T&M used for learning	Design Phase - This is concerned with building a knowledge base about the product or service and is based on the outcome of the above i.e. the translation of customer CTQ into engineering/functional requirements and CTP	2.7.2.3	[116]
5	A.4.4, A.4.6 to A.4.14	Knowledge capture, Why SMEs should use T&M	Optimise Phase - This is concerned with balancing quality, cost, and time to market while detailing the design.	2.7.2.4	[116]
6	A.4.2, A.4.4, A.4.6 to A.4.14	Use of VOC, Knowledge capture, Why SMEs should use T&M	Verify Phase - This is concerned with ensuring that the product or service designed is aligned with the VOC and the customers CTQs	2.7.2.5	[116]
7	A.4.23	Preference for Kano Model, Affinity diagram and VOC	Do you? Quality Function Deployment is a set of product development tools used to transfer the concepts of quality control from the manufacturing process into the new product development process	2.7.3.1	[116]
8	A.4.23	Use of VOC, Kano Model and Affinity diagram	The Kano Model is used to understand levels of customer satisfaction based on product attributes - how do you understand customer satisfaction based on product function?	2.7.3.1.1	[116],[129]
9	A.1.5, A.4.2, A.4.23	Utilization of knowledge from external sources, Use of VOC, Methods of VOC capture, Preference for Kano Model, Affinity diagram and VOC	Methods of capturing the VOC include surveys, focus groups, one on one interviews, customer specifications, field reports, complaint logs and the appendix characteristics	2.7.3.1.2	[116],[65]
10	A.4.2,A.4.23	Use of VOC, Preference for Kano Model, Affinity diagram and VOC	VOCT P1 - identify customer usage of the product, predict possible usage of the product and assist in market studies through usage analysis	2.7.3.1.2	[116],[65]
11	A.4.2,A.4.23	Use of VOC, Preference for Kano Model, Affinity diagram and VOC	VOCT P2 - identifies spoken and unspoken demands based upon the Voice of the Customer and usage information	2.7.3.1.2	[65], [123]

A.18	Characteristics	Variables	T&M Questions	Thesis Section	Reference
12	A.4.2, A.4.23	Use of VOC, Preference for Kano Model, Affinity diagram and VOC	Affinity Diagram - This is a method used by a team to organise and gain insight into a set of qualitative information, such as voiced customer requirements	2.7.3.1.2.1	[116],[123],[130]
13	A.4.4, A.4.6 to A.4.14	Knowledge capture, Why SMEs should use T&M	Do you? - identification of the possible modes of failure of a product or process, and of the likely consequences of such failure	2.7.3.2	[116]
14	A.4.4, A.4.6 to A.4.14	Knowledge capture, Why SMEs should use T&M	Do you? - Concept classification tree - comparison and narrowing - narrowing of concepts is conducted by systematically examining each option. Secondly, using this method allows the identification of independent approaches	2.7.3.3.1	[121]
15	A.4.4, A.4.6 to A.4.14	Knowledge capture, Why SMEs should use T&M	Concept combination table - systematic way to examine combinations of concepts. Potential combinations must be developed and refined to find the overall best solution	2.7.3.3.2	[121]
16	A.4.4, A.4.6 to A.4.14, A.4.20,A.4.24	Knowledge capture, Why SMEs should use T&M, Specific and Simplified T&M usage, Use of TRIZ	Do you? - TRIZ is a series of creativity triggers which help the problem solver see the problem from many perspectives	2.7.3.4	[132], [134]
17	A.4.2,A.4.20,A.4.24	Knowledge capture, Specific and Simplified T&M usage, Use of TRIZ	IFR defined in terms of VOC - The IFR is where the designer envisages the ideal solution to a problem and works towards it as a goal (the ideal is achieved by not making the system more complicated (using free or available resources), not introducing new disadvantages, trying to keep the advantages of the original system, and turning anything harmful in the system into something useful)	2.7.3.4.1.1	[134], [138]
18	A.4.17,A.4.20,A.4.24	Visual/Easy T&M usage, Specific and Simplified T&M usage, Use of TRIZ	Functional Analysis - What does this system do? What does each element of the system do? What does each element act on? Is it: Useful? Harmful? Necessary? Adequate? Inadequate?	2.7.3.4.1.2	[136]
19	A.4.20,A.4.24	Specific and Simplified T&M usage, Use of TRIZ	Trimming - total cost decomposes into the cost of each system part so eliminating or trimming parts without eliminating their required functions increases value to the organisation and customer	2.7.3.4.1.2	[138]
20	A.4.20,A.4.24	Specific and Simplified T&M usage, Use of TRIZ	TRIZ makes the designer look for a higher level solution by designing out the contradiction (e.g. strength v weight)	2.7.3.4.2	[138],i[139]

A.18	Characteristics	Variables	T&M Questions	Thesis Section	Reference
21	A.4.4, A.4.6 to A.4.14,A.4.17,A.4.20	Knowledge capture, Why SMEs should use T&M, Visual/Easy T&M usage, Specific and Simplified T&M usage	Pugh Concept Selection Technique can be used to evaluate and combine solutions	2.7.3.4.5.1	[116],[147]
22	A.4.1, A.4.2, A.4.3, A.4.20	Use of T&M, Use of VOC, Use of DFMA, Specific and Simplified T&M usage	DFM methods can be applied at different stages of the design process i.e. the conceptual design stage, the assembly stage, the selection of materials/processes and finally the detailed design stage	2.7.3.5	[150]
23	A.4.2,A.4.3,A.4.17, A.4.20	Use of VOC, Use of DFMA, Visual/Easy T&M usage, Specific and Simplified T&M usage	Do you use any of these - The most common methods are the Boothroyd and Dewhurst (B-D) DFMA, Hitachi Assembleability Evaluation Method (AEM) and the Lucas DFA Method	2.7.3.5	[149] [150], [152]
24	A.4.2,A.4.3,A.4.17, A.4.20	Use of VOC, Use of DFMA, Visual/Easy T&M usage, Specific and Simplified T&M usage	The following general guidelines apply to DFA/DFM: simplify the design and reduce the number of parts, standardise and use common parts and materials, design for ease of fabrication, design within process capabilities and avoid unneeded surface finish requirements, mistake-proof product design and assembly (poka-yoke), design for parts orientation and handling, design for ease of assembly, design modular products, and design for automated production (if high volume products)	2.7.3.5.1	[153]
25	A.4.2,A.4.3,A.4.20	Use of VOC, Use of DFMA, Specific and Simplified T&M usage	Have you - a more specific set of DFMA guidelines can be developed by a company which suits their product design and manufacturing process requirements	2.7.3.5.1	[153]
26	A.4.2,A.4.3,A.4.20	Use of VOC, Use of Good Design Practice, Specific and Simplified T&M usage	Therefore, SPSD goes beyond DFE by incorporating economic and social aspects and it is recommended that this is incorporated into the company strategy	2.7.3.5.2	[156]
27	A.4.17, A.4.20, A.4.25, A.4.26, A.4.27	Visual/Easy T&M usage, Specific and Simplified T&M usage, Use of Robust	Do you do this rather than Robust Design - SMEs would be more likely to control the noise factors (e.g. design a hermetically sealed unit to control humidity) rather than use complicated experiments to design them out	2.7.3.6	[166]

A.18	Characte ristics	Variables	T&M Questions	Thesis Section	Reference
		Design, Use of Response Surface Analysis, Use of Basic Robust Design			
28	A.4.20, A.4.25, A.4.26,A.4.27,A.4.28	Specific and Simplified T&M usage, Use of Robust Design, Use of Response Surface Analysis, Use of Basic Robust Design, Why DOE usage	Do you carry out robust design at any of these stages (Robust Design Process) -system design, parameter design, tolerance design	2.7.3.6.1	[159],[168]
29	A.4.20, A.4.25, A.4.26,A.4.27,A.4.28	Specific and Simplified T&M usage, Use of Robust Design, Use of Response Surface Analysis, Use of Basic Robust Design, Why DOE usage	Robust Parameter has four Design Steps - 1. Problem Formulation 2. Data Collection/Simulation/Design of Experiments (DOE) 3. Factor/Parameter Effects Analysis 4. Prediction/Confirmation	2.7.3.6.1	[169]
30	A.4.20, A.4.25, A.4.26,A.4.27,A.4.28	Specific and Simplified T&M usage, Use of Robust Design, Use of Response Surface Analysis, Use of Basic Robust Design, Why DOE usage	Do you - DOE - It is a systematic approach of investigating a system/product/process using a series of structured designed tests in which planned changes are made to the input variables	2.7.3.6.1.2	[159]
31	A.4.17, A.4.20, A.4.25, A.4.26,A.4.27,A.4.28	Visual/Easy T&M usage, Specific and Simplified T&M usage, Use of Robust Design, Use of Response Surface Analysis, Use of Basic	Data Collection/Simulation/DOE - The experiments can be carried out in either hardware or through simulation. It is best to have a simple model that captures the design concept such that the specific control, noise and signal parameters can be changed	2.7.3.6.1.2	[169]

A.18	Characteristics	Variables	T&M Questions	Thesis Section	Reference
		Robust Design, Why DOE usage			
32	A.4.4, A.4.6 to A.4.14,A.4.17,A.4.20	Knowledge capture, Why SMEs should use T&M, Visual/Easy T&M usage, Specific and Simplified T&M usage	The control parameter effects are calculated and the results analyzed to pick the optimum control parameter settings	2.7.3.6.1.3	[121], [169]
33	A.4.4, A.4.6 to A.4.14,A.4.17,A.4.20	Knowledge capture, Why SMEs should use T&M, Visual/Easy T&M usage, Specific and Simplified T&M usage	Using the baseline and optimum settings of the control parameters the performance of the product design is predicted resulting in optimum conditions. These conditions are then validated by performing confirmation experiments and comparing to the predictions	2.7.3.6.1.4	[121],[169]
34	A.4.17, A.4.20, A.4.29	Visual/Easy T&M usage, Specific and Simplified T&M usage, Use of One-factor-at-a-time	One-factor-at-a-time plans can be used in companies where budget and schedule changes affect ongoing experiments, and in dynamic PD environments	2.7.3.6.2	[167]
35	A.4.30, A.4.31	Deleted	Is 'Islands of Automation' an issue	2.7.4 - Deleted	[332]
36	A.4.30, A.4.31	Deleted	Do you use PDM software?	2.7.4.2 - Deleted	[332], [333]
37	A.4.30, A.4.31	Deleted	Do you use PLM software?	2.7.4.3 - Deleted	[334]

Appendix A.19 PDP Questions

A.19	Characteristics	Variables	PDP Questions	Thesis Section	Reference
1	A.5.1,A.5.2, A.5.3,A.5.4, A.5.8, A.5.9,A.5.10, A.5.13,A.5.14	Use of a PDP with best practice	Sequential process - each phase stops at a functional department 'wall' and is 'thrown' over	2.12.1	[250],[251]

A.19	Characteristics	Variables	PDP Questions	Thesis Section	Reference
2	A.5.3	Use of Iteration	Sequential process - If the working model fails to deliver the desired performance characteristics, engineers search for design changes that will close the gap and the design-build-test cycle is repeated or looped in software/hardware (redundancy?)	2.12.1	[68]
3	A.5.1,A.5.2,A.5.3,A.5.4,A.5.8,A.5.9,A.5.10,A.5.13,A.5.14,A.5.16,A.5.17	Use of a PDP with best practice, Use of Stage Gate, When to use Stage Gate	Do you use these (Stage Gate Process) stages - Discovery, Scoping, Build Business Case, Development, Testing and Validation, Launch, Post Launch Review	2.12.2	[65]
4	A.5.16,A.5.17	Use of Stage Gate, When to use Stage Gate	Stage Gate - Each stage costs more than the preceding one, so that the plan is based on increasing incremental commitments i.e. as uncertainties decrease, expenditures are allowed to rise and risk is managed	2.12.2	[65]
5	A.5.16,A.5.17	Use of Stage Gate, When to use Stage Gate	Do you use Gates – Before each stage there is a gate. Do you make go/kill/hold/recycle decisions before each stage and plan a path forward	2.12.2	[65]
6	A.5.3,A.5.9, A.5.14,A.5.18	Use of Iteration, Use of Process Driven PDP with Simple T&M, Prototype/Expt PDP, Use of Evolutionary Prototyping PDP	Evolutionary Prototyping Process - This is based on learning and gaining feedback from actual prototypes of the product	2.12.3	[255],[256]
7	A.5.3,A.5.9, A.5.14,A.5.19	Use of Iteration, Use of Process Driven PDP with Simple T&M, Prototype/Expt PDP, Use of Design to Schedule/Budget	Design to Schedule/Budget process - After the prioritisation of the quality and functional concerns and the organisation of tasks by importance, the iteration process begins – priority features are developed first. Each iteration is an improvement over the previous one with iterations occurring until a budget or schedule limit is reached	2.12.4	[255],[256]
8	A.5.13,A.5.20,A.5.21	Sequence of Tasks, Non-repetitive process, Using a Learning Environment	Which best describes your development environment - structural based or knowledge based?	2.12.5	[257]

A.19	Characteristics	Variables	PDP Questions	Thesis Section	Reference
9	A.5.22,A.5.23	Creation of Knowledge, Use of Redundancy	Trade-off Curves and Performance targets - The data for these curves is gained from prototypes with the different trade-off design alternatives representing different performance targets for the radiator design - use live knowledge for decision making	2.12.5.1	[257]
10	A.5.22,A.5.23	Creation of Knowledge, Use of Redundancy	The solutions deemed too risky are placed in a knowledge base to be used by other projects across the company (this is done for every subsystem)	2.12.5.1	[257]
11	A.5.22,A.5.23, A.18.14, A.18.15	Creation of Knowledge, Use of Redundancy, Use of T&M	Use of Set-Based CE Design philosophy - Multiple sets of possibilities (concepts) are worked on by all functions at the subsystem level against broad targets, systematically eliminating or combining to tighter targets	2.12.5.2	[257]
12	A.5.23	Use of Redundancy	Redundancy is achieved by the designer always having a sub-system unit that will work. As knowledge of what will work is gained redundancies are dropped	2.12.5.2	[257]
13	A.5.13, A.5.24	Sequence of Tasks, Use of Responsibility Based Planning	The Chief Engineer (they go through many full design cycles – they are the best engineers on the project with over 20 years experience and make all the technical decisions)	2.12.5.3	[257]
14	A.5.13, A.5.24	Sequence of Tasks, Use of Responsibility Based Planning	Key Integrating Events (e.g. styling approval or tooling release - the target) - The Chief Engineer sets responsibilities for the results and the engineers work out their plans to meet the target dates and communicate the plan to the chief engineer who consolidates the plans to ensure coordination and confidence - integrating events drive both product delivery and the narrowing of choices	2.12.5.3	[257]
15	A.5.13, A.5.24	Sequence of Tasks, Use of Responsibility Based Planning	The design reviews are hands on i.e. technical managers reviewing the technical results of a highly knowledgeable workforce (not the amount of tasks completed)	2.12.5.3	[257]
16	A.5.1,A.5.2, A.5.3,A.5.4, A.5.8, A.5.9,A.5.10, A.5.13,A.5.14, A.5.25	Use of a PDP with best practice, Use of System Engineering	The SE 'V' - where requirements are taken and functionally decomposed into modules (the down stroke of the V), then the system modules are synthesised into the completed system (the upstroke of the V) which is concerned with validation and verification (testing)	2.12.6	[269]

A.19	Characteristics	Variables	PDP Questions	Thesis Section	Reference
17	A.5.1,A.5.2, A.5.3,A.5.4, A.5.8, A.5.9,A.5.10, A.5.13,A.5.14, A.5.26	Use of a PDP with best practice, Use of Concurrent Engineering	CE - Involve all the departments in the company (including customers and suppliers) at the earliest possible stage, design and manufacturing issues are considered at the beginning of the PDP, multi-design alternatives are evaluated earlier, people are working with soft concepts not hand crafted prototypes - simulations, Set milestones throughout the development process, Design products and manufacturing and support processes in parallel, use digital product models (DPM), Integrate CAE, CAD and CAM tools to reduce cycle time, Use T&M for quality	2.12.7	[250], [251]
18	A.5.5	Danger of speeding up the PDP	Attempts at reduced lead times (speeding up the PDP) in SMEs result in short-cuts, reduced product quality (do not compromise quality), reduction in team cooperation. Knock on is increased resource and people costs	2.4.1.1	[335]

Appendix A.20 Product Design Questions

A.20	Characteristics	Variables	Product Design Questions	Thesis Section	Reference
1	A.6.1,A.6.3,A.6.4,A.6.5,A.6.6	Use of industrial design	Do you use industrial design (internal or external)?	2.4.1.1	[42]

Appendix A.21 Organisational Structure Questions

A.21	Characteristics	Variables	Organisational Structure Questions	Thesis Section	Reference
1	A.7.16	Redesign of Structure after Strategy Change	When you change Strategy, did you change Structure? - Changes in strategy may require a new structure for successful implementation - New strategies require different skills and key activities	2.6	[97]
2	A.7.18	Use of Decentralisation	Organisational Decision Making - Is your company decentralised or centralised - influenced by the organisation's environment, size and economic performance	2.6.2	[99], [100],[101]
3	A.7.19	Use of formalisation and standardisation	What level of formalisation and standardisation (higher, better)?	2.6.2	[99],[100],[101]
4	A.7.20	Use of reciprocal interdependence	How do you - Coordinating and Integrating Activities (Reciprocal interdependence)	2.6.2	[99]

A.21	Characteristics	Variables	Organisational Structure Questions	Thesis Section	Reference
5	A.1.2, A.7.2,A.7.8, A.7.17, A.7.21	Use of Structure for Innovation, Use of CFT, Employee autonomy	Ask questions on Organic and Mechanistic Structures - It is important for the SME to get the right balance between mechanistic and organic structures in line with the contingency factors	2.6.2.1 and 2.6.2.2	[99], [100],[103]
6	A.7.2,A.7.21	Use of Structure for Innovation	Which of the following Org Structure does your organisation use for product development activity?	2.6.3, 2.6.4	[100],[104]
7	A.7.13,A.7.14, A.7.17,A.7.18, A.7.20	Use of network development as a 'path', 'Probing the future' with partners, Use of a flat structure, Use of Decentralisation, Use of reciprocal interdependence	Do you use Virtual Organisations? These organisations stay small and are highly centralised, with little departmentalisation. Individuals and/or small companies work together on a project-by-project basis and therefore each project can be staffed according to its demands. Virtual organizations are flexible and non-bureaucratic, while overhead and long-term risks and costs are minimized. However, they limit management's control over key parts of its business and communication links are crucial.	2.6.4.1	[101],[100], [105]
8	A.7.11,A.7.12, A.7.13,A.7.14, A.7.15,A.7.17, A.7.18,A.7.20	Use of Structure for Communications, Use of CFT, Use of network development as a 'path', 'Probing the future' with partners, Employee Autonomy, Use of a flat structure, Use of Decentralisation, Use of reciprocal interdependence	Boundryless (as used in Learning Org) - As there is no pre-defined structure, the design is not defined by, or limited to, horizontal, vertical or external boundaries. This organisation minimizes the chain of command, limits spans of control, and replaces departments with empowered teams. Vertical barriers are broken down using cross-hierarchical teams, participative decision making, and 360-degree performance appraisals. Horizontal barriers are broken down using cross-functional teams, project-driven activities, lateral transfers, and job rotation. External barriers are broken down through globalization, strategic alliances, customer-organisation linkages, and telecommuting	2.6.4.2	[105],[100], [101],[107]
9	A.7.8,A.7.12	Use of Teams/Flat Structure, Use of CFT's	Do you use CFT?	2.6.5	[108],[109]

A.21	Characteristics	Variables	Organisational Structure Questions	Thesis Section	Reference
10	A.7.3, A.7.17, A.7.18	Use of Team Leaders, Use of Flat Structure, Use of decentralisation	Do you use Team Collocation?	2.6.5.1	[108],[109]
11	A.7.3	Use of Team Leaders	Use of Team Leaders	2.4.1.3	[27]
12	A.7.4, A.7.13, A.7.14	Use of a panel of Lead users, Use of network development as a 'path', 'Probing the future' with partners	Created a panel of lead users – test new products/product improvements and provide in-depth feedback to the customer	2.4.1.3	[27]
13	A.7.5, A.7.12, A.7.13, A.7.14	Use of workshops, Use of CFT's, Use of network development as a 'path', 'Probing the future' with partners	Invite users (customer) to the SME to discuss strengths/weaknesses of the products with a cross-section of employees	2.4.1.3	[27]
14	A.5.8, A.7.6, A.7.13, A.7.14	Use of Phase reviews, Customer involvement in design, Use of network development as a 'path', 'Probing the future' with partners	Customer involvement in the design process and their feedback on provisional designs	2.4.1.3	[27]
15	A.7.7, A.8.30	Evaluation of Competitor products, Use of Reverse Engineering	Employees evaluate competitor products strengths and weaknesses	2.4.1.3	[27]
16	A.7.10, A.7.12, A.7.14	Use of Technical Teams, Use of CFT's, 'Probing the future' with partners	Teams of engineers and other functional groups sent to customers' premises to solve their problems by developing new products and gaining feedback on market potential of solutions. All employees systematically exposed to customers via meetings and visits	2.4.1.3	[33],[27],[24]

A.21	Characteristics	Variables	Organisational Structure Questions	Thesis Section	Reference
17	A.1.5, A.7.13	Utilization of knowledge from external sources (Open strategy), Creation of a 'path'	The continual development of new networks of customers and suppliers (partners) should be viewed as a 'path' using a trial and error approach thus gaining new market and technological knowledge	2.4.1.6	[33]
18	A.7.14	Use of 'probing the future'	'Probing the future' (with partners) increased credibility as solution providers attracting new customers with novel problems and suppliers with novel technologies	2.4.1.6	[33]

Appendix A.22 Technology Questions

A.22	Characteristics	Variables	Technology/Technology Development Questions	Thesis Section	Reference
1	A.8.9, A.8.10, A.8.11, A.8.12, A.8.13	Why CIM should be used, Suitable CIM long term use, Use of appropriate CIM, Use of 3D CAD	Do you use 3D CAD?	2.8.1	[179]
2	A.8.9, A.8.11, A.8.12,	Why CIM should be used, Suitable CIM long term use, Use of appropriate CIM	Do you use 2D CAD? Where an operation is simple enough to draw and does not require parametric modelling. When the overhead of parametric relationships is not desired. Where it is difficult to go back and remove associativity, constraints etc (depends on the 3D CAD system chosen). When a model is too complex to be completely defined in parametric. When a model is received from another CAD system and parametric data is not available. Where 2D can be used to work out information like the point where two arcs intersect and this information is brought to 3D CAD systems i.e. used as an aid to 3D modelling	2.8.1	[182]
3	A.8.18	Use of Feature Based CAD	Do you use Feature Based CAD systems?	2.8.1	[181],[183]
4	A.8.15	Use of CAD Assembly	The assembly modeller can be queried to provide information on; interferences and clearances between parts, compute mass properties for the entire assembly, and automatically create exploded views, bill of materials, and an assembly drawing	2.8.1.3	[184]

A.22	Characteristics	Variables	Technology/Technology Development Questions	Thesis Section	Reference
5	A.8.16, A.18.17	Use of Integration (IGES/CAM)	CAD system sent a description of the part as a drawing in an IGES file. IGES files are a standard for transferring drawing information between CAD/CAM systems. This file was read into a CAM system and an operator used it to generate the RS274D code or G/M Codes	2.8.2.1.2	[188], [186],[190]
6	A.8.16, A.18.17	Use of Integration (STEP/CAM)	AP214 file which contains a 3D model is sent to a process planner who reads the file into a process planning system which outputs an AP238 file containing all the information required to make the part	2.8.2.1.2	[188], [189],[190]
7	A.8.14, A.8.16, A.8.18	Use of Feature Recognition, Use of Integration, Use of Feature Based CAD	An integrated CAD/CAM system creates instructions for making a part on a machine tool (using feature recognition) and sends those instructions (via DNC, LAN, WAN or the Internet) to a CNC milling machine containing an embedded CAM system	2.8.2.1.2	[188],[186], [190]
8	A.8.17	Use of CAPP (VPP)	CAPP - VPP uses existing process plans which are edited to the new part requirements and are based on group technology (GT)	2.8.2.2	[179],[191], [192],[193]
9	A.8.17	Use of CAPP (GPP)	CAPP - In the GPP approach a process plan is generated automatically from engineering specifications of the finished part i.e. from the ground up...CAD/CAPP/CAM Integration - Planning of Activities Resources and Technology (PART) is a GPP CAPP system	2.8.2.2, 2.8.2.3	[179],[191], [192],[193],[194]
10	A.8.18	Use of Feature Based CAD	Feature Recognition - Machineable features that are recognised automatically can be automatically linked to corresponding machining routines stored in knowledge-based databases. When linked to the automated tool path generation available in most CAM packages the result is a fully automated CAM process	2.8.2.4	[196]
11	A.8.20	Use of Front End CAE	The analysis is carried out early in the development stage resulting in an earlier optimised design and ultimately a smoother prototype to production transition	2.8.3.1	[199]

A.22	Characteristics	Variables	Technology/Technology Development Questions	Thesis Section	Reference
12	A.8.21	Use of FEA	Do you use FEA Analysis?	2.8.3.2	[197],[199],[200]
13	A.8.20	Use of Front End CAE	Do you use CFD?	2.8.3.3	[201],[202], [203]
14	A.8.20	Use of Front End CAE	Kinematics is therefore easier to carry out; it shows the physical position of all the cycling parts in an assembly/mechanism relative to time. It carries out steady-state motion (no acceleration) simulation and interference analysis of assemblies (some software packages also provide reaction forces from the motion)	2.8.3.4	[204], [205]
15	A.8.20	Use of Front End CAE	Dynamic analysis gives motion data; forces, accelerations, velocities, and exact locations of joints, or points on geometry: Do you do the following? See List	2.8.3.4	[204], [205]
16	A.8.22	Use of Collaboration Technology	Netmeeting?	2.8.4.2.1	[213], [336], [215]
17	A.8.22	Use of Collaboration Technology	WebEx?	2.8.4.2.2	[216]
18	A.8.22, A.8.23, A.8.24, A.8.25	Use of Collaboration Technology, Use of Web Enabled PDP, Maturity of PDP	Web-enabling of the product development process (or process automation/management) - Adv - Collaboration, management of the process, project, product development tools, project schedule, portfolio management, resource management and PD strategy (business side)	2.8.4.3	[217],[218]
19	A.8.26, A.8.27,	Use of Rapid Prototyping	What do you use: The main types of RP technology used are as follows; SLA (3D Systems, 44.7%), SLS (3D Printing, 13.7%) and 3D Printing (Stratasys,10.7%) are the main systems	2.8.5	[222]
20	A.8.27	Use of Rapid Prototyping	Functional Models, Fit/Assembly Test, Visual Aids for Engineering, Patterns for Prototype tooling, Patterns for Cast Metal, Tooling Components, Visual Aids for Toolmakers, Proposals, Direct	2.8.5	[222]

A.22	Characteristics	Variables	Technology/Technology Development Questions	Thesis Section	Reference
			Manufacturing, Ergonomic Studies, and Quoting		
21	A.8.28	Use of Rapid Tooling	Do you use Indirect Rapid Tooling	2.8.6	[226]
22	A.8.28	Use of Rapid Tooling	Do you use Direct Rapid Tooling	2.8.6	[226]
23	A.8.29	Use of Rapid Manufacturing	Do you use RM	2.8.7	[222]
24	A.8.30, A.8.31	Use of Reverse Engineering	Do you Reverse Engineer	2.8.8	[227], [228],[229]
25	A.8.1	Use of T&M for Ideation	Do you do Strategic Ideation - Ideation using tools and methodologies can lead to new breakthrough ideas and these technologies can then be developed incrementally	2.3.2.7	Myself
26	A.1.7,A.8.2	Use of Miles and Snow, How Technology is Developed	Do you develop technology offline and merge with new products.	2.4.1.1	[42]
27	A.8.8	How Technology is Developed	Do you develop new technology within your PDP?	2.4.1.6	[33]
28	A.8.2	How Technology is Developed	Do you develop incremental products of current offerings (safer) or radical new products	2.4.1.1	[42]
29	A.8.3	Level of Tech Expenditure	What is your level of expenditure on technology?	2.4.1.3	[27]
30	A.8.4	Lack of Expertise	What levels of qualifications does your organisation have?	2.4.1.3	[27]

Appendix A.23 Leadership Questions

A.23	Characteristics	Variables	Leadership Questions	Thesis Section	Reference
1	A.9.2,A.9.6	Competency and knowledge linked to leaders time in the SME	How Many Years? - Leaders should be in the company a considerable number of years	2.4.1.3	[27]

A.23	Characteristics	Variables	Leadership Questions	Thesis Section	Reference
2	A.9.1,A.9.3	O/M controlling or facilitating	How much control - use of CFT? O/M as facilitator - If O/M controls decisions on market research, design specifications, prototyping, pre-production tooling etc - repressive behaviour in PD i.e. O/M should assume the role of facilitator in encouraging employee participation (culture encourages empowerment), delegation of authority from O/M to CFT increases learning	2.4.1.1 and 2.4.1.3	[35], [27],[33]
3	A.9.3,A.9.7	Level of leadership by management	Are you an O/M? - Actions of managers whether they are owners or not is important – provide resources and validity to NPD - lead and participate within all the processes	2.4.1.6	[33]

Appendix A.24 Change Management Questions

A.24	Characteristics	Variables	Change Management Questions	Thesis Section	Reference
1	A.10.1, A.10.4, A.10.6, A.10.7	Top down change issues, Use of CM, Pre-emptive communication, When to engage employees	Have you encountered - There are a number of common issues with change	2.10.1	[236], [237],[238],[240]
2	A.9.3, A.9.4, A.10.1, A.10.2, A.10.3, A.10.4, A.10.5, A.10.6, A.10.7	O/M controlling or facilitating, Visionary and Committed Leadership required for change, Top down change issues, Use of Process Based CM, Use of CM, Pre-emptive communication, When to engage employees	Do you use Change Management Processes	2.10.2	[238]
3	A.10.1, A.10.2, A.10.3, A.10.4	Top down change issues, Use of Process Based CM, Use of CM	How do you achieve the following?	2.10.1	[238]

Appendix A.25 Culture Questions

A.25	Characteristics	Variables	Culture Questions	Thesis Section	Reference
1	A.11.1,A.11.2,A.11.3, A.14.8,A.14.11,A.14.14	Presence of a quality systems creates an enabling culture	Do you have a quality culture? ISO?	2.4.1.3	[27]
2	A.11.5,A.11.6,A.2.6,A.3.1	Mistakes must be tolerated to enable innovation	Do you have a blame culture?	2.4.1.3 and 2.4.1.5	[27], [34]
3	A.11.5,A.11.6	Risk training	Do you have training towards prudent risk taking	2.4.1.3	[27]
4	A.11.10	Cultural encouragement	Do you use an Employee of the year award	2.4.1.3	[27]
5	A.11.11	Communication Culture	Communication Culture - Quarterly magazine, weekly team leader meetings, regular planning meetings, encourages informal communication	2.4.1.3	[27]
6	A.11.13	Communication Culture	Allow corridor meetings	2.4.1.6	[33]

Appendix A.26 Marketing Questions

A.26	Characteristics	Variables	Marketing and Branding Questions	Thesis Section	Reference
1	A.12.2, A.12.3, A.12.5, A.12.7,A.12.8, A.12.9,A.12.10, A.12.11, A.12.12, A.12.13, A.12.16,	Lack of SME marketing research, Marketing is Critical for NPD, Use of Backend Marketing Only, 4Ps are Universal, Type of Environment, Role and Relevance Diagnostic Tool, Use of MLO, Level of Growth, Type of Focus	Which of the following characteristics does your SME organisation follow/use?	2.11.1	[244]
2	A.12.4, A.12.5, A.12.7, A.12.16	Use of 4Ps, Use of Backend Marketing Only, 4Ps are Universal, Type of Focus	At the Implementing Phase the positioning strategy or attach plan is translated into a reality by assembling an appropriate 4Ps mix - Product, Price, Promotion, Placement - ask relevant questions		[246]

A.26	Characteristics	Variables	Marketing and Branding Questions	Thesis Section	Reference
3	A.12.4	Use of 4Ps	The advantages of branding are viewed from three perspectives: The consumer, the manufacturer and the retailer	2.11.2	[246],[248]
4	A.12.4, A.12.5, A.12.7, A.12.16	Use of 4Ps, Use of Backend Marketing Only, 4Ps are Universal, Type of Focus	Controlling Phase - Tactical control is about short-term operational efficiencies at the level of the marketing mix	2.11.2	[248]
5	A.12.4, A.12.5, A.12.7, A.12.16	Use of 4Ps, Use of Backend Marketing Only, 4Ps are Universal, Type of Focus	Controlling Phase - Do you have a marketing information system: the ability to capture information from the SMEs financial records, the ability to carry out ongoing gathering of marketing intelligence from the market place and the ability to undertake specific market research studies	2.11.2	[248]
6	A.12.15, A.12.17	Younger SMEs are Marketing Orientated, Use of Networking	How do SME owner/managers network and how this activity contributes to marketing activity	2.11.3	[249]
7	A.12.15, A.12.17	Younger SMEs are Marketing Orientated, Use of Networking	Although networking was often planned, this research found that unplanned networking was common and second nature to the owner/manager e.g. listening to problems and identifying issues solvable with their expertise at say a trade show	2.11.3	[249]

Appendix A.27 Intellectual Property Questions

A.27	Characteristics	Variables	Intellectual Property Questions	Thesis Section	Reference
1	A.13.1, A.13.2, A.13.3, A.13.4, A.13.5,A.13.6, A.13.7, A.13.10, A.13.11	Type of IPP used, Use of Patents for Products, Importance of IP, Issues with IP, Use of Secrecy, Type of Product	The methods of capturing and protecting the competitive advantage of processes and products follow: Patents to prevent copying. Patents to secure royalty income. Secrecy. Lead time i.e. Fast Time To Market. Moving quickly down the learning curve. Sales or service efforts. Which one do you use?	2.9.2	[232]

A.27	Characteristics	Variables	Intellectual Property Questions	Thesis Section	Reference
2	A.13.2, A.13.3, A.13.4, A.13.5,A.13.6, A.13.7, A.13.8, A.13.10, A.13.11	Use of Patents for Products, Importance of IP, Issues with IP, Use of Secrecy, Large/SME IP, Type of Product	Do you Patent your products?	2.9.2	[232]
3	A.13.4, A.13.5, A.13.6, A.13.7, A.13.8,A.13.10	Issues with IP, Use of Secrecy, Large/SME IP, Type of Product	Why do you not patent: List: Attempts were made to copy two thirds of the SMEs' patents with only one in five using the courts to defend their patents. SMEs do not find patenting cost-effective as a means of protection. For 49% of the SMEs the potential cost of patent defence litigation had a "very big" or "significant" impact on their development activities investment. The current patent system does not work for SMEs (especially in the USA where MNCs use their vast resources to intimidate SMEs)…and A.13.4, A.13.6, A.13.10	2.9.2	[233]
4	A.13.12, A.13.13, A.13.14	Use of IPP Policy, IPP awareness, IP Portfolio linked to Strategy	From the perspective of company policy - do you have/use the following	2.9.3	[235]
5	A.13.6	Issues with IP	A means of limiting the expense factor for SMEs: File for a national patent before going European or world wide. Also, the target markets should be considered before patenting (is it necessary to patent world wide?) and the product life cycle before deciding on the number of years the patent covers i.e. will a short term patent cover the invention. Publishing the invention can be used as a defensive strategy as it prevents other people from obtaining a patent	2.9.3	[230]
6	A.13.13, A.13.14	IPP awareness, IP creates value	Creation of an IP Strategy - The following is a list of best practices for IP strategy	2.9.3	[230]
7	A.13.13, A.13.14	IPP awareness, IP Portfolio linked to Strategy	If you have an IP portfolio do you?	2.9.3	[230]

Appendix A.28 Performance Measurement Questions

A.28	Measurement	Performance Measurement Questions	Section 2.13.1/ Reference
1	Strategy	There is a clear definition of the company's mission/objectives.	[280]
2	Strategy	There is management consensus concerning the company's objectives.	[280]
3	Strategy	Performance goals are communicated to lower levels in the company.	[280]
4	Strategy	The purpose of each performance criterion is clear.	[280]
5	Strategy	Measures are directly related to the company's manufacturing strategy.	[280]
6	Strategy	Performance measures cover long-, short- and medium-term goals.	[280]
7	Strategy	What was the strategic reason the project was undertaken (development process variable): To solve a set of market or customer needs	[285]
8	Strategy	What was the strategic reason the project was undertaken (development process variable): To react to a competitive offering	[285]
9	Strategy	What was the strategic reason the project was undertaken (development process variable): To take advantage of a technical development	[285]
10	Strategy	What was the strategic reason the project was undertaken (development process variable): Because management decided it was strategically necessary	[285]
11	Organisational Structure	What is the organisational structure? - Cross-functional teams	112
12	Organisational Structure	What is the organisational structure? - Co-location of team members	112
13	Organisational Structure	What is the organisational structure? - Project leader champion	112
14	T&M	Measurements from: Quality function deployment technique	[280]
15	T&M	Measurements from: Taguchi methods	[280]
16	T&M	Measurements from:: Continuous process improvement technique	[280]
17	T&M	Number, Type and Timing of Market research projects	112
18	T&M	Used: Computer Aided Design	112
19	T&M	Used: Computer Aided Engineering	112
20	T&M	Used: Deign for Manufacturability	112
21	T&M	Used: Design for Assembly	112
22	T&M	Used: Computer Integrated Manufacturing	112
23	T&M	Concept Generation: Number of new product ideas, product enhancement ideas evaluated in the last year	[29]
24	T&M	Concept Generation: Number of new product based business areas/ventures started in the last 5 years	[29]
25	T&M	Concept Generation: Product planning horizon (years, product generations)	[29]
26	Technology	R&D/Technology acquisition cost per new product	[29]

A.28	Measurement	Performance Measurement Questions	Section 2.13.1/ Reference
27	Technology	R&D Project that lead to new or enhanced products, process innovations, licences, patents, (% no. of projects, % R&D expenditure)	[29]
28	Technology	No. of licences in/out over the last 3 years	[29]
29	Technology	Cost/benefit performance of completed R&D projects	[29]
30	IP	Total no. of patents held	[15]
31	IP	No. of patents for new products/technology in last year	[15]
32	IP	No. of patents over the last 3 years	[29]
33	IP	Now many patent applications have you filed in the last year	[17]
34	PDP	Time spent on changes to original product spec (months)	[280]
35	PDP	Time Through Each Phase: Development time (months) = from detailed design (first team meeting) to Introduction (date of first production for sale from the manufacturing facility)	[285]
36	PDP	Time Through Each Phase: Concept to Customer (months) = concept development (approval of strategy or idea) to Introduction	[285]
37	PDP	Time Through Each Phase: Total Time (months) = Identify Target (first planning meeting) to Introduction	[285]
38	PDP	Type of Process Used: No process used	[285]
39	PDP	Type of Process Used: Traditional Phase review process	[285]
40	PDP	Type of Process Used: Stage gate	[285]
41	PDP	New products (last 3 years) no. of design changes in last year resulting from customer complaints.	[15]
42	PDP	How many product launched in 3 years were partially designed by suppliers	[15]
43	PDP	Average overrun	[15]
44	PDP	Average time of product enhancement	[15]
45	PDP	Average time of redesign	[15]
46	PDP	Avg. time of product enhancement	[15]
47	Quality	Actual product performance versus predicted: (Percentage of) Units reworked	[280]
48	Quality	Actual product performance versus predicted: (Percentage of) Units of defect	[280]
49	Quality	How much spent (cost) on guarantees in last year - warranties, recalls, repairs of new products	[15]
50	Quality	Cost of scrap	[280]
51	Quality	Avg. Supplier lead time	[280]
52	Quality	Product failure rates	[280]
53	Quality	Customer surveys of product or service quality	[280]
54	Time	Lead Time (performance of manufacturing)	[280, 284]
55	Time	Delivery Time (actual versus promised)	[15, 280, 281, 284]
56	Financial	R&D as a % of Turnover	[280]
57	Financial	Actual cost compared to budget	[280]
58	Financial	Cost of Product Development effort	[15]

A.28	Measurement	Performance Measurement Questions	Section 2.13.1/ Reference
59	Financial	Expenditure of R&D as % of Sales	[15]
60	Financial	Product performance – Cost (unit cost, production cost, development cost)	[29]
61	Financial	Manufacturing cost (design performance)	[29]
62	Financial	Ability to reach a targeted cash flow, or a targeted return on assets, return on investment, or return in equity	[280]
63	Financial	Number of Sales Leads (Overall and by source)	[248]
64	Financial	Cost per Lead (Overall and Source)	[248]
65	Financial	Cost per Profit/Sale (Overall and Agent)	[248]
66	Financial	Productivity: Output per employee or per labour-hour	[280]
67	Financial	Productivity: Output per unit of raw material	[280]
68	Financial	Productivity: Number of errors per unit	[280]
69	Financial	Productivity: Number of billing errors per unit	[280]
70	Financial	Productivity: Absenteeism	[280]
71	Financial	Productivity: Injury lost days	[280]
72	Financial	Currently what percentage of your sales are industrial components (sold to other firms as parts for their products) and what percentage are sold as final product	[15]
73	Customer Sat	Customer perceived product durability	[280]
74	Customer Sat	Customer perceived product reliability	[280]
75	Customer Sat	Customer perceived overall product performance	[280]
76	Customer Sat	Complaints and Retention Rates	[280]
77	Customer Sat	Product delivered on specification	[281]
78	Customer Sat	Contacts with outside companies	[281]
79	Customer Sat	Avg Commercial Success Rate of Tech New Products	[15]
80	Customer Sat	Design meeting customer needs, product range and variety	[29]
81	HR	% Projects delayed, cancelled due to lack of funding	[29]
82	HR	% Projects delayed, cancelled due to lack of human resources	[29]
83	HR	Quality training - % of employees with quality responsibility (part of CI)	[280]
84	HR	Surveys of employee satisfaction/attitudes	[280]
85	HR	Improvement of employee skill/knowledge levels	[280]
86	Delivery Pref	Percent of orders delivered to schedule	[280]
87	Delivery Pref	Number of complaints regarding delivery	[280]
88	Delivery Pref	Number of customer detected design faults	[15, 280]
89	Service Measure	Surveys of customer satisfaction	[280]
90	Service Measure	Third party assessments of product performance or customer satisfaction	[280]
91	Service Measure	Ability to adapt or tailor products to customer needs	[280]
92	Service Measure	Waiting time in a service prior to transaction	[280]

A.28	Measurement	Performance Measurement Questions	Section 2.13.1/ Reference
93	Service Measure	Response time to customer requests for ‘specials’	[280]
94	Financial	ROI from Development Efforts	[65]
95	Financial	Percentage of sales generated by new products after 3 years	[65]
96	Financial	Percentage of growth generated by new products after 3 years (note: define new product)	[65]
97	Financial	During the past three years, your market-share in your industry has…	Section 4.3 / Ref [292]
98	Financial	Percentage sales from new products in the last three years has…	Section 4.3 / Ref [292]
99	Financial	Indicate your company's overall performance/success in relation to your competitors (with similar sales volumes) with a number between 1 and 6 where 1 is low and 6 is high	Section 4.3 / Ref [292]

Appendix B Checklist for any given Questionnaire Item

1. Are questionnaire items clear, simple and precise – This ensures the respondent knows what question is been asked [290, 292]
2. Avoid double barrel questions – look for the word ‘and’.
3. Ensure respondents competency to answer.
4. Are the questions relevant?
5. Ensure that the questionnaire controls respondents from making up there own answers.
6. Use short items.
7. Avoid negative terms in an Item e.g. the word ‘not’ as people will read over it.
8. Keep wording simple.
9. Avoid biased items and terms.
10. Ensure Measurement Quality
11. In relation to format – is the white space maximised i.e. do not crowd questions.
12. Ensure that the response format boxes are adequately spaced apart.
13. Ensure double spacing between response categories as this is better for check marks.
14. Is the demographic data at the bottom of the questionnaire?
15. Put instructions on the questionnaire.
16. Use indexes as measure of variables.
17. What are the implications for each possible response?
18. Use levels of measurement – Nominal, Ordinal, Interval and Ratio.
19. Closed Ended Questions – Select answer from a list provided (popular as they have greater uniformity of responses and are therefore easier to process).

[290]

20. Is the question manageable or does it involve burdensome tasks?
21. Does the question contain concepts or nomenclature that may not be in common use?
22. Does the question have any ambiguities or does it use any potentially shared definitions?
23. Is the question specific enough – within each item is the main variable clear?

24. Is the question stand-alone? Would any definitions of assumptions be required?
25. Does the question help to exhaustively assess its related variable?
26. Is there any interference (that is, will the answer to the question be influenced by the answer to the previous question) associated with the question or could it potentially introduce any other interference?
27. Is the question leading? Does it allow for swings in opinion/position and does it allow for any potential neutrality?
28. Could the question be combined with another?
29. Are there sufficient residual 'others' available to the respondent?
30. What is the real value of the question? What if it were deleted?
31. Each question adds independent value to the study?
32. Are there sufficient constructs to allow evaluation of the variable represented?

[292]

33. Avoid negative items.
34. Provide an explicit middle.
35. Carefully word threatening questions

[294]

36. The email should also be short and direct the respondent directly to the survey URL

[293]

37. Make the survey look shorter: Don't number 1 to 205 – Labelled 1 and 1.1, 1.2 etc.
38. Split by sections and put instructions at the top of each section.
39. Provided a mental break by putting short questions between large questions – check this is on the checklist.
40. After a series of difficult questions place a few short easy questions therefore providing a mental break.

[303]

Appendix C.1 Pre-test Instructions

Subject: Survey of Product Development Expertise in Irish SMEs

Dear <name>,

Thank you for agreeing to take part in my pre-test online questionnaire – your assistance is greatly appreciated. Below are the instructions for the pre-test and the link to the survey. Please feel free to comment on any aspects of the pre-test, the instructions for completing the questionnaire and the questionnaire itself.
The purpose of the questionnaire is to gather data on 'best practice' product development approaches in indigenous SMEs involved in the development of products. Since SMEs are our country's future, I am trying to understand where Ireland's indigenous SMEs are in relation to moving to a knowledge based economy. It is hoped that the results of this survey will enable policy development that will benefit SMEs.

Instructions:

1. Please complete the questionnaire as it is according to the Questionnaire Completion Instructions. Add as many comments in the comments box at the end of each section as you like.
2. Suggest any additions to the questionnaire.
3. Discuss aspects of the existing questionnaire that might need to be changed.
4. Suggest any changes to the completion instructions and the method of administration.

Please indicate how you felt about the following aspects of the questionnaire (you can just reply to this email and type under the following questions if you like):

a. Was it simple to understand?
b. Was it clear?
c. Was it difficult to answer?
d. Was it ambiguous?

e. Were the questions specific enough?
f. Did the questionnaire take too long to complete?
g. Were the concepts mentioned commonly known in your opinion? Should there be more background information?
h. How did you feel about answering the business performance questions?

Please collate your comments and return.

Again, thank you very much. Here is a link to the survey:

http://www.surveymonkey.com/s.aspx

The password is PDS2008. This link is uniquely tied to this survey and your email address; please do not forward this message.

Barry McDermott,
Department of Mechanical and Manufacturing Engineering,
Dublin City University,
Dublin 9.
Ph.

Reminder:

Hi <Name>,

Just a reminder about my pre-test online questionnaire – can you take a look at it today?

Regards,
Barry.

Appendix C.2 Pilot and Final Questionnaire

Appendix C.3 Pilot 2008 - with Variables

Appendix C.4 Final Analysis

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
1	Q1PC1 (Item Q1.1,Q1.2, Q1.3)	Teamwork, probing, paths, VOC	Q5.4	Utilization of knowledge from external sources (Open strategy), Creation of a 'path'	A.21.9, A.18.3 / A.21.13, A.19.17, A.18.3 / A.21.14, A.19.17, A.18.3 // A.21.15 / A.15.29, A.21.18	A.7.5, A.7.13, A.7.14, A.1.5
2	Q1PC1 (Item Q1.1,Q1.2, Q1.3)	Teamwork, probing, paths, VOC	Q16.2, Q16.3, Q16.4	Use of VOC, Preference for Kano Model	A.21.9, A.18.3 / A.21.13, A.19.17, A.18.3 / A.21.14, A.19.17, A.18.3 // A.18.8, A.18.10, A.18.11	A.4.2, A.5.8, A.5.10, A.7.5, A.7.13, A.7.14, A.7.23
3	Q24PCce (Item Q24.9, Q24.10, Q24.11, Q24.12)	Use of a PDP with best practice, Use of Concurrent Engineering, Use of Front End CAE	Q1.1, Q1.2, Q1.3, Q1.4	Teamwork, VOC, CE Engineering, Evaluation of Competitor products, Use of Reverse Engineering	A.19.17, A.22.11 / A.19.17 / A.19.17 / A.19.17 / A.19.18 // A.21.9, A.18.3 / A.21.13, A.19.17, A.18.3 / A.21.14, A.19.17, A.18.3	A.7.8, A.7.12

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
4	Q24PCkbd (Q24.4, Q24.5, Q24.6, Q24.7, Q24.8)	Creation of Knowledge, Use of Redundancy, Use of Iteration, Use of Process Driven PDP with Simple T&M, Prototype/Expt PDP, Use of Evolutionary Prototyping PDP	Q1.1, Q1.2, Q1.3, Q1.4	Teamwork, VOC, CE Engineering, Evaluation of Competitor products, Use of Reverse Engineering	A.19.9, A.19.6, A.19.10, A.19.5, A.19.11, A.19.12, A.19.15 // A.21.9, A.18.3 / A.21.13, A.19.17, A.18.3 / A.21.14, A.19.17, A.18.3	A.7.8, A.7.12
5	Q19.12	Use of Reverse Engineering	Q1.4	Evaluation of Competitor products, Use of Reverse Engineering	A22.24 // A.21.15	A.8.30, A.8.31, A.7.7, A.8.30
6	Q26.1	Use of reciprocal interdependence (forming task forces, creating, establishing rules and procedures)	Q2.0	Sequence of Tasks, Non-repetitive process, Using a Learning Environment, Use of formalisation and standardisation, Use of reciprocal interdependence	A.19.8, A.21.3, A.21.4 // A.21.4	A.5.13, A.5.20, A.7.19, A.7.20
7	Q4.0	O/M controlling or facilitating, Visionary and Committed Leadership required for change, Top down change issues, Use of Process Based CM, Use of CM, Pre-emptive communication, When to engage employees	Q3.1, Q3.2, Q3.3, Q3.4, Q3.5	Top down change issues, Use of CM, Pre-emptive communication, When to engage employees	A.24.2 // A.21.1	A.9.3, A.9.4, A.9.6, A.10.7

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
8	Q5.2	Use of a PDP not excluding stages, use of a strategy, FFE usage	Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0	The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	A.15.8 // A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12 // A.15.9	A.1.3, A.1.4, A.1.6
9	Q12PCbackend (Item Q12.1, Q12.2, Q12.3)	Use of 4Ps, Use of Backend Marketing Only, 4Ps are Universal, Type of Focus	Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.8, Q5.9and Q6	Use of a strategy / Use of a PDP not excluding stages, use of a strategy, FFE usage / Use of a PDP not excluding stages, use of a strategy / The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	A.26.2, A.26.3, A.26.4 // A.15.1 / A.5.8 / A.15.4 / A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12	A.1.13 / A.12.4, A.12.5, A.12.7/ A.1.1, A.1.3

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
10	Q35, Q36, Q37	Market share, Sales from New Products, Overall Success/Performance	Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.9and Q6	Use of a strategy / Use of a PDP not excluding stages, use of a strategy, FFE usage / Use of a PDP not excluding stages, use of a strategy / The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	A.28.97 / A.28.98 / A.28.99, A.28.100 // A.15.1 / A.5.8 / A.15.4 / A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12	A.28.98
11	Q10.1	Use of a PDP not excluding stages, use of a strategy, FFE usage	Q7.1, Q7.2, Q7.3	Use of a PDP not excluding stages, use of a strategy, FFE usage	A.15.13 // A.15.13	A.1.1, A.1.3

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
12	Q5Q6PCstrategy (Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0)	Use of a strategy / Use of a PDP not excluding stages, use of a strategy, FFE usage / Use of a PDP not excluding stages, use of a strategy / The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	Q7.2	Use of a PDP not excluding stages, use of a strategy, FFE usage	A.15.1 / A.5.8 / A.15.4 / A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12 // A.15.13	A.1.1, A.1.3
13	Q5Q6PCstrategy (Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.8, Q5.9 and Q6.0)	Use of a strategy / Use of a PDP not excluding stages, use of a strategy, FFE usage / Use of a PDP not excluding stages, use of a strategy / The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	Q7.4	Use of a PDP not excluding stages, use of a strategy, FFE usage	A.15.1 / A.5.8 / A.15.4 / A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12 // A.15.13	A.1.1, A.1.3, A.1.4

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
14	Q5.5	Use of product platforms, T&M to capture knowledge	Q7.3	Use of a PDP not excluding stages, use of a strategy, FFE usage	A.15.14 // A.15.13	A.1.15 / A.1.1, A.1.3, A.1.4
15	Bar Graph - Q10 - Ho is a Differentiated Strategy is not used				A.15.13	A.1.3
16	Frequency Analysis - For Q11.1, Q11.2, Q11.3, Q11.4, 11.5 - Ho states that SMEs are not marketing led organisations (MLO)				A.26.1 / A.26.7	A.12.8, A.12.9, A.12.10, A.12.11, A.12.12, A.12.17
17	Q13 Frequency Table Analysis - Ho states that SME employees are seen in a negative light				A.17.1	A.3.1, A.3.2, A.11.4, A.11.6, A.2.6
18	Frequency Analysis on 16.0, 17.0 and 18.0 - Ho states that SMEs are using elements of T&M and are not aware of the actual methodologies				A.18.4 / A.18.8 / A.18.10 / A.18.11 / A.18.12 / A18.13, A.25.3 / A.18.14 / A.18.7 / A.18.15 / A.18.16 / A.18.21 / A.18.28 / A.18.30 / A.18.24 / A18.34 / A.18.17 / A.18.20 / A.18.26 / A.18.27 / A.20.1 / A.18.31	A.4.4, A.4.5, A.4.6, A.4.7, A.4.8, A.4.9, A.4.10, A.4.11, A.4.12, A.4.13, A.4.14, A.4.15, A.4.16, A.4.19, A.4.23, A.4.24, A.4.28

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
19	Q17.1 and Q16.2, Q16.3, Q16.4 and Q16.5 - Ho states that SMEs are using QFD techniques in practice and not realising				A.18.7 // A.18.8 / A.18.10 / A.18.11 / A.18.12	A.4.4, A.4.5, A.4.6, A.4.7, A.4.8, A.4.9, A.4.10, A.4.11, A.4.12, A.4.13, A.4.14, A.4.15, A.4.16, A.4.19, A.4.23, A.4.24, A.4.28
20	Ho states that SMEs are using KBD techniques in practice				A.19.9, A.19.6, A.19.10, A.19.5, A.19.11, A.19.12, A.19.15 // A.19.17, A.22.11 / A.19.17 / A.19.17 / A.19.17 / A.19.18	A.5.5, A.5.9, A.5.10, A.5.12, A.5.13, A.5.16, A.5.19, A.5.22, A.5.23, A.5.24, A.5.26
21	Ho states that SMEs are using TRIZ techniques in practice				A.22.25 // A.18.16 // A.18.17/ A.18.20	A.8.1

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
22	Q19.1	Use of T&M for Ideation	Q16.0, Q18.0	Knowledge capture, Measurement, T&M used for learning, Use of VOC, Kano Model and Affinity diagram, Knowledge capture, Why SMEs should use T&M, Risk training, Knowledge capture, Why SMEs should use T&M, Use of TRIZ, Visual/Easy T&M usage, Specific and Simplified T&M usage, Use of Robust Design, Use of Response Surface Analysis, Use of Basic Robust Design	A.22.25 // A.18.8 / A.18.10 / A.18.11 / A.18.12 / A18.13, A.25.3 // A.18.15 / A.18.17 / A.18.20 / A.18.31	A.4.4, A.4.6, A.4.7, A.4.8, A.4.9, A.4.10, A.4.11, A.4.12, A.4.13, A.4.14, A.4.20, A.4.24
23	Ho states that SMEs are not using ‘best practice’ CAD/CAM integration - Compare - Q19.6 and Q19.8				A.22.5 // A.22.6	A.8.16
24	Q20.1/Q20.2	How Technology is Developed	Q1.1, Q1.2, Q1.3, Q1.4	Teamwork, VOC, CE Engineering, Evaluation of Competitor products, Use of Reverse Engineering	A.22.28 // A.21.9, A.18.3 / A.21.13, A.19.17, A.18.3 / A.21.14, A.19.17, A.18.3	A.8.2

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
25	Q20.1/20.2	How Technology is Developed	Q5.1, Q5.2, Q5.3, Q5.6, Q5.7, Q5.8, Q5.9, Q6.0	Use of a strategy / Use of a PDP not excluding stages, use of a strategy, FFE usage / Use of a PDP not excluding stages, use of a strategy / The use of pre-development activity i.e. Fuzzy Front End, The use of pre-development activity i.e. Fuzzy Front End, Externally orientated strategic view, Use of Miles and Snow // Use of a PDP not excluding stages, use of a strategy, FFE usage	A.22.28 // A.15.1 / A.5.8 / A.15.4 / A.15.3 / A.15.5 / A.15.5 / A.15.5 / A.15.12	A.8.2
26	Ho states that SMEs are using secrecy for IPP - Q21.0 (Q22.0 and Q23.0)				A.27.1 / A27.4 / A.27.6 / A.27.7	A.13.1, A.13.2, A.3.3, A.3.4, A.13.6, A.13.7, A.13.10, A.13.11, A.13.12, A.13.13, A.13.14
27	Q36.0	Sales from New Products	Q21.1, Q21.2, Q21.3, Q23.1 and Q23.2	Type of IPP used, Use of Patents for Products, Importance of IP, Issues with IP, Use of Secrecy, Type of Product // Use of IPP Policy, IPP awareness, IP Portfolio linked to Strategy	A.27.1 // A.27.6 / A.27.7	A.13.1, A.13.2, A.13.3, A.13.4, A.13.5, A.13.6, A.13.7, A.13.8, A.13.9, A.13.10, A.13.11, A.13.12, A.13.13, A.13.14

Sub-Hypotheses No.	Possible Dependent (Y axis)	Variables (dependent)	Possible Independent (X axis)	Variables (independent)	Questionnaire Table Appendices	Relevant Product Development Process Elements
28	Q353637PC	Market share, Sales from New Products, Overall Success/Performance	Q24 KBD, Q24 CE, Q5 Strategy, Q1.0	See above under individual variables	See Above	A.5.26
29	Q37.0	Overall Success/Performance	Q24 KBD, Q24 CE, Q5 Strategy, Q1.0	See above under individual variables	See Above	A.5.26

Appendix C.5 Cold Calling Strategy

Hi <Receptionist>, my name is Barry McDermott and I am calling from Dublin City University.
How many people are in your company? Can I speak to your Managing Director or R&D Manager? If I am unable to get to speak to the respondent – get the receptionist name, respondents name and an email address from the receptionist of the respondent.

Hi <MD/R&D Man>, my name is Barry McDermott and I am calling from Dublin City University.

I am conducting research into the product development approaches of SMEs and from your website I see that you are Irish and carry out Product Development activity in the area of <area>?

Excellent, I am conducting a national survey into the product development approaches of Irish SME, the results of which will be made available to you if you so wish. There is an option at the end of the survey to request my findings. It will only take 15min and is strictly confidential.

Can you help with my research?

Can I ask: Does this clash with your holidays or when is the best time (takes 15min)?

OK, I do not want to hold you on the phone too long, if I can have your email address I will send the link. **Confidentiality concern:** If you prefer I could email you a word doc which you could email back or post to me?

Thanks <Mr. Name>; I will send that on in ten minuets.

Appendix C.6 – Final Questionnaire Email

Final Questionnaire Email Style One:

Subject: Product Development Expertise in Irish SMEs

Dear <Mr. Name>,

As discussed in our telephone conversation, I am conducting a Dublin City University (DCU) study into the level of development expertise within Irish SMEs via a 15min online survey.

The purpose of the questionnaire is to gather data on 'best practice' product development approaches in indigenous SMEs involved in the development of products/equipment. Since SMEs are our country's future, I am trying to understand where Ireland's indigenous SMEs are in relation to moving to a knowledge-based economy. It is hoped that the results of this survey will enable policy development that helps you carry out Product Development while considering your lack of resources (time, money, human).

Your responses are completely confidential and the findings of the study will be made available to all respondents who request them (this will inform you of best practice within your industry). Once your results are inputted as data all reference to your company are lost. You will find the password and link below:

Password: PDS2008

http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

Thank you for your feedback and valuable time.

Regards,
Barry.
Ph.

Ph. 057 9327 344

STATEMENT OF CONFIDENTIALITY, ANONYMITY AND NON-DISCLOSURE

Any data or information supplied through the questionnaire answers or by e-mail is completely confidential and will not be disclosed to any parties within or external to Dublin City University. No e-mails or respondent details will be disclosed to third parties. Any further assurances required are available on request in whatever way required by respondents. Once the data from the questionnaires is entered onto the study database it will no longer be possible to link respondents to their supplied data. E-mails will be destroyed securely.

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Final Questionnaire Email Style Two:

Subject: Product Development Expertise in Irish SMEs

Dear <Receptionist Name>,

As discussed, can you forward this to your <Managing Director or R&D Manager or Mr. Name>.

Dear <Managing Director or R&D Manager or Mr. Name>,

I am conducting a Dublin City University (DCU) study into the level of development expertise within Irish SMEs via a 15min online survey.
The purpose of the questionnaire is to gather data on 'best practice' design/development approaches in indigenous SMEs involved in the development of products/equipment. Since SMEs are our country's future, I am trying to understand where Ireland's indigenous SMEs are in relation to moving to a knowledge-based economy. It is hoped that the results of this survey will enable policy development that helps you carry out Product Development while considering your lack of resources (time, money, human).

Your responses are completely confidential and the findings of the study will be made available to all respondents who request them (this will inform you of best practice within your industry). Once your results are inputted as data all reference to your company are lost. You will find the password and link below:

Password: PDS2008

http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

Thank you for your feedback and valuable time.

Regards,
Barry.
Ph.

STATEMENT OF CONFIDENTIALITY, ANONYMITY AND NON-DISCLOSURE

Any data or information supplied through the questionnaire answers or by e-mail is completely confidential and will not be disclosed to any parties within or external to Dublin City University. No e-mails or respondent details will be disclosed to third parties. Any further assurances required are available on request in whatever way required by respondents. Once the data from the questionnaires is entered onto the study database it will no longer be possible to link respondents to their supplied data. E-mails will be destroyed securely.

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Appendix C.7 – Final Questionnaire Reminders

Reminder One Style One:

Subject: Product Development Expertise in Irish SMEs (R1)

Dear Mr. <Name>,

Will you get an opportunity to respond to my survey? I require your response to finish my nationwide research as I have a limited number of possible respondents.

Password: PDS2008
http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

I really need and appreciate your help with this Mr. <Name>.

Thanks,
Barry.
Ph.

Reminder One Style Two:

Subject: Product Development Expertise in Irish SMEs (R1)

Dear <receptionist name>,

Will your <Managing Director or R&D Manager or Mr. Name> get an opportunity to respond to my survey? I require a response to finish my PhD research as I have a limited number of possible respondents.

Password: PDS2008

http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

I really need and appreciate your help with this <receptionist name>.

Thanks,
Barry.
Ph.

Final Reminder Style One:

Subject: Product Development Expertise in Irish SMEs (Final Reminder)

Dear <Mr Name>,

Will you get an opportunity to respond to my survey by COB 5 August 2008? I require your response to finish my nationwide research as I have a limited number of possible respondents.

Password: PDS2008

http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

I really need and appreciate your help with this <Mr Name>.

Thanks,
Barry.
Ph.

Final Reminder Style Two:

Subject: Product Development Expertise in Irish SMEs (Final Reminder)

Dear <receptionist name>,

Will <Managing Director or R&D Manager or Mr. Name> get an opportunity to respond to my survey? I require his response to finish my nationwide research as I have a limited number of possible respondents.

Password: PDS2008

http://www.surveymonkey.com/s.aspx?sm=Cx3KqEcQeFvvLhshk0r_2b_2bQ_3d_3d

I really need and appreciate your help with this <receptionist name>.

Thanks,
Barry.
Ph.