2013 IEEE INTERNATIONAL CONFERENCE ON
INDUSTRIAL ENGINEERING AND ENGINEERING MANAGEMENT

IEEE

IEEM 2013

10 - 13 DECEMBER 2013 | BANGKOK, THAILAND

www.IEEM.org

Organized by : IEEE TMC Thailand Chapter
IEEE TMC Singapore Chapter
IEEE TMC Hong Kong Chapter
IEEE SMC Hong Kong Chapter

Organizers & Committees

General Chair
Pakorn Adulbhan
The Royal Institute of Thailand, Thailand

Organizing Chairs
Tritos Laosirihongthong
Thammasat University, Thailand
Roger Jiao
Georgia Institute of Technology, USA

Program Chairs
Min Xie
City University of Hong Kong, Hong Kong
Ronnachai Sirovetnukul
Mahidol University, Thailand

International Advisors

Daniel Berg
Rensselaer Polytechnic Institute, United States

Boaz Golany
Technion, Israel

Thong Ngee Goh
National University of Singapore, Singapore

Way Kuo
City University of Hong Kong, Hong Kong

Mike Gregory
Cambridge University, United Kingdom

Robert W. Grubbström
Linköping Institute of Technology, Sweden

Martin Helander
Nanyang Technological University, Singapore

Larry Y.C. Ho
Harvard University, United States and Tsinghua University, China

Tinus Pretorius
University of Pretoria, South Africa

Ralf Reichwald
Technical University of Munich, Germany

Gavriel Salvendy
Purdue University, USA and Tsinghua University, China

Mitchell M. Tseng
Hong Kong University of Science and Technology, Hong Kong

Ue-Pyng Wen
National Tsing Hua University, Taiwan

Advisory Committee

Arthorn Sinsawad
Chair, IEEE Thailand Section

Somkit Lertpaithoon
Rector, Thammasat University, Thailand

Prapat Wangskarn
Dean, Faculty of Engineering, Thammasat University, Thailand

Jirarat Teeravaraprug
Department Head, Department of Industrial Engineering, Thammasat University, Thailand

Dumrong Taweesangsakulthai
Chair, Industrial Engineering Committee, The Engineering Institute of Thailand Under H.M. The King's Patronage, Thailand

Ampika Krairit
Advisor, Industrial Engineering Committee, The Engineering Institute of Thailand Under H.M. The King's Patronage, Thailand

Voratas Kachitvichyanukul
Asian Institute of Technology, Thailand

Songlin Chen
IEEE TMC Singapore Chapter Chair

Edwin Cheung,
IEEE TMC Hong Kong Chapter Chair

James Liu,
IEEE SMC Hong Kong Chapter Chair

Tritos Laosirihongthong,
IEEE TMC Thailand Chapter Chair

Technical Program Committee

Michel Aldanondo
Univ Toulouse Mines Albi, France

Luciana Alencar
Federal University of Pernambuco, Brazil

Imad Alsyouf
University of Sharjah, UAE

Teresa Alvarez
University of Valladolid, Spain

Mehdi Amiri-Aref
Mazandaran University of Science and Technology, Iran

Tarik Aouam
American University of Sharjah, UAE

Pedro Arezes
University of Minho, Portugal

Ana Paula Barroso
UNIDEMI, FCT-UNL, Portugal

Samuel Bassetto
Ecole Polytechnique de Montreal, Canada

Nadjib Brahimi
University of Sharjah, UAE

Paul Chang
National Changhua University of Education, Taiwan

Shin-Guang Chen
Tungnan University, Taiwan

Cheng-Wu Chen
National Kaohsiung Marine University, Taiwan

Bing Chen
Northwestern Polytechnical University, China

Jui-Sheng Chou
National Taiwan University of Science and Technology, Taiwan

Thierry Coudert
Univ Toulouse ENIT-LGP, France

Stefan Creemers
IESEG Management School, France

Yves De Smet
Université Libre de Bruxelles, Belgium

Fikri Dweiri
University of Sharjah, UAE

Chao Fang
Wuhan University, China

Laurent Geneste
Univ Toulouse ENIT-LGP, France

Antonio Grilo
Faculdade de Ciências e Tecnologia da Universidade Nova de Lisboa, Portugal

Guillermo Gutierrez
Instituto Tecnológico de Morelia, Mexico

Md. Mamun Habib
American International University Bangladesh, Bangladesh

Rika Ampuh Hadiguna
Andalas University, Indonesia

Siana Halim
Petra Christian University, Indonesia

Takashi Hasuikte
Osaka University, Japan

Jishnu Hazra
Indian Institue of Management Bangalore, India

Chin-Yu Huang
National Tsing Hua University, Taiwan

Supachart Iamratanakul
Kasetsart University, Thailand

Shinji Inoue
Tottori University, Japan

Raja Jayaraman
Khalifa University of Science, Technology & Research, UAE

Minghai Jiao
Northeastern University, China

Mingzhou Jin
University of Tennessee, USA

Yuya Kajikawa
Tokyo Institute of Technology, Japan

Matti Karvonen
Lappeenranta University of Technology, Finland

Chompoonoot Kasemset
Chiang Mai University, Thailand

Soo Beng Khoh
Motorola Solutions, Malaysia

Chil-Chyuan Kuo
Ming Chi University of Technology, Taiwan

Chien-Liang Kuo
Chinese Culture University, Taiwan

C.K. Kwong
The Hong Kong Polytechnic University, China

Tyrone T. Lin
National Dong Hwa University, Taiwan

Weidong Lin
Temasek Polytechnic, Singapore

Chu-Ti Lin
National Chiayi University, Taiwan

Chen-ju Lin
Yuan Ze University, Taiwan

Chun-Cheng Lin
National Chiao Tung University, Taiwan

Jun Lin
Xian Jiaotong University, China

Bor-Shong Liu
St. John's University, Taiwan

Yiliu Liu
Norwegian University of Science and Technology, Norway

Jian Liu
University of Arizona, USA

Mei-Chen Lo
National United University, Taiwan

Huitian Lu
South Dakota State University, USA

Virginia Machado
UNIDEMI, FCT-UNL, Portugal

Jose Machado
University of Minho, Portugal

Harekrishna Misra
Institute of Rural Management Anand, India

Lars Moench
University of Hagen, Germany

Wasawat Nakkiew
Chiang Mai University, Thailand

Tatsushi Nishi
Osaka University, Japan

Ville Ojanen
Lappeenranta University of Technology, Finland

Selma Oliveria
University Sao Paulo, Brazil

Mohamed K. Omar
Nottingham University Business School, Malaysia

Taezoon Park
Soongsil University, South Korea

Syafiie Syafiie
University Putra Malaysia, Malaysia

Jennifer Percival
University of Ontario Institute of Technology, Canada

Leon Pretorius
University of Pretoria, South Africa

Suksan Prombanpong
King Mongkut's University of Technology Thonburi, Thailand

Kit Fai Pun
University of the West Indies, Trinidad and Tobago

Hendry Raharjo
Chalmers University of Technology, Sweden

Kem Ramdass
University of Johannesburg, South Africa

R.M. Chandima Ratnayake
University of Stavanger, Norway

Ralph Riedel
Chemnitz University of Technology, Germany

Fernando Romero
University of Minho, Portugal

Mojahid Saeed Osman
King Fahd University of Pertoleum and Minerals, Saudi Arabia

Tomoko Saiki
Tokyo Institute of Technology, Japan

Ichiro Sakata
The University of Tokyo, Japan

Ilias Santouridis
TEI of Larissa, Greece

Kiyoshi Sawada
University of Marketing and Distribution Sciences, Japan

Mahmood Shafiee
Cranfield University, UK

Ahm Shamsuzzoha
University of Vaasa, Finland

Sung Shim
Seton Hall University, USA

Ali Siadat
Arts et Metiers ParisTech, France

Ronnachai Sirovetnukul
Mahidol University, Thailand

Stuart So
The University of Queensland, Australia

Harm-Jan Steenhuis
Eastern Washington University, USA

Nachiappan Subramanian
The University of Nottingham Ningbo, China

Fabrice Talla Nobibon
KU Leuven, Belgium

Yoshinobu Tamura
Yamaguchi University, Japan

Hisato Tashiro
The University of Tokyo, Japan

Pei-Lee Teh
Monash University, Malaysia

Purit Thanakijkasem
King Mongkut's University of Technology Thonburi, Thailand

Ramayah Thurasamy
Universiti Sains Malaysia, Malaysia

Norbert Trautmann
University of Bern, Switzerland

Ming-Lang Tseng
Lung Hwa University of Science and Technology, Taiwan

Yuan-Jye Tseng
Yuan Ze University, Taiwan

Leonilde Varela
University of Minho, Portugal

Enrico Vezzetti
Politecnico di Torino, Italy

Shengyong Wang
The University of Akron, USA

Yonggui Wang
University of International Business and Economics, China

Chirag Warty
Ahilya Technologies, USA

Seng Fat Wong
University of Macau, Macau

Zheng Guo Xu
Zhejiang University, China

Bingwen Yan
Cape Peninsula University of Technology, South Africa

QZ Yang
Circular Economy Research Centre, China

Jaekyung Yang
Chonbuk National University, South Korea

Min Yao
Zhejiang University, China

Norio Yoshida
University of Toyama, Japan

Suhaiza Zailani
Universiti Sains Malaysia, Malaysia

Cai Wen Zhang
Sun Yat-sen University, China

Linda Zhang
IESEG School of Management, France

Allan Nengsheng Zhang
Singapore Institute of Manufacturing Technology, Singapore

Table of Contents

TK 1 Technology & Knowledge Management (1)

TK 2 Technology & Knowledge Management (2)

OR 1 Operations Research (1)

OR 2 Operations Research (2)

HF 1 Human Factors (1)

DM 1 Decision Analysis & Methods (1)

SC 1 Supply Chain Management (1)

SC 2 Supply Chain Management (2)

SI 1 Service Innovation & Management (1)

QC 1 Quality Control & Management (1)

PP 1 Production Planning & Control (1)

SM 1 Systems Modeling & Simulation (1)

EE 1 Engineering Economy & Cost Analysis (1)

PM 1 Project Management (1)

EB 1 E-Business & E-Commerce (1)

RM 1 Reliability & Maintenance Engineering (1)

SR 1 Safety, Security & Risk Management (1)

GM Global Manufacturing & Management

Poster Session 1

TK 4 Technology & Knowledge Management (4)

TK 5 Technology & Knowledge Management (5)

OR 3 Operations Research (3)

OR 4 Operations Research (4)

HF 2 Human Factors (2)

ET Engineering Education & Training

DM 2 Decision Analysis & Methods (2)

DM 3 Decision Analysis & Methods (3)

SC 3 Supply Chain Management (3)

SC 4 Supply Chain Management (4)

SC 5 Supply Chain Management (5)

SC 6 Supply Chain Management (6)

HS 2 Healthcare Systems & Management (2)

SI 2 Service Innovation & Management (2)

SM 2 Systems Modeling & Simulation (2)

QC 3 Quality Control & Management (3)

PP 2 Production Planning & Control (2)

PP 3 Production Planning & Control (3)

PM 2 Project Management (2)

EE 2 Engineering Economy & Cost Analysis (2)

IP Information Processing & Engineering

FP Facilities Planning & Management

EB 2 E-Business & E-Commerce (2)

TK 3 Technology & Knowledge Management (3)

SR 2 Safety, Security & Risk Management (2)

IS Intelligent Systems

MS Manufacturing Systems

Poster Session 2

IEEE.org IEEE *Xplore* IEEE-SA IEEE Spectrum More Sites SUBSCRIBE SUBSCRIBECart Create Account Personal Sign In

Browse My Settings Help Institutional Sign In

Institutional Sign In

All

Search within Publication

ADVANCED SEARCH

Quick Links
Search for Upcoming Conferences
IEEE Publication Recommender
IEEE Author Center

Browse Conferences > IEEE International Conference ... > 2013 IEEE International Confer...

IEEE International Conference on Industrial Engineering and Engineering Management

Proceedings

The proceedings of this conference will be available for purchase through Curran Associates.

Industrial Engineering and Engineering Management (IEEM), 2013 IEEE International Conference on

Print on Demand **Purchase at Partner**

External Hard-drive **Purchase at Partner**

Copy Persistent Link Browse Title List Sign up for Conference Alerts

Proceedings All Proceedings Popular

2013 IEEE International Conference on Industrial Engineering and Engineering Management doi

DOI: 10.1109/IEEM30508.2013

Search within results **Per Page: Per Page 25** | Export | Email Selected Results

Showing **301-325** of **347**

Filter

sort: Sort Sequence | Email

Refine

Author

Affiliation

Conference Location

Technical and non-technical innovation models in China's SMEs: A case study
Jin Chen; Juxiang Zhou; Feng Xu; Yue Yin
Publication Year: 2013 , Page(s): 1495 - 1499

Abstract (1403 Kb)

Technical and non-technical innovation models in China's SMEs: A case study
Jin Chen; Juxiang Zhou; Feng Xu; Yue Yin
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

The impact of scientific knowledge resources on innovation performance: A case study
Juxiang Zhou; Jin Chen; Xiaoting Zhao; Xiangzhen Yu; Yue Yin
Publication Year: 2013 , Page(s): 1500 - 1504

Abstract (1389 Kb)

The impact of scientific knowledge resources on innovation performance: A case study
Juxiang Zhou; Jin Chen; Xiaoting Zhao; Xiangzhen Yu; Yue Yin
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

Developing proprietary or open source technology: Learning from five case studies
R. R. K. Sharma; Ajay Jha; Sandeep S Rajput

Quick Links
Search for Upcoming Conferences
IEEE Publication Recommender
IEEE Author Center

Proceedings
The proceedings of this conference will be available for purchase through Curran Associates.

Industrial Engineering and Engineering Management (IEEM), 2013 IEEE International Conference

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.

Accept & Close

Print on
Demand **Purchase at Partner**

External Hard-
drive **Purchase at Partner**

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.

Accept & Close

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.
Accept & Close

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.

Accept & Close

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.
Accept & Close

Abstract (1425 Kb)

Measurement of manufacturing effectiveness of a company using analytical hierarchical process: A case study

R. R. Lekurwale; M. M. Akarte; D. N. Raut
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

A conceptual framework of an integrated fuzzy ANP and TOPSIS for supplier selection based on supply chain risk management
Sittichok Sinrat; Walailak Atthirawong
Publication Year: 2013 , Page(s): 1607 - 1611

Abstract (1558 Kb)

A conceptual framework of an integrated fuzzy ANP and TOPSIS for supplier selection based on supply chain risk management

Sittichok Sinrat; Walailak Atthirawong
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

An Analytic Network Process model to support decision making in a pharmaceutical supply chain
V. H. Machado; A. P. Barroso; V. Cruz Machado
Publication Year: 2013 , Page(s): 1612 - 1616
Cited by: Papers (1)

Abstract (1471 Kb)

An Analytic Network Process model to support decision making in a pharmaceutical supply chain

V. H. Machado; A. P. Barroso; V. Cruz Machado
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

Economic, environmental and social responsible supply chain design using differential evolution multi objective algorithm
Sh. Gholizadeh Tayyar; D. Roy; S. F. Ghaderi
Publication Year: 2013 , Page(s): 1617 - 1621
Cited by: Papers (1)

Abstract (1725 Kb)

Economic, environmental and social responsible supply chain design using differential evolution multi objective algorithm

Sh. Gholizadeh Tayyar; D. Roy; S. F. Ghaderi
2013 IEEE International Conference on Industrial Engineering and Engineering Management
Year: 2013

Load More

Previous < 11 12 13 14 >

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.

Accept & Close

CHANGE USERNAME/PASSWORD
PAYMENT OPTIONS
COMMUNICATIONS PREFERENCES
US & CANADA: +1 800 678 4333
VIEW PURCHASED DOCUMENTS
PROFESSION AND EDUCATION
WORLDWIDE: +1 732 981 0060

TECHNICAL INTERESTS CONTACT & SUPPORT

About IEEE *Xplore* | Contact Us | Help | Accessibility | Terms of Use | Nondiscrimination Policy | Sitemap | Privacy & Opting Out of Cookies

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.

© Copyright 2021 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.

IEEE Account

- » Change Username/Password
- » Update Address

Purchase Details

- » Payment Options
- » Order History
- » View Purchased Documents

Profile Information

- » Communications Preferences
- » Profession and Education
- » Technical Interests

Need Help?

- » **US & Canada:** +1 800 678 4333
- » **Worldwide:** +1 732 981 0060
- » Contact & Support

About IEEE *Xplore* | Contact Us | Help | Accessibility | Terms of Use | Nondiscrimination Policy | Sitemap | Privacy & Opting Out of Cookies

A not-for-profit organization, IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.
© Copyright 2021 IEEE - All rights reserved. Use of this web site signifies your agreement to the terms and conditions.

IEEE websites place cookies on your device to give you the best user experience. By using our websites, you agree to the placement of these cookies. To learn more, read our Privacy Policy.

Accept & Close

Scopus Preview
Dashboard Author search Sources
FA

Document details

1 of 1
Export Download More...

Cited by 0 documents

Inform me when this document is cited in Scopus:
Set citation alert
Set citation feed

Related documents

Find more related documents in Scopus based on:
Authors Keywords

IEEE International Conference on Industrial Engineering and Engineering Management
18 November 2014, Article number 6962679, Pages 1597-1601
2013 IEEE International Conference on Industrial Engineering and Engineering Management, IEEM 2013; Bangkok; Thailand; 10 December 2013 through 13 December 2013; Category numberCFP13IEI-ART; Code 109355

An improved binary linear programming approach for life cycle assessment system boundary identification (Conference Paper)

Afrinaldi, F., Zhang, H.-C., Carrell, J.

View additional authors

Save all to author list

[a]Department of Industrial Engineering, Texas Tech University, Lubbock, TX, United States
[b]Department of Industrial Engineering, Andalas University, Padang, Indonesia

View additional affiliations

Abstract

According to ISO standards life cycle assessment (LCA) consists of goal definition and scoping, inventory analysis, life cycle impact assessment and interpretation. In goal definition and scoping LCA system boundary is defined. Since LCA is time consuming then there is a need for a systematic approach to determine which processes needed to be included in the system boundary. This paper fulfills the need by proposing an improved binary linear programming model for LCA system boundary identification. The objective function of the model is to minimize the number of processes included in the system boundary and its constraints are the specified mass, energy and economic value ratios. In order to demonstrate its applicability an example is presented. A sensitivity analysis is also conducted in order to illustrate how the change in the specified mass, energy and economic value ratio will affect current optimum system boundary.
© 2013 IEEE.

SciVal Topic Prominence

Topic: Global Warming Potential | Cogeneration Plants | Power Markets

Prominence percentile: 35.090

Author keywords

LCA | linear programming | system boundary

Indexed keywords

Engineering controlled terms: ISO Standards | Linear programming | Sensitivity analysis

Engineering uncontrolled terms: Binary linear programming | Goal definitions | Inventory analysis | Life Cycle Assessment (LCA) | Life cycle impact assessment | Objective functions | Standards life cycles | System boundary

Engineering main heading: Life cycle

ISSN: 21573611
ISBN: 978-147990986-5
Source Type: Conference Proceeding
Original language: English
DOI: 10.1109/IEEM.2013.6962679
Document Type: Conference Paper
Publisher: IEEE Computer Society

© Copyright 2020 Elsevier B.V., All rights reserved.

About Scopus

What is Scopus
Content coverage
Scopus blog
Scopus API
Privacy matters

Language

日本語に切り替える
切换到简体中文
切換到繁體中文
Русский язык

Customer Service

Help
Contact us

ELSEVIER

Terms and conditions ↗ Privacy policy ↗

Copyright © Elsevier B.V ↗. All rights reserved. Scopus® is a registered trademark of Elsevier B.V.
We use cookies to help provide and enhance our service and tailor content. By continuing, you agree to the use of cookies.

RELX

IEEM 2013

THE IEEE INTERNATIONAL CONFERENCE ON
INDUSTRIAL ENGINEERING AND ENGINEERING MANAGEMENT

10 - 13 December 2013 Bangkok, Thailand | www.IEEM.org

IEEE

Proof of Attendance

Prepared for

Feri Afrinaldi
Texas Tech University

IEEM13-P-0176: An Improved Binary Linear Programming Approach for Life Cycle Assessment System Boundary Identification

Feri Afrinaldi[1], Hong-Chao Zhang[2], John Carrell[2]
[1]Texas Tech University, United States, Andalas University, Indonesia
[2]Texas Tech University, United States

MEETING MATTERS INTERNATIONAL PTE LTD

for Pakorn Adulbhan,

General Chair, Organizing Committee

December, 2013

Scanned with CamScanner

An Improved

by Feri Afrinaldi

Submission date: 24-Feb-2021 12:34PM (UTC+0800)

Submission ID: 1516768983

File name: programming_approach_for_LCA_system_boundary_identification.pdf (1.09M)

Word count: 3869

Character count: 16891

An Improved Binary Linear Programming Approach for Life Cycle Assessment System Boundary Identification

Feri Afrinaldi[1,2], Hong-Chao Zhang[1], John Carrell[1]
[1]Department of Industrial Engineering, Texas Tech University, Lubbock, Texas, USA
[2]Department of Industrial Engineering, Andalas University, Padang, Indonesia
(feri.afrinaldi@ttu.edu, hong-chao.zhang@ttu.edu, john.carrell@ttu.edu)

Abstract - **According to ISO standards life cycle assessment (LCA) consists of goal definition and scoping, inventory analysis, life cycle impact assessment and interpretation. In goal definition and scoping LCA system boundary is defined. Since LCA is time consuming then there is a need for a systematic approach to determine which processes needed to be included in the system boundary. This paper fulfills the need by proposing an improved binary linear programming model for LCA system boundary identification. The objective function of the model is to minimize the number of processes included in the system boundary and its constraints are the specified mass, energy and economic value ratios. In order to demonstrate its applicability an example is presented. A sensitivity analysis is also conducted in order to illustrate how the change in the specified mass, energy and economic value ratio will affect current optimum system boundary.**

Keywords - **LCA, linear programming, system boundary**

I. INTRODUCTION

As environmental awareness of the society increases, industries find that it is beneficial to produce environmental friendly products. In order to achieve this, the first step to do is to measure product's environmental impacts. One of the tools that can be used is life cycle assessment (LCA) which assesses environmental impacts of product from material extraction to end-of-life treatment. LCA consists of four phases: (1) goal definition and scoping, (2) inventory analysis, (3) life cycle impact assessment (LCIA) and (4) interpretation [1]. Furthermore, according to SAIC [2], in goal and scoping, system boundary of the LCA study is defined.

Tillman et al. [3] classified LCA system boundary into boundaries between the technological system and nature, geographical area, time horizon, capital goods and boundaries between the life cycle of the studied product and related life cycles. Other authors such as Guinée et al., as cited in [4], distinguished LCA system boundaries into boundaries between technical systems and the environment, between technological systems under study and other technological systems, and boundaries between significant and insignificant processes.

This paper focuses on boundaries between significant and insignificant processes. Since LCA is a time consuming process, in practice, there is a need for a systematic method to define which processes needed to be included or excluded in the LCA system boundary.

II. EXISTING APPROACHES FOR LCA SYSTEM BOUNDARY IDENTIFICATION

In ISO standards, the system boundary is defined through the following procedures [5]: (1) define an initial system boundary, (2) conduct sensitivity analysis, and (3) improve the system boundary by adding new unit processes shown to be significant by sensitivity analysis. According to Suh et al. [5] and Reynold et al. [6], this approach has practical difficulties because environmental impacts need to be quantified before system boundary is defined.

By considering the weakness of the guideline provided by the ISO standards, Reynolds et al. [6] proposed a method known as Relative Mass-Energy-Economic (RMEE) to help practitioners in defining LCA system boundary. The RMEE compares mass, energy and economic value ratios of a unit process to a parameter known as boundary cut-off ratio. However, in RMEE, the procedure needs to be done all over again if the boundary cut-off ratio changes [7].

Other methods in defining LCA system boundary can be found in Suh et al. [5] and Suh and Huppes [8]. Three methods are discussed by the authors, process analysis approach, economic input/output (I/O) approach and hybrid approach. Furthermore, the hybrid approach is distinguished into tiered hybrid, I/O based hybrid and I/O based hybrid [8].

The disadvantage of the process analysis approach is that it is limited to the processes included to the chosen system boundary therefore subjectivity is involved [5]. For the I/O LCA, since monetary value is used then price variability may distort physical flows within industrial sectors [5]. For the hybrid approach, according to [5], tiered hybrid approach has problem with double counting and integrated hybrid approach is time consuming. Furthermore, significant error may occur when significant processes are modeled by using the aggregated data available in I/O based hybrid approach [8].

The application of the optimization approach in defining the LCA system boundary can be found in Afrinaldi et al. [7]. The authors employed a binary linear programming model. Since the approach is an optimization technique then sensitivity analysis is easy to be done. However, this approach possesses several problems. The authors present two objective functions that can be selected by the analysts, (1) total number of processes minimization and (2) mass, energy and economic value ratios maximization, and one of the

978-1-4799-0986-5/13/$31.00 ©2013 IEEE

constraints is the budget constraint. It does not seem appropriate to include budget constraints in LCA because if particular processes have significant environmental impacts then they have to be included in the LCA study although much cost is needed to assess their impacts. Moreover, it is not necessary to maximize mass, energy and economic value ratios because those ratios are predetermined.

III. PROPOSED METHODOLOGY

This methodology improves the binary linear programming approach presented in Afrinaldi et al. [7]. Here, budget constraints are omitted. Specified mass, energy and economic value ratios are treated as the constraints. Consequently, only the total number of processes minimization is treated as the objective function. The use of mass, energy and economic value ratios in this paper and in Afrinaldi et al. [7] was based on Raynolds et al. [6]. Let us consider that $i = \{1, 2, 3\}$ represents life cycle stage of a product where 1 is material production, 2 is manufacturing and 3 is end-of-life treatment. The decision variables are defined as the following.

$x_j^{(i)}$ = The j^{th} process of life cycle stage *i*.

$x_{jk}^{(i)}$ = The k^{th} process of process *j*.

$x_{jkl}^{(i)}$ = The l^{th} process of process *jk*.

The value of the decision variables is binary as given by (1). An example of decision variable structure is presented in Fig. 1.

$$x_j^{(i)} = x_{jk}^{(i)} = x_{jkl}^{(i)} = \begin{cases} 1, & \text{if inside the boundary} \\ 0, & \text{if outside the boundary} \end{cases} \quad (1)$$

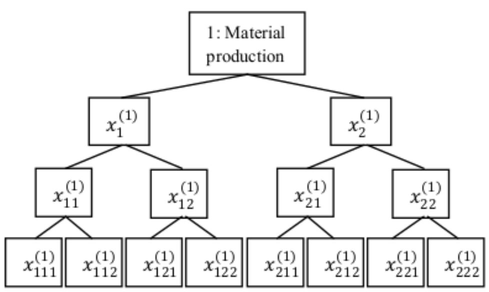

Fig. 1. An example of decision variable structure

As shown in decision variable definition and in Fig. 1, only processes with up to three subscripts are considered. This is done for simplification purpose. Furthermore, let us define the following.

α = Specified ratio of total mass flowing inside system boundary to total mass flowing inside product life cycle.

β = Specified ratio of total energy flowing inside system boundary to total energy flowing inside product life cycle.

γ = Specified ratio of total economic value of processes inside system boundary to total economic value of processes inside product life cycle.

$m_j^{(i)}$ = mass flowing in the j^{th} process of life cycle stage *i*.

$m_{jk}^{(i)}$ = mass flowing in the k^{th} process of process *j*.

$m_{jkl}^{(i)}$ = mass flowing in the l^{th} process of process *jk*.

$e_j^{(i)}$ = energy flowing in the j^{th} process of life cycle stage *i*.

$e_{jk}^{(i)}$ = energy flowing in the k^{th} process of process *j*.

$e_{jkl}^{(i)}$ = energy flowing in the l^{th} process of process *jk*.

$v_j^{(i)}$ = economic value of the j^{th} process of life cycle stage *i*.

$v_{jk}^{(i)}$ = economic value of the k^{th} process of process *j*.

$v_{jkl}^{(i)}$ = economic value of the l^{th} process of process *jk*.

The specified minimum mass, energy and economic value ratios are given by (2), (3) and (4).

$$\frac{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} m_j^{(i)} x_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} m_{jk}^{(i)} x_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} m_{jkl}^{(i)} x_{jkl}^{(i)}\right)}{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} m_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} m_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} m_{jkl}^{(i)}\right)} \geq \alpha \quad (2)$$

$$\frac{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} e_j^{(i)} x_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} e_{jk}^{(i)} x_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} e_{jkl}^{(i)} x_{jkl}^{(i)}\right)}{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} e_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} e_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} e_{jkl}^{(i)}\right)} \geq \beta \quad (3)$$

$$\frac{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} v_j^{(i)} x_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} v_{jk}^{(i)} x_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} v_{jkl}^{(i)} x_{jkl}^{(i)}\right)}{\left(\sum_{i=1}^{3}\sum_{j=1}^{J} v_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} v_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} v_{jkl}^{(i)}\right)} \geq \gamma \quad (4)$$

The binary linear programming model is given by the following.

$$Min \sum_{i=1}^{3}\sum_{j=1}^{J} x_j^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} x_{jk}^{(i)} + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} x_{jkl}^{(i)} \quad (5)$$

subject to

$$\sum_{j=1}^{J} x_j^{(i)} \le M \qquad \text{for } i = 1, 2, 3. \quad (6)$$

$$\sum_{j=1}^{J}\sum_{k=1}^{K} x_{jk}^{(i)} \le M x_{j'}^{(i)} \qquad \text{for } i = 1, 2, 3; \text{ for } j' = 1, 2, \ldots J. \quad (7)$$

$$\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} x_{jkl}^{(i)} \ge M x_{j'k'}^{(i)} \qquad \text{for } i = 1, 2, 3; \text{ for any combination of } j' \text{ and } k'; \; j' = 1, 2, \ldots J \text{ and } k' = 1, 2, \ldots K. \quad (8)$$

$$\left(\begin{array}{l} \sum_{i=1}^{3}\sum_{j=1}^{J} m_j^{(i)}\left(\alpha - x_j^{(i)}\right) + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} m_{jk}^{(i)}\left(\alpha - x_{jk}^{(i)}\right) \\ \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} m_{jkl}^{(i)}\left(\alpha - x_{jkl}^{(i)}\right) \end{array} \right) \le 0 \quad (9)$$

$$\left(\begin{array}{l} \sum_{i=1}^{3}\sum_{j=1}^{J} e_j^{(i)}\left(\beta - x_j^{(i)}\right) + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} e_{jk}^{(i)}\left(\beta - x_{jk}^{(i)}\right) \\ \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} e_{jkl}^{(i)}\left(\beta - x_{jkl}^{(i)}\right) \end{array} \right) \le 0 \quad (10)$$

$$\left(\begin{array}{l} \sum_{i=1}^{3}\sum_{j=1}^{J} v_j^{(i)}\left(\gamma - x_j^{(i)}\right) + \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K} v_{jk}^{(i)}\left(\gamma - x_{jk}^{(i)}\right) \\ \sum_{i=1}^{3}\sum_{j=1}^{J}\sum_{k=1}^{K}\sum_{l=1}^{L} v_{jkl}^{(i)}\left(\gamma - x_{jkl}^{(i)}\right) \end{array} \right) \le 0 \quad (11)$$

$$x_j^{(i)}, x_{jk}^{(i)}, x_{jkl}^{(i)}, x_{j'}^{(i)}, x_{j'k'}^{(i)} \in \{0,1\} \quad (12)$$

Note that (2), (3) and (4) are not linear. They are linearized by applying simple algebra and the results are (9), (10) and (11). Inequalities (6), (7) and (8) are linking constraints implying that if a particular process is selected than its parent process has to be selected too. This is done by introducing a variable denoted as M where its value at least has to be equal to upper bound of any sum of variables in the problem.

IV. NUMERICAL EXAMPLE

Let's assume that an LCA study is conducted to assess a product. The life cycle of the product is divided into three stages, material production, manufacturing and end-of-life treatment. Table I presents all processes inside the product's life cycle, the amount of mass flowing inside each process, the amount of energy flowing inside each process and the economic value of each process. Note that all values in Table I are per functional unit of the product. In order to conduct the study it is specified that $\alpha = \beta = \gamma = 0.90$. The objective is to define the system boundary of the study so that the specified requirements are met. Substituting the value of α, β, γ, mass, energy and economic values presented in Table I to the model, (5) to (12), yields the following binary linear programming model.

$$Min \;\; x_1^{(1)} + x_2^{(1)} + \cdots + x_{222}^{(3)}$$

subject

$$x_1^{(1)} + x_2^{(1)} \le M$$
$$x_1^{(2)} + x_2^{(2)} \le M$$
$$x_1^{(3)} + x_2^{(3)} \le M$$
$$x_{11}^{(1)} + x_{12}^{(1)} \le M x_1^{(1)}$$
$$x_{21}^{(1)} + x_{22}^{(1)} \le M x_2^{(1)}$$
$$x_{11}^{(2)} + x_{12}^{(2)} \le M x_1^{(2)}$$
$$x_{21}^{(2)} + x_{22}^{(2)} \le M x_2^{(2)}$$
$$x_{11}^{(3)} + x_{12}^{(3)} \le M x_1^{(3)}$$
$$x_{21}^{(3)} + x_{22}^{(3)} \le M x_2^{(3)}$$
$$x_{111}^{(1)} + x_{112}^{(1)} \le M x_{11}^{(1)}$$
$$x_{121}^{(1)} + x_{122}^{(1)} \le M x_{12}^{(1)}$$
$$x_{211}^{(1)} + x_{212}^{(1)} \le M x_{21}^{(1)}$$
$$x_{221}^{(1)} + x_{222}^{(1)} \le M x_{22}^{(1)}$$
$$x_{111}^{(2)} + x_{112}^{(2)} \le M x_{11}^{(2)}$$
$$x_{121}^{(2)} + x_{122}^{(2)} \le M x_{12}^{(2)}$$
$$x_{211}^{(2)} + x_{212}^{(2)} \le M x_{21}^{(2)}$$
$$x_{221}^{(2)} + x_{222}^{(2)} \le M x_{22}^{(2)}$$
$$x_{111}^{(3)} + x_{112}^{(3)} \le M x_{11}^{(3)}$$
$$x_{121}^{(3)} + x_{122}^{(3)} \le M x_{12}^{(3)}$$
$$x_{211}^{(3)} + x_{212}^{(3)} \le M x_{21}^{(3)}$$
$$x_{221}^{(3)} + x_{222}^{(3)} \le M x_{22}^{(3)}$$

$$\left(\begin{array}{l} 18.62\left(0.9 - x_1^{(1)}\right) + 8.97\left(0.9 - x_2^{(1)}\right) + \cdots + \\ 82.98\left(0.9 - x_{222}^{(3)}\right) \end{array} \right) \le 0$$

$$\left(\begin{array}{l} 14.92\left(0.9 - x_1^{(1)}\right) + 82.16\left(0.9 - x_2^{(1)}\right) + \cdots + \\ 98.18\left(0.9 - x_{222}^{(3)}\right) \end{array} \right) \le 0$$

$$\left(\begin{array}{l} 12.76\left(0.9 - x_1^{(1)}\right) + 63.55\left(0.9 - x_2^{(1)}\right) + \cdots + \\ 82.04\left(0.9 - x_{222}^{(3)}\right) \end{array} \right) \le 0$$

$$x_1^{(1)}, x_2^{(1)}, \cdots, x_{222}^{(3)} \in \{0,1\}$$

In order to solve the above binary linear programming problem $M = 100$ is applied. The optimum solution is that all processes are inside the system boundary except processes denoted as $x_{11}^{(1)}, x_{111}^{(1)}, x_{112}^{(1)}, x_{212}^{(1)}, x_{221}^{(1)}, x_{122}^{(1)}$ and $x_{222}^{(3)}$ which are equal to zero. Optimum objective function value of this solution is equal to 35 meaning that there are 35 processes inside the system boundary. This solution produces mass ratio = 0.908, energy ratio = 0.901 and economic value ratio = 0.90.

TABLE I
DATA FOR THE NUMERICAL EXAMPLE

Life cycle	Process	Mass	Energy	Economic value	Process	Mass	Energy	Economic value	Process	Mass	Energy	Economic value
Material Production $x^{(1)}$	$x^{(1)}_1$	18.62	14.92	12.76	$x^{(1)}_{11}$	1.16	57.35	5.56	$x^{(1)}_{111}$	4.71	2.77	1.26
									$x^{(1)}_{112}$	3.75	18.06	36.27
					$x^{(1)}_{12}$	20.84	92.23	5.01	$x^{(1)}_{121}$	55.51	80.11	66.71
									$x^{(1)}_{122}$	34.36	27.51	68.13
	$x^{(1)}_2$	8.97	82.16	63.55	$x^{(1)}_{21}$	95.02	78.00	18.61	$x^{(1)}_{211}$	11.48	68.76	48.42
									$x^{(1)}_{212}$	34.42	6.32	6.03
					$x^{(1)}_{22}$	64.60	40.41	90.77	$x^{(1)}_{221}$	10.63	6.78	43.75
									$x^{(1)}_{222}$	55.94	89.44	65.60
Manufacturing $x^{(2)}$	$x^{(2)}_1$	59.91	96.70	1.01	$x^{(2)}_{11}$	3.24	58.49	69.45	$x^{(2)}_{111}$	23.20	55.68	11.15
									$x^{(2)}_{112}$	48.31	74.48	46.60
					$x^{(2)}_{12}$	76.93	19.63	89.79	$x^{(2)}_{121}$	95.77	22.72	95.06
									$x^{(2)}_{122}$	98.22	59.21	52.37
	$x^{(2)}_2$	96.54	54.14	37.75	$x^{(2)}_{21}$	13.41	25.08	18.25	$x^{(2)}_{211}$	97.09	17.84	70.21
									$x^{(2)}_{212}$	71.56	64.70	18.37
					$x^{(2)}_{22}$	36.12	94.01	1.87	$x^{(2)}_{221}$	93.52	93.93	33.57
									$x^{(2)}_{222}$	90.69	67.61	62.82
End-of-life $x^{(3)}$	$x^{(3)}_1$	96.63	86.98	53.12	$x^{(3)}_{11}$	10.24	83.77	88.13	$x^{(3)}_{111}$	92.16	48.51	47.55
									$x^{(3)}_{112}$	44.78	63.45	73.41
					$x^{(3)}_{12}$	86.18	62.26	58.38	$x^{(3)}_{121}$	75.40	69.09	16.25
									$x^{(3)}_{122}$	65.72	46.44	11.27
	$x^{(3)}_2$	3.55	67.85	76.99	$x^{(3)}_{21}$	82.63	74.27	54.16	$x^{(3)}_{211}$	41.86	87.96	96.01
									$x^{(3)}_{212}$	78.31	16.67	59.22
					$x^{(3)}_{22}$	41.19	76.40	41.04	$x^{(3)}_{221}$	97.62	29.31	90.25
									$x^{(3)}_{222}$	82.98	98.18	82.04

V. SENSITIVITY ANALYSIS FOR THE NUMERICAL EXAMPLE

The purpose of the sensitivity analysis is to see how the change in the values of the specified mass ratio (α), energy ratio (β) and economic value ratio (γ) will affect current optimum system boundary. It is known that the closer the values of those parameters are to one the more processes are included in the system boundary. However the magnitude of the effect needs to be known. In order to see how the total number of processes inside system boundary changes the following approaches will be followed.

- One parameter will be varied from 0.9 to 1.0 and the other two parameters will be kept at 0.90, shown in Fig. 2.
- Two parameters will be varied from 0.9 to 1.0 and the other parameter will be kept at 0.9, shown in Fig. 3, 4 and 5.

Fig. 2 shows that all parameters have the same effect to the change in total number of processes included inside the system boundary if they are varied from 0.9 to 0.92. From 0.92 to 0.94 the change in β and γ has more effect to total number of processes inside the system boundary than the change in α. From 0.94 to 0.95, γ has the highest effect to total number of processes included inside the system boundary and is followed by β. The effect of β and γ stops at 0.95 because when β and γ are higher than 0.95 then there is no feasible solution for the problem. Furthermore, Fig. 2 shows that the highest effect to the change in total number of processes included inside the system boundary occurs when α is varied from 0.95 to 0.96. Finally the effect of α stops at $\alpha = 0.96$ because when $\alpha > 0.96$ there is no feasible solution for the problem.

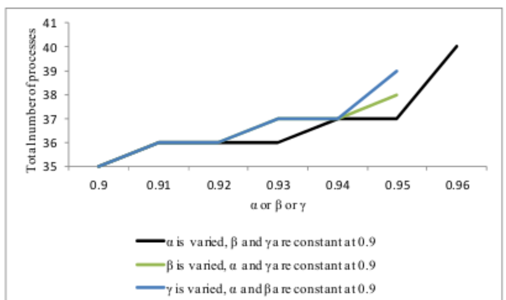

Fig. 2. Change in total number of processes inside system boundary when one parameter is varied one at a time

Fig. 3 shows that when α and β are simultaneously changed and economic value ratio γ is kept at 0.90 then the change in total number of processes included inside the system boundary increases from 36 to 40. From Fig. 3, it can be inferred that the total number of processes included inside the system boundary significantly increases when α increases from 0.95 to 0.96. The change in total number of processes included inside the system boundary when α and γ are simultaneously changed and β is kept at 0.90 is shown in Fig. 4. Fig. 4 shows that the minimum number of processes that can be achieved inside the system boundary is 35 and the highest number of processes inside the system boundary is 40. Similar to

Fig. 3, in Fig. 4 the total number of processes inside the system boundary significantly increases when α increases from 0.95 to 0.96. This result confirms Fig. 2.

Fig. 5 shows how total number of processes included inside the system boundary changes when β and γ are simultaneously changed and α is kept at 0.90. From the figure, it can be seen that the minimum and maximum number of processes obtained are 35 and 39 respectively. Fig. 5 also shows that the total number of processes increases gradually from 35 to 39.

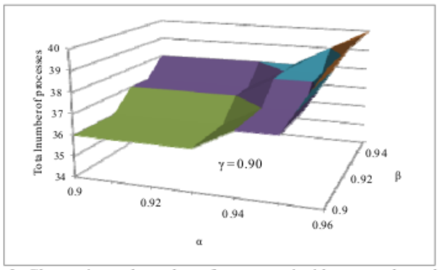

Fig. 3. Change in total number of processes inside system boundary when α and β are varied, $\gamma = 0.90$

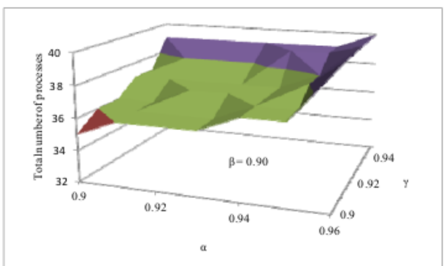

Fig. 4. Change in total number of processes inside system boundary when α and γ are varied, $\beta = 0.90$

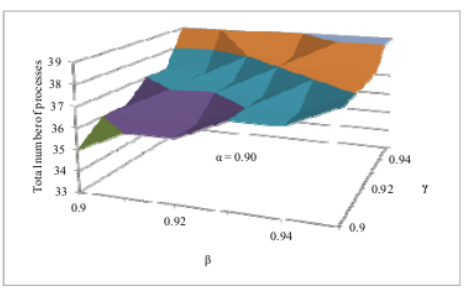

Fig. 5. Change in total number of processes inside system boundary when β and γ are varied, $\alpha = 0.90$

VI. DISCUSSION AND CONCLUSION

This paper presents an improved binary linear programming approach for LCA system boundary identification. The main contribution of this work is that it provides an alternative methodology in determining which unit processes are to be included or excluded in an LCA study system boundary. According to [6], LCA system boundary selection method should be quantitative and repeatable, simple, reflect the significant of input/output relative to the system as a whole. The propose approach satisfies these criteria. However it also posses some limitations: (1) similar to the process analysis approach, the unit processes included in the model are limited within the chosen system boundary and (2) the propose method cannot reflect the environmental significant of the unit processes since only mass, energy and economic ratios are used in the model. By considering the above strength and weaknesses, for future research, it is suggested that before the optimization approach is conducted, a systematic approach is utilized in order to determine unit processes included in the model. It is seemed that the I/O LCA approach has potential for this purpose.

REFERENCES

[1] ISO 14041, *Environmental Management - Life Cycle Assessment - Goal and Scope Definition and Inventory Analysis*, International Organization for Standardization, 1998.

[2] SAIC: Scientific applications international corporation, *Life cycle assessment: principle and practice*, National Risk Management Research Laboratory Office of Research and Development and U.S. Environmental Protection Agency, Cincinntai, OH, USA, 2006.

[3] Tillman, A. M., Ekvall, T., Baumann, H., Rydberg, T., "Choice of System Boundary in Life Cycle Assessment", *Journal of Cleaner Production*, vol. 2, no. 1, pp. 21 – 29, 1994.

[4] Finveden, G., Hauschild, M. Z., Ekvall, T., Guinée, J., Heijungs, R., Hellweg, S., Koehler, A., Pennington, D., Suh, S., "Recent Development in Life Cycle Assessment", *Journal of Environmental Management*, vol. 91, pp. 1-21, 2009.

[5] Suh, S., Lenzen, M., Treloar, G. J., Hondo, H., Horvath, A., Huppes, G., Jolliet, O., Klann, U., Krewitt, W., Moriguchi, Y., Munksgaard, J., Norris, G., "System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches", *Environmental Science & Technology*, vol. 38, no. 3, pp. 657-664, 2004.

[6] Raynolds, M., Fraser, R., Checkel, D., "The Relative Mass-Energy-Economic (RMEE) Method for System Boundary Selection", *International Journal of Life Cycle Assessment*, vol. 5, no. 1, pp. 37 – 46, 2000.

[7] Afrinaldi, F., Zhang, H-C., Carrel, J., "A Binary Linear Programming Approach for LCA System Boundary Identification", *in Proc. 20th CIRP International Conference on Life Cycle Engineering*, pp. 435-440, Singapore, 2013.

[8] Suh, S., Huppes, G., "Methods for Life Cycle Inventory of a Product", *Journal of Cleaner Production, vol. 13, no. 1*, pp. 687-697, 2005.

An Improved

ORIGINALITY REPORT

15%	9%	13%	0%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	"Re-engineering Manufacturing for Sustainability", Springer Nature, 2013 Publication	3%
2	www.depts.ttu.edu Internet Source	1%
3	Sangwon Suh, Manfred Lenzen, Graham J. Treloar, Hiroki Hondo et al. "System Boundary Selection in Life-Cycle Inventories Using Hybrid Approaches", Environmental Science & Technology, 2004 Publication	1%
4	uir.unisa.ac.za Internet Source	1%
5	Marlene Arangú, Miguel Salido. "A fine-grained arc-consistency algorithm for non-normalized constraint satisfaction problems", International Journal of Applied Mathematics and Computer Science, 2011 Publication	1%

"Tools and Algorithms for the Construction and

6	Analysis of Systems", Springer Science and Business Media LLC, 2007 Publication	1%
7	scholarsmine.mst.edu Internet Source	1%
8	Graham J. Treloar, Peter E.D. Love, Gary D. Holt. "Using national input/output data for embodied energy analysis of individual residential buildings", Construction Management and Economics, 2001 Publication	<1%
9	Marlo Raynolds, Roydon Fraser, David Checkel. "The Relative Mass-Energy-Economic (RMEE) Method for System Boundary Selection", The International Journal of Life Cycle Assessment, 2000 Publication	<1%
10	"Software Technologies for Embedded and Ubiquitous Systems", Springer Science and Business Media LLC, 2009 Publication	<1%
11	www.overleaf.com Internet Source	<1%
12	learningwitherrors.org Internet Source	<1%
13	Parosh Aziz Abdulla, Aletta Nylén. "Chapter 5	

Timed Petri Nets and BQOs", Springer Science and Business Media LLC, 2001
Publication

<1%

14	ascelibrary.org Internet Source	<1%
15	www.dsa.unipr.it Internet Source	<1%
16	citeseerx.ist.psu.edu Internet Source	<1%
17	Nan Zhang, Ellen Townes-Anderson. "Regulation of Structural Plasticity by Different Channel Types in Rod and Cone Photoreceptors", The Journal of Neuroscience, 2002 Publication	<1%
18	link.springer.com Internet Source	<1%
19	worldwidescience.org Internet Source	<1%
20	www.irbnet.de Internet Source	<1%
21	A. N. Nedashkovska. "Solving polynomial nonlinear matrix equations by a linearization method", Cybernetics and Systems Analysis, 2006 Publication	<1%

22	openaccess.leidenuniv.nl Internet Source	<1%
23	silo.tips Internet Source	<1%
24	jp1.estis.net Internet Source	<1%
25	Li, Hua, Hong Chao Zhang, John Carrell, and Derrick Tate. "Use of an energy-saving concept to assess life-cycle impact in engineering", International Journal of Sustainable Manufacturing, 2010. Publication	<1%
26	caafi.org Internet Source	<1%
27	minerva-access.unimelb.edu.au Internet Source	<1%
28	es.scribd.com Internet Source	<1%
29	amsdottorato.unibo.it Internet Source	<1%
30	fr.scribd.com Internet Source	<1%
31	mafiadoc.com Internet Source	<1%

32	elib.uni-stuttgart.de Internet Source	<1%
33	Marlo Raynolds. "The relative mass-energy-economic (RMEE) method for system boundary selection Part 1: A means to systematically and quantitatively select LCA boundaries", The International Journal of Life Cycle Assessment, 01/2000 Publication	<1%
34	Rebitzer, G.. "Life cycle assessment", Environment International, 200407 Publication	<1%

Exclude quotes	On	Exclude matches	Off
Exclude bibliography	On		