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University of Pretoria

Development of a Life Cycle Impact Assessment procedure for Life Cycle Management in South Africa

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A thesis submitted in partial fulfilment of the requirements for the degree

Philosophiae Doctor

in the

Department of Engineering and Technology Management
Faculty of Engineering, the Built Environment and Information Technology

University of Pretoria

July 2004

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Declaration

I declare that the thesis, which I hereby submit for the degree Philosophiae Doctor (Engineering Management) at the University of Pretoria, is my own work and has not been previously submitted by me for a degree at another University.

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Research summary

Development of a Life Cycle Impact Assessment procedure for Life Cycle Management in South Africa

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Degree: Philosophiae Doctor (Engineering Management)

Competitive industries in the manufacturing sector have a holistic Life Cycle Management (LCM) view of business practices. Life Cycle Assessment (LCA), which forms part of the LCM approach, is increasingly used as a decision support tool in the South African manufacturing industry. The Life Cycle Impact Assessment (LCIA) phase of the LCA tool has been standardised within the ISO 14000 family and aims to quantify the environmental impacts of economic activities. A number of LCIA methodologies have been developed in Europe, which can be applied directly when life cycle systems are assessed. The LCIA procedures that are most commonly used in the South African manufacturing industry include the CML, Ecopoints, EPS and Eco-indicators 95 and 99 procedures.

The five European methods are evaluated based on the applicability of the respective classification, characterisation, normalisation and weighting elements for the South African situation. The evaluation and comparison is further based on a cradle-to-gate Screening Life Cycle Assessment (SLCA) case study of the production of dyed two-fold wool yarn in South Africa. Shortcomings are identified with the European methodologies in the South African context in terms of comprehensiveness and modelling approaches.

A LCIA framework and calculation procedure, termed the Resource Impact Indicator (RII) model, is subsequently proposed for South Africa, which is based on the

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protection of four natural resource groups: water, air, land, and mined abiotic resources. A distance-to-target approach is used for the normalisation of midpoint categories, which focuses on the ambient quality and quantity objectives for the four resource groups. The quality and quantity objectives are determined for defined South African Life Cycle Assessment (SALCA) regions and take into account endpoint or damage targets. Following the precautionary approach, RIIs are calculated for the resource groups from conventional Life Cycle Inventories (LCIs). The calculation of the RIIs ensures that all natural resources that are important from a South African perspective are duly considered in a LCIA. The results of a LCIA are consequently not reliant on detailed LCIs and the number of midpoint categories that converge on a single resource group.

The proposed model is evaluated with the SLCA wool case study. The case study establishes the importance of region-specificity, for LCIs and LCIAs. The proposed LCIA model further demonstrates reasonable ease of communication of LCIA results to decision-makers or managers.

Subjective weighting values for the resource groups are also proposed, based on survey results from manufacturing industry sectors in the South African automotive value chain, and the expenditure of the South African national government on environmental issues. The subjective weighting values are used to calculate overall Environmental Performance Resource Impact Indicators (EPRIIs) when comparing life cycle systems with each other. The EPRII approach is applied to a specific LCM problem in the South African context, i.e. evaluating and comparing environmental performance for supply chain management purposes in the developing country context. Thereby, RIIs are provided for key Cleaner Production process parameters in the South Africa context: water usage, energy usage, and waste produced per manufactured product.

Keywords

Life Cycle Management, Life Cycle Engineering, Life Cycle Assessment, Life cycle Impact Assessment, engineering management, environmental performance, environmental impacts, supply chain management, cleaner production, South Africa.

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Research project structure

The research project consists of the following three main parts:

- A qualitative (Chapter 2) and quantitative (Chapter 3) review of the current European LCIA procedures that are used in the South African manufacturing sector in order to identify any potential shortcomings (from a South African perspective) with respect to the emphasis that is placed on different environmental aspects.
- The development of a South African specific LCIA procedure, based on the existing European models, which addresses the potential shortcomings. Specifically, the required region-specificity is addressed (Chapter 4), before compiling and demonstrating the developed LCIA procedure with a case study (Chapter 5).
- The application of the developed model for a South African specific LCM problem, i.e. the evaluation of environmental performances of companies in supply chain management (Chapter 6).

After the final conclusions of the research project, the LCIA procedure is compiled in a Java software format for further application purposes in the manufacturing industry of South Africa (Chapter 7 and Appendices G and H).

With respect to the development and application of the LCIA procedure, the strategy of the research project is summarised in the following figure:

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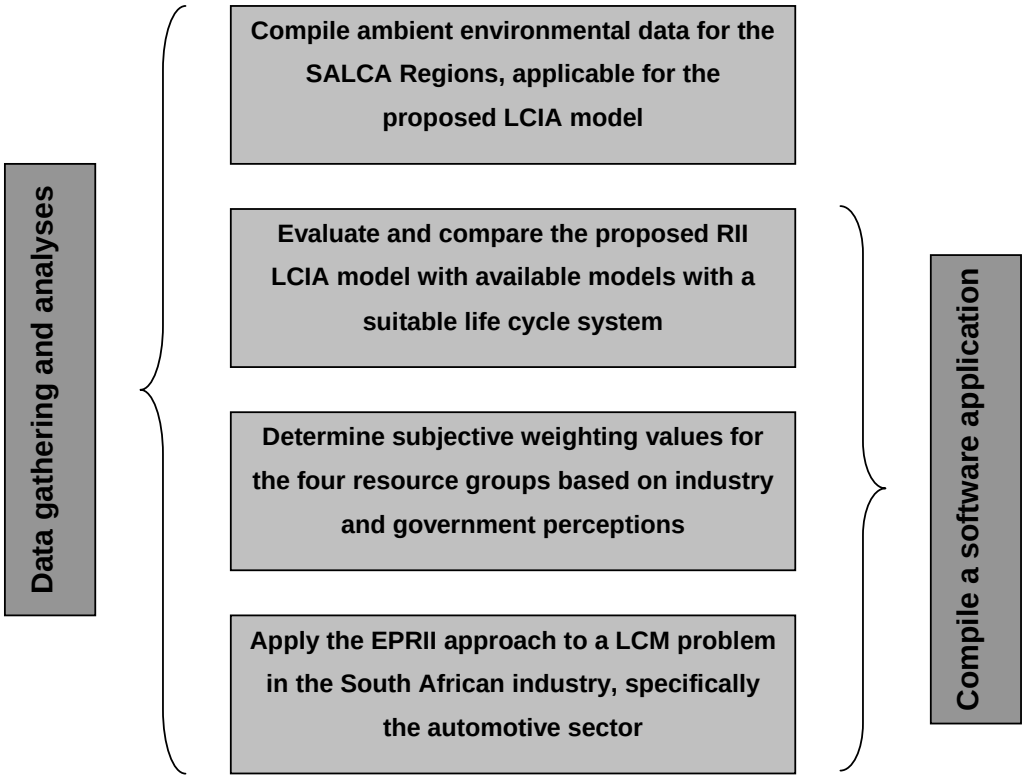

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Acknowledgements

The author hereby acknowledges the extensive contributions of the following individuals, organisations and institutions:

- The Environmental Process Solutions group of the Process Technology Centre (PTC), and the Centre for Textiles and Clothing (CTC) in the Division of Manufacturing and Materials Technology (M&Mtek) of the Council for Scientific and Industrial Research (CSIR), and especially Drs Sibbele Hietkamp and Francois Barkhuysen, with whom the author collaborated in order to compile the wool case study, specifically the Life Cycle Inventory (LCI) of the case study.
- The Division of Water, Forestry and the Environment (Environmentek) of the CSIR, which provided background ambient information on the water catchments of South Africa for the LCIA procedure.
- The Centre of Environmental Studies (CFES) of the University of Pretoria, and especially Prof Albert van Jaarsveld and Dr Belinda Reyers, who assisted with mapping the primary water catchments with the national land cover database of South Africa in order to identify the current land usage in the defined SALCA Regions of the LCIA procedure.
- The Institute for Soil, Climate and Water of the Agricultural Research Council (ARC), which provided background ambient information in terms of pollutants in soils in different regions of South Africa.
- The national Department of Environmental Affairs and Tourism (DEAT), which was an important source of information, predominantly through the published National State of the Environment reports.
- The Swiss Federal Institute of Technology in Zurich (ETH), and especially Mr Renat Heuberger, with whom the author collaborated to apply the Analytical Hierarchy Process (AHP) in order to establish subjective weighting values for the four natural resource groups in the LCIA procedure.
- The BMW group of South Africa, and particularly Me Dalene Viljoen and Mr Sanjay Premraj, who, through personal communications, provided valuable data on the first-tier suppliers in the automotive sector of South Africa.

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List of Acronyms

AHP	Analytical Hierarchy Process
AIJ	Aggregation of Individual Judgments
AIP	Aggregation of Individual Priorities
ALCM	Asset Life Cycle Management
AoP	Areas of Protection
CDM	Clean Development Mechanism
CML	Centre for Environmental Studies, Leiden University, the Netherlands
DfE	Design for Environment
DfS	Design for Sustainability
EEM	Environmental Evaluation Matrix
EIA	Environmental Impact Assessment
ELU	Environmental Load Unit
EMS	Environmental Management System
EPI	Environmental Performance Indicator
EPRII	Environmental Performance Resource Impact Indicator
EPS	Environmental Priorities Strategies
GDP	Gross Domestic Product
IRD	Initial Rate of Deposition
ISO	International Organization for Standardization
LCA	Life Cycle Assessment
LCC	Life Cycle Costing
LCE	Life Cycle Engineering
LCI	Life Cycle Inventory
LCIA	Life Cycle Impact Assessment
LCM	Life Cycle Management
LSU	Large Stock Unit
LUT	Land Use Type
MCDA	Multi Criteria Decision Analysis
MIDP	Motor Industry Development Programme
MRD	Maximum Rate of Deposition
OEM	Original Equipment Manufacturer
PLCM	Product or Project Life Cycle Management
RII	Resource Impact Indicator
RMEE	Relative Mass-Energy-Economic method
SALCA	South African Life Cycle Assessment Regions
SLCA	Streamlined or Screening Life Cycle Assessment

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Appendix A: Water quality data for the SALCA Regions

Appendix B: South African land cover data

Appendix C: South African conserved vegetation data

Appendix D: Current and target values for the RII calculations

Appendix E: Landfill site calculations for average waste treatment

Appendix F: Life Cycle Inventories of key process parameters

Appendix G: Screen shots of the LCIA software application

Appendix H: LCIA software application and Java code