

## **Table of Contents**

<b>List of Figures.....</b>	<b>xiii</b>
<b>List of Tables .....</b>	<b>xxi</b>
<b>List of Contributing Authors .....</b>	<b>xxiii</b>
<b>Contributions Listed by Authors.....</b>	<b>xxv</b>
<b>List of Abbreviations.....</b>	<b>xxvii</b>
<b>1 Introduction.....</b>	<b>1</b>
1.1 The Collaborative Research Center 392 .....	2
1.2 The Basic Approach.....	3
1.3 General structure .....	6
<b>2 Case Study Vacuum Cleaner: From Vision to Reality .....</b>	<b>9</b>
2.1 Clarifying the Task.....	9
2.2 Conceptual Design .....	19
2.3 Embodiment and Detailed Design .....	26
2.4 Result: The Vacuum Cleaner Prototype.....	28
2.5 Conclusions.....	33
<b>3 The Product Life Cycle.....</b>	<b>35</b>
3.1 Material Processing.....	36
3.1.1 New Method for the Holistic Assessment of Material Processing .....	36
3.1.2 Material circulations for life cycle assessment of environmentally friendly products .....	47
3.2 Production.....	50
3.2.1 Method for Inventory Analysis of Production Processes.....	51
3.2.2 Forming Processes .....	55
3.2.3 Machining Processes.....	66
3.2.4 Surface Treatment of Metallic Work-pieces.....	76

3.2.5 Injection Moulding of Plastics .....	85
3.3 The Use Phase in Design for Environment .....	92
3.3.1 Structuring of the Use Phase.....	93
3.3.2 Methodical Support for Product Developers .....	98
3.4 End of Life .....	106
3.5 Know-how Provision via Activity Guidelines .....	119
<b>4 Environmental Assessment .....</b>	<b>127</b>
4.1 An Introduction to Life Cycle Assessment .....	127
4.2 Impact Assessment.....	129
4.2.1 The Methodology of Impact Assessment.....	129
4.2.2 Impact Categories .....	132
4.2.3 New Impact Categories for Product Design .....	134
4.2.4 Aggregation .....	138
4.2.5 Uncertainty in Environmental Assessment.....	140
4.3 Environmental Assessment in the Product Development Process	147
4.3.1 Widely-Used Methods for Simplified Environmental Assessment in Product Design.....	148
4.3.2 The Meta-Method Approach.....	150
<b>5 From the Market to Holistically Optimised Product Concepts .....</b>	<b>155</b>
5.1 Innovation Process and Sustainable Development .....	156
5.1.1 Integration of DfE in Companies.....	157
5.1.2 Findings and Derived Research Questions .....	161
5.1.3 The Sustainable Innovation Process .....	165
5.2 Marketability Issues of Environmentally Friendly Products .....	170
5.2.1 Consumer Behaviour and Environmentally Friendly Products	170
5.2.2 Perception and Purchase of Environmentally Friendly Products	172
5.2.3 Ecological Segments of Customers and Products.....	175
5.2.4 Knowledge Activation, Information and Buying Behaviour.	177
5.2.5 Enhancing the Attractiveness of Environmentally Friendly Products .....	180
5.2.6 Conclusion .....	183
5.3 Ergonomics in Environmentally Friendly Product Design .....	184
5.3.1 Background.....	184
5.3.2 Methodological Issues .....	185
5.3.3 Empirical Research Program .....	189
5.3.4 Conclusion .....	191
5.4 Requirements for Environmentally Friendly and Marketable Products.....	194
5.4.1 Quality Function Deployment (QFD) – Translating Customer Specifications into Product Characteristics .....	194

---

5.4.2 Life Cycle Quality Function Deployment (LC-QFD).....	196
5.4.3 Interrelation Matrix.....	202
5.4.4 Strategy Portfolio .....	204
5.4.5 Extended Requirements List .....	205
5.5 Systematic Concept Development .....	206
5.5.1 Strategy-Based Design for Environment .....	207
5.5.2 Stepwise Concretising of Principle Solutions.....	210
5.5.3 Comparative Evaluation of Product Concepts .....	214
5.5.4 Size-Ranged Products .....	216
5.6 Interdisciplinary Teamwork in Product Development.....	219
5.6.1 Task-Related Diversity as Main Characteristic of Interdisciplinary Teams .....	219
5.6.2 Benefits of Task-Related Diversity.....	220
5.6.3 Drawbacks of Task-Related Diversity .....	221
5.6.4 Interventions .....	223
<b>6 From Concept to Application.....</b>	<b>225</b>
6.1 Integrated Model for Sustainable Product Design .....	227
6.1.1 Integrated Approach of CRC 392 .....	227
6.1.2 State-of-the-Art: Methods and Tools .....	229
6.1.3 The Information Model in CRC 392.....	234
6.1.4 Methodology for Development of an Information Model ....	237
6.1.5 Methods and Tools for Modelling the Integrated Model.....	248
6.2 The ecoDesign Workbench.....	259
6.2.1 Requirements for an Integrated IT Environment .....	260
6.2.2 Architecture of the ecoDesign Workbench.....	265
6.2.3 Life Cycle Assessment for Computer Aided Design (LCAD)	270
6.3 Evaluation of the Usability of the ecoDesign Workbench.....	282
6.3.1 Usability as Main Objective.....	282
6.3.2 Formative Approach .....	282
6.3.3 Previous Studies.....	283
6.3.4 Method .....	283
6.3.5 Results.....	284
6.3.6 Key Conclusions .....	286
<b>7 Final Summary .....</b>	<b>287</b>
<b>References .....</b>	<b>293</b>
<b>Index.....</b>	<b>315</b>



## List of Figures

<b>Fig. 1.1.</b> Matrix-Organisation of CRC 392 .....	3
<b>Fig. 1.2.</b> The vision of the CRC392 .....	4
<b>Fig. 1.3.</b> Concept of the Integrated Product and Process Development (IPPD) .....	5
<b>Fig. 1.4.</b> The ecoDesign Workbench.....	6
<b>Fig. 2.1.</b> Requirements gathered from different sources.....	10
<b>Fig. 2.2.</b> Example results of the market analyses: decision factors of the purchase .....	11
<b>Fig. 2.3.</b> Environmental impacts of a vacuum cleaner with filter bags....	12
<b>Fig. 2.4.</b> User-product interface .....	13
<b>Fig. 2.5.</b> Shadowing of users while vacuuming .....	15
<b>Fig. 2.6.</b> Checklists for identifying environmental requirements on products.....	16
<b>Fig. 2.7.</b> LCA of different systems of vacuum cleaners.....	17
<b>Fig. 2.8.</b> Eco-indicator 99 of the use phase of vacuum cleaners with water filter (L'Ecologico) in comparison with paper filter (Bosch) .....	17
<b>Fig. 2.9.</b> Intake of dust through different cleaner heads.....	17
<b>Fig. 2.10.</b> LC-QFD of a vacuum cleaner (excerpt) .....	18
<b>Fig. 2.11.</b> Extended requirements list including the functional unit (excerpt) .....	19
<b>Fig. 2.12.</b> Combining principal solutions using a morphological matrix..	21
<b>Fig. 2.13.</b> Systematic variation of a cleaner head with brushes as a working surface .....	21
<b>Fig. 2.14.</b> Function model for the filter system of an existing vacuum cleaner (excerpt).....	23
<b>Fig. 2.15.</b> Tensing an abrasive belt with cooling fluid (on the left side) led to the endless filter tape (on the right side) .....	24
<b>Fig. 2.16.</b> Improved filter box after Environmental-FMEA.....	24
<b>Fig. 2.17.</b> Loss of suction of the developed filter system compared existing systems .....	25
<b>Fig. 2.18.</b> ecoDesign Workbench of CRC 392 .....	27
<b>Fig. 2.19.</b> Brush cleaner head with enclosed air canals .....	28
<b>Fig. 2.20.</b> Brush cleaner head with transparent cover.....	29

<b>Fig. 2.21.</b> Exploded view of the brush cleaner head showing the contra-directional double-helix arrangement of the brushes .....	29
<b>Fig. 2.22.</b> Design concept to reduce the process conditional loss of suction power.....	30
<b>Fig. 2.23.</b> CAD prototype design of the vacuum cleaner.....	30
<b>Fig. 2.24.</b> Function prototype of the vacuum cleaner .....	31
<b>Fig. 2.25.</b> Function prototype of the filter box.....	32
<b>Fig. 2.26.</b> Arrangement of the measuring set.....	32
<b>Fig. 2.27.</b> Arrangement of the user feedback device at the cleaner head..	33
<b>Fig. 3.1.</b> The process chain of the basic oxygen converter steel with steps having environmental consequences .....	37
<b>Fig. 3.2.</b> Material flow network for the steel production process .....	38
<b>Fig. 3.3.</b> System matrix of the example network and solution (input (-), output (+)) .....	40
<b>Fig. 3.4.</b> Blast furnaces and important chemical reactions (Taube 1998). .....	41
<b>Fig. 3.5.</b> Solution for the network model for 1 kg steel (input (-), output (+)) .....	42
<b>Fig. 3.6.</b> Overview of tube manufacturing processes.....	42
<b>Fig. 3.7.</b> Raw materials and energy consumption for the manufacturing of a longitudinal welded tube from conventional slab cast construction steel (left) and from conventional slab cast primary aluminium (right).....	45
<b>Fig. 3.8.</b> Comparing report of steel and aluminium tubes. Method: Eco-indicator 99(l) / Europe EI 99 I/I.....	46
<b>Fig. 3.9.</b> Qualitative analysis for steel production and recycling (Wolf 2001) .....	47
<b>Fig. 3.10.</b> The mass route of steel in life cycle .....	48
<b>Fig. 3.11.</b> Abbreviations used for mass energy and route of steel .....	50
<b>Fig. 3.12.</b> Methods and standards for an LCI of production processes....	52
<b>Fig. 3.13.</b> Generic forming process chain (Schlotheim 2000) .....	56
<b>Fig. 3.14.</b> System boundary for forming processes.....	57
<b>Fig. 3.15.</b> Direct and indirect extrusion of work-piece (Schlotheim 2000) .....	58
<b>Fig. 3.16.</b> Hydro-mechanical deep drawing (Schuler 1996) .....	62
<b>Fig. 3.17.</b> Comparison between deep drawing and hydro-mechanical drawing.....	63
<b>Fig. 3.18.</b> Experimental set-up for validation of deep drawing process (Groche 2002) .....	64
<b>Fig. 3.19.</b> Comparison of force courses of tailored blank and pure blanks (Groche 2002) .....	65
<b>Fig. 3.20.</b> Energy consumption of tailored blanks for the above described geometry (Groche 2002) .....	66
<b>Fig. 3.21.</b> Milling of aluminium.....	67

---

<b>Fig. 3.22.</b> LCI system boundary of the machining process.....	68
<b>Fig. 3.23.</b> Process chain of the machining process (cf. Schiefer 2001) ....	69
<b>Fig. 3.24.</b> Determination of power characteristics and energy requirements of machine tools (Schiefer 2001) .....	71
<b>Fig. 3.25.</b> Distribution of the secondary energy demand at different locations of the plant (cf. Schiefer 2001) .....	72
<b>Fig. 3.26.</b> Example of fuzzy sets of the machining process (Schiefer 2001) .....	76
<b>Fig. 3.27.</b> Comparison of the film structure of a Chromium film deposited at different pressures: <i>left</i> , Argon pressure $1 \times 10^{-2}$ mbar; <i>right</i> , Argon pressure $3 \times 10^{-2}$ mbar; magnification is 3000x in both cases.....	81
<b>Fig. 3.28.</b> Schematic representation of the deposition step of magnetron sputtering for the determination of the energy consumption. ....	84
<b>Fig. 3.29.</b> Substrate holder with substrates rotating around multiple axes	85
<b>Fig. 3.30.</b> The injection moulding cycle .....	86
<b>Fig. 3.31.</b> Procedure to establish the part specific energy consumption for an injection moulding machine .....	88
<b>Fig. 3.32.</b> Specific energy consumption for the injection moulding of a model part from thermoplastic materials: acrylonitrile-butadiene-styrene (ABS), polyamide (PA), polypropylene (PP) and polycarbonate (PC)....	89
<b>Fig. 3.33.</b> System boundary for injection moulding of thermosetting materials .....	90
<b>Fig. 3.34.</b> The use phase within the product's life cycle (Schott 1998, Birkhofer and Grüner 2002).....	92
<b>Fig. 3.35.</b> Structuring the use phase in sub-phases (Dannheim et al. 1998, Dannheim 1999).....	93
<b>Fig. 3.36.</b> Usage behaviour and environmental impacts (Dannheim et al. 1998) .....	96
<b>Fig. 3.37.</b> Methods to support product developers in analysing environmental impacts emerging from the use phase and accompanying processes .....	98
<b>Fig. 3.38.</b> The Use-Phase-Analysis-Matrix (excerpt) (Oberender and Birkhofer 2003a).....	99
<b>Fig. 3.39.</b> Steps for processing the UPA-Matrix (Oberender and Birkhofer 2003a).....	100
<b>Fig. 3.40.</b> Checklists to support the product developer in applying the UPA-Matrix (excerpt) (Oberender and Birkhofer 2003a) (part 1).....	100
<b>Fig. 3.41.</b> Transferability of models.....	102
<b>Fig. 3.42.</b> Behavioural structure and components of a washing machine	103
<b>Fig. 3.43.</b> Eco-FMEA to analyse the user behaviour (Dannheim et al. 1998) .....	103

<b>Fig. 3.44.</b> Dependencies between the users' behaviour and inventory data .....	104
<b>Fig. 3.45.</b> Effect chain of a vehicle from energy storing device to movement and influence of the user on inventory data .....	105
<b>Fig. 3.46.</b> The matrix of Eco-Value Analysis of a coffee maker (excerpt) (Oberender and Birkhofer 2004) .....	105
<b>Fig. 3.47.</b> Integration of the end of life into product development (Szpath et al. 2002).....	107
<b>Fig. 3.48.</b> Mass flow of material after the use phase (Wolf 2001).....	108
<b>Fig. 3.49.</b> Decontamination effect due to removal of individual hazardous parts of WEEE (Cuhls et al. 1998).....	110
<b>Fig. 3.50.</b> Disposal of residual waste in European States (Hogg et al. 2001) .....	114
<b>Fig. 3.51.</b> Approach for the design of activity guidelines.....	120
<b>Fig. 3.52.</b> Categories of control-levers.....	121
<b>Fig. 3.53.</b> Example for a rule for the environmentally friendly process .	124
<b>Fig. 3.54.</b> Example for activity guideline spreadsheet (page 1).....	125
<b>Fig. 3.55.</b> Example for activity guideline spreadsheet (page 2).....	126
<b>Fig. 4.1.</b> Phases of a LCA according to ISO 14040, 14042 (modified)..	128
<b>Fig. 4.2.</b> System boundaries of a waste management system .....	130
<b>Fig. 4.3.</b> Environmental compartments .....	131
<b>Fig. 4.4.</b> Results from the case study "reduction of the odour flow rate" ..	136
<b>Fig. 4.5.</b> Method set and aggregation according to "Darmstädter Modell" (Pant 2000, Rohde et al. 2004) (abbreviations see table Table 4.4).....	139
<b>Fig. 4.6.</b> Binary logic (classic set theory) vs. fuzzy logic (fuzzy set theory) (Atik 2001).....	144
<b>Fig. 4.7.</b> Method tree for the analysis and modelling of uncertainty in LCA (Atik 2001).....	146
<b>Fig. 4.8.</b> Opportunities to influence and assess environmental effects during the product development process (Atik 2001) .....	147
<b>Fig. 4.9.</b> Schematic representation of the Eco Indicator 95 weighting method (Goedkoop 1995) .....	149
<b>Fig. 4.10.</b> Criteria for the determination of weighting factors (Atik 2001) .....	151
<b>Fig. 4.11.</b> Presentation of the Meta-Method results illustrated by an industrial high pressure cleaner.....	152
<b>Fig. 4.12.</b> Comparative application of the Meta-Method in case studies (Atik 2001).....	153
<b>Fig. 4.13.</b> Screenshot of the TEA graphical user interface .....	154
<b>Fig. 5.1.</b> Business objectives.....	158
<b>Fig. 5.2.</b> Motivation for carrying out environment related measures.....	158

---

<b>Fig. 5.3.</b> Influences of different company departments on environmental protection measures.....	159
<b>Fig. 5.4.</b> Use of LCA in product development.....	160
<b>Fig. 5.5.</b> Knowledge pyramid (best-practice model) .....	161
<b>Fig. 5.6.</b> System innovation as a result of single technological and social innovations (Qualitative sketch) .....	163
<b>Fig. 5.7.</b> The innovation process.....	165
<b>Fig. 5.8.</b> The model of the sustainable innovation process .....	169
<b>Fig. 5.9.</b> Different dimensions of the research programme on marketability of environmentally friendly products.....	171
<b>Fig. 5.10.</b> Two electric kettles with different prestige values and identical functional value.....	180
<b>Fig. 5.11.</b> Importance of attributes for the value of individual pleasure (left) and for the prestige value (right) (1=not important; 5=very important) .....	181
<b>Fig. 5.12.</b> Preference of surface materials (0=low preference, 25=high preference) .....	182
<b>Fig. 5.13.</b> Screenshot of simulation environment CHESS .....	188
<b>Fig. 5.14.</b> Overall structure of a HoQ .....	195
<b>Fig. 5.15.</b> Calculation of the importance of the product characteristics (excerpt from a HoC) .....	196
<b>Fig. 5.16.</b> Procedure of the Life Cycle Quality Function Deployment (LC-QFD) .....	197
<b>Fig. 5.17.</b> Sources for customer specifications .....	198
<b>Fig. 5.18.</b> Kano diagram of customer satisfaction .....	200
<b>Fig. 5.19.</b> Questionnaire of the Simplified Kano Method (excerpt) .....	201
<b>Fig. 5.20.</b> VoC and VoE interrelation matrix of the vacuum cleaner (excerpt) .....	203
<b>Fig. 5.21.</b> Strategy portfolio (excerpt) .....	204
<b>Fig. 5.22.</b> Extended requirements list including the functional unit (excerpt) .....	206
<b>Fig. 5.23.</b> Examples of direct and indirect strategies (Grüner 2001) .....	207
<b>Fig. 5.24.</b> Decision diagram for the use phase with sensitivity analysis for a vacuum cleaner.....	208
<b>Fig. 5.25.</b> The product model pyramid exemplified by the development of a vacuum cleaner, adapted from Ernzer and Birkhofer (Ernzer and Birkhofer 2003b).....	211
<b>Fig. 5.26.</b> Connection between the successive concretising of product models and the design degrees of freedom (Sauer et al. 2003).....	214
<b>Fig. 5.27.</b> Examples for alternative vacuum cleaner concepts .....	214
<b>Fig. 5.28.</b> Polar diagram representing the holistic rating of three vacuum cleaner concepts .....	216

<b>Fig. 5.29.</b> Relative environmental impact diagram of the examined DC motor series .....	218
<b>Fig. 5.30.</b> Postulated consequences of task-related diversity in teams ...	222
<b>Fig. 5.31.</b> Postulated effects of integration activities.....	222
<b>Fig. 6.1.</b> Interactions within an integrated product model .....	226
<b>Fig. 6.2.</b> Information model (schematic view).....	228
<b>Fig. 6.3.</b> Simplified information model in UML.....	235
<b>Fig. 6.4.</b> A cut-out of feature spreadsheet.....	237
<b>Fig. 6.5.</b> Environmental dictionary: definition of concept .....	241
<b>Fig. 6.6.</b> Environmental dictionary: opinions for every concept.....	242
<b>Fig. 6.7.</b> UML structure reference model for production processes .....	246
<b>Fig. 6.8.</b> Transformation from process model to object model .....	247
<b>Fig. 6.9.</b> Variants for choosing processes for the transformation .....	248
<b>Fig. 6.10.</b> Methods-building a software environment for development of an integrated information model.....	249
<b>Fig. 6.11.</b> Building of object-oriented model.....	250
<b>Fig. 6.12.</b> An example about classes and their relationships .....	251
<b>Fig. 6.13.</b> Implementation of an operation using GUI.....	252
<b>Fig. 6.14.</b> GUI for case differentiation.....	253
<b>Fig. 6.15.</b> GUIs for loop.....	254
<b>Fig. 6.16.</b> Spreadsheet template for partial models.....	255
<b>Fig. 6.17.</b> A cut-out of the partial model “Deep Drawing” .....	256
<b>Fig. 6.18.</b> A cut-out of inventory data set .....	257
<b>Fig. 6.19.</b> Methodical framework for the adaptation of the information model.....	258
<b>Fig. 6.20.</b> Modules of the ecoDesign Workbench (1:CAD, 2:LCAD, 3:LCM).....	259
<b>Fig. 6.21.</b> Vision of an efficient collaborative life cycle design .....	261
<b>Fig. 6.22.</b> Concept for the data workflow in the ecoDesign Workbench	264
<b>Fig. 6.23.</b> System integration with system-specific and system-neutrally interfaces (Anderl and Trippner 2000).....	265
<b>Fig. 6.24.</b> Architecture of the ecoDesign Workbench.....	266
<b>Fig. 6.25.</b> Data exchange approach between CAD system and ecoDesign Workbench over an API.....	268
<b>Fig. 6.26.</b> Process and product views in the Life Cycle Modeller .....	269
<b>Fig. 6.27.</b> Flow chart of the environmental assessment in the LCAD ....	272
<b>Fig. 6.28.</b> Fuzzy arithmetic based processing of LCA data (based on Atik and Schulz 2000).....	273
<b>Fig. 6.29.</b> Weighting of the specific contribution .....	274
<b>Fig. 6.30.</b> Adapted weighting matrix (Atik and Schulz 2000).....	274
<b>Fig. 6.31.</b> Environmental relevance rule base (Atik and Schulz 2000)...	275

---

<b>Fig. 6.32.</b> Fuzzy logic based weighting and assessment (based on Atik and Schulz 2000, Atik 2001) .....	276
<b>Fig. 6.33.</b> Partition of the technical criteria (based on Breiing and Knosala 1997) .....	278
<b>Fig. 6.34.</b> Value scale according to Kesselring and as fuzzy membership functions.....	279
<b>Fig. 6.35.</b> Technical weighting matrix .....	279
<b>Fig. 6.36.</b> Polar-/ spider net diagram of the results .....	280
<b>Fig. 6.37.</b> Presentation of the <i>Eco-Index</i> results .....	281
<b>Fig. 6.38.</b> <i>Eco-Index</i> contributions in different life cycle phases.....	281
<b>Fig. 6.39.</b> Results of the IsoMetrics <sup>L</sup> (adapted from Felsing et al. 2004a). .....	285



## List of Tables

<b>Table 2.1.</b> General development strategies for environmental use process optimisation (Dannheim 1997) .....	14
<b>Table 3.1.</b> Comparison of calculations with experimental results.....	66
<b>Table 3.2.</b> Bandwidths of electrical and heating power characteristics specific to the machine location .....	71
<b>Table 3.3.</b> Average resource consumption and waste amount per kilogram chip by turning and milling in line production (Schiefer 2001).....	73
<b>Table 3.4.</b> Average resource consumption and waste amount per minute utilisation time by turning and milling in line production (Schiefer 2001)	74
<b>Table 3.5.</b> Emission parameters of the machining process.....	74
<b>Table 3.6.</b> Summary of the relevant environmental influence factors in nitriding.....	78
<b>Table 3.7.</b> Product categories (Wolf 2001).....	109
<b>Table 3.8.</b> Recovery rates $r_{DismR}$ of the metal parts in cables and engines (Wolf 2001).....	111
<b>Table 3.9.</b> Recovery rates $r_{ShredR}$ of metals from shredding dependent on the content of that material in the product volume (Wolf 2001).....	111
<b>Table 3.10.</b> Transfer coefficients for heavy metals input in burnable waste (in %).....	116
<b>Table 3.11.</b> Concentration of BFRs in selected WEEE (Morf et al. 2002) .....	117
<b>Table 4.1.</b> Selected odour threshold values .....	135
<b>Table 4.2.</b> Characterisation factors considering PM10 formation .....	137
<b>Table 4.3.</b> Estrogenic Activity Potentials (EAP) according to (Gülden et al. 1998) .....	138
<b>Table 4.4.</b> Environmental importance of the selected impact categories	140
<b>Table 4.5.</b> Matrix for specification of data quality with five data quality indicators (DQI) (Weidema 1998) .....	143
<b>Table 4.6.</b> Abstract of environmental assessment methods (comp. Atik 2001) .....	150
<b>Table 5.1.</b> Four types of Eco-Design.....	162
<b>Table 5.2.</b> Overview of 19 studies on ergonomic design requirements I	192
<b>Table 5.3.</b> DfE strategies and assigned design guidelines (Grüner 2001) .....	210

<b>Table 5.4.</b> Environmental evaluation chart for three vacuum cleaner concepts.....	215
<b>Table 5.5.</b> Calculation scheme for determining the environmental impact contributions $a_i$ to the basic design.....	218
<b>Table 5.6.</b> Attributes of diversity in teams (examples), adapted from Jackson (1996) .....	220
<b>Table 5.7.</b> Contents and objectives of a mixed training and team development measure for interdisciplinary project teams.....	223