# Procedia CIRP

Affiliated with CIRP (http://www.cirp.net) , The International Academy for Production Engineering

Open Access

ISSN: **2212-8271**

Guide for Authors

Submit Your Paper

Track Your Paper

View Articles

## Stay up-to-date

Register your interests and receive email alerts tailored to your needs
Click here to sign up (http://www.elsevier.com/PreferenceCentre)

*What is Procedia CIRP?*

Procedia CIRP is an open access product focusing entirely on publishing high quality proceedings from CIRP conferences, enabling fast dissemination so that conference delegates can publish their papers in a dedicated online issue on ScienceDirect. *Procedia CIRP* is indexed in the EI Compendex and Scopus databases.

Procedia CIRP will publish papers from CIRP and CIRP-sponsored conferences. Conferences should be relevant to an international audience and cover timely topics.

*Copyright information*
For authors publishing in Procedia CIRP, accepted manuscript will be governed by CC BY-NC-ND. For further details see our copyright information. *How are conferences evaluated for inclusion in Procedia CIRP?*

Conference proceedings are accepted for publication in Procedia CIRP based on suitability of scope and are required to meet certain criteria, including the assurance that all papers are original, will be subject to peer review and will not be published elsewhere.

Please note, only conferences of CIRP, or officially CIRP sponsored conferences are able to be published in Procedia CIRP.

*What is the process for submitting conference proceedings to Procedia CIRP?*

The conference organizer should contact the CIRP office who will confirm the conference's relationship with CIRP and forward the details to the relevant person within Elsevier. The conference name and date, organizer name, as well as the expected number of pages and desired date for the proceedings to appear online should be included in this message if possible.

Hide full aims and scope +

This journal supports the following content innovations

- Interactive Plot Viewer (https://www.elsevier.com/books-and-journals/content-innovation/iplots)

## Stay up-to-date

Register your interests and receive email alerts tailored to your needs
Click here to sign up (http://www.elsevier.com/PreferenceCentre)

## Most Downloaded Articles (http://www.journals.elsevier.com/procedia-cirp/most-downloaded-articles/)

The most downloaded articles from Procedia CIRP in the last 90 days.

1. Green Supply Chain Management, Environmental Collaboration and Sustainability Performance (http://www.sciencedirect.com/science/article/pii/S2212827114008488)
   Thoo Ai Chin | Huam Hon Tat | ...
2. Service Innovation and Smart Analytics for Industry 4.0 and Big Data Environment (http://www.sciencedirect.com/science/article/pii/S2212827114000857)
   Jay Lee | Hung-An Kao | ...
3. Review of Electrochemical and Electrodischarge Machining (http://www.sciencedirect.com/science/article/pii/S2212827113000760)
   K.P. Rajurkar | M.M. Sundaram | ...

View all

## Conferences (http://www.journals.elsevier.com/procedia-cirp/conferences/)

6th CIRP Conference on Assembly Technologies and Systems (http://www.journals.elsevier.com/procedia-cirp/conferences/6th-cirp-conference-on-assembly-technologies-and-systems/)

14th CIRP Conference on Computer Aided Tolerancing - CAT 2016 (http://www.journals.elsevier.com/procedia-cirp/conferences/14th-cirp-conference-on-computer-aided-tolerancing-cat-2016/)

23rd CIRP Conference on Life Cycle Engineering (http://www.journals.elsevier.com/procedia-cirp/conferences/23rd-cirp-conference-on-life-cycle-engineering/)

View all

## Recent Articles (http://www.journals.elsevier.com/procedia-cirp/recent-articles/)

Recently published articles from Procedia CIRP.

Structured Innovation with TRIZ in Science and Industry - Creating Value for Customers and Society (http://www.sciencedirect.com/science/article/pii/S2212827116000482)
Iouri Belski | Pavel Livotov | ...

Modelling Constraints in the Conceptual Design Process with TRIZ and F3 (http://www.sciencedirect.com/science/article/pii/S2212827116000494)
Khairul Manami Kamarudin | Keith Ridgway | ...

Value Stream Analysis for Complex Processes and Systems (http://www.sciencedirect.com/science/article/pii/S2212827116000500)
Teemu Toivonen | Juha Siitonen

View all



## Most Cited Articles (http://www.journals.elsevier.com/procedia-cirp/most-cited-articles/)

The most cited articles published since 2011, extracted from Scopus (http://www.scopus.com) .

1. Review of electrochemical and electrodischarge machining (http://www.scopus.com/inward/record.url?partnerID=HzOxMe3b&scp=84883890602&origin=inward)
   K. P. Rajurkar | M. M. Sundaram | ...
2. Technological and economical comparison of roughing strategies via milling, EDM and ECM for titanium-and nickel-based blisks (http://www.scopus.com/inward/record.url?partnerID=HzOxMe3b&scp=84875225156&origin=inward)
   F. Klocke | M. Zeis | ...
3. Designing for additive manufacturing (http://www.scopus.com/inward/record.url?partnerID=HzOxMe3b&scp=84879193125&origin=inward)
   B. Vayre | F. Vignat | ...

View all

## Special Issues (http://www.journals.elsevier.com/procedia-cirp/special-issues/)

Special issues published in Procedia CIRP.

Structured Innovation with TRIZ in Science and Industry: Creating Value for Customers and Society (http://www.sciencedirect.com/science/journal/22128271/39)
Volume 39 (2016)
Iouri Belski

Proceedings of the 4th International Conference on Through-life Engineering Services (http://www.sciencedirect.com/science/journal/22128271/38)
Volume 38 (2015)
Rajkumar Roy | Ashutosh Tiwari | ...

CIRP 25th Design Conference Innovative Product Creation (http://www.sciencedirect.com/science/journal/22128271/36)
Volume 36 (2015)
Moshe Shpitalni | Anath Fischer | ...

View all


Procedia CIRP

Readers

View Articles (http://www.sciencedirect.com/science/journal/22128271)

User rights (http://www.elsevier.com/journals/procedia-cirp/2212-8271/user-rights)

Volume/ Issue Alert (http://www.sciencedirect.com/science/alerts)

Authors (http://www.elsevier.com/authors/home)

Author Information Pack (http://www.elsevier.com/journals/procedia-cirp/2212-8271?generatepdf=true)

Submit Your Paper (http://ees.elsevier.com/procir/)

Track Your Paper (http://help.elsevier.com/app/answers/detail/a_id/89/p/8045/)

Early Career Resources (http://www.elsevier.com/early-career-researchers/training-and-workshops)

Librarians (http://www.elsevier.com/librarians/home)

Abstracting/ Indexing (http://www.elsevier.com/journals/procedia-cirp/2212-8271/abstracting-indexing)

Editors (http://www.elsevier.com/editors/home)

Guest Editor Guide (http://1.elscdn.net/promis_misc/Procedia CIRP_Guest Editor Guide.pdf)

FTP Guide (http://1.elscdn.net/promis_misc/How to upload files to Elsevier FTP.pdf)

Guest Editor EES Instructions (http://1.elscdn.net/promis_misc/procir-guidelines-for-guest-editor-role.pdf)

Guest Editors (http://www.elsevier.com/editors/guest-editors)

Publishing Ethics Resource Kit (http://www.elsevier.com/editors/perk)

EES Support (http://elsevier6.custhelp.com/app/answers/list/p/8045)

Reviewers (http://www.elsevier.com/reviewers/home)

Login as Reviewer (http://ees.elsevier.com/procir/default.asp?pg=login.asp)

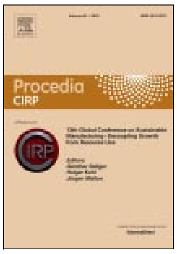
Reviewer Guidelines (https://www.elsevier.com/reviewersguidelines)

Advertisers/ Sponsors (http://www.elsevier.com/advertisers/home)

Advertisers Media Information (http://www.elsevier.com/05153700)

Societies (http://www.elsevier.com/societies/home)

Back to top



# Procedia CIRP

Open Access | About this Journal | Submit your Article

Get new article feed
Subscribe to new volume alerts
Add to Favorites

CIRP



Procedia CIRP
Volume 40, Pages 1-716 (2016)
13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use
Edited by Günther Seliger, Holger Kohl and Jürgen Mallon

< Previous vol/iss | Next vol/iss >

Volume 41 (2016)

Volumes 31 - 40 (2015 - 2016)

Volume 40
pp. 1-716 (2016)
13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use

Volume 39
pp. 1-230 (2016)
Structured Innovation with TRIZ in Science and Industry: Creating Value for Customers and Society

Volume 38
pp. 1-288 (2015)
Proceedings of the 4th International Conference on Through-life Engineering Services

Volume 37
pp. 1-270 (2015)
CIRPe 2015 - Understanding the life cycle implications of manufacturing

Volume 36
pp. 1-290 (2015)
CIRP 25th Design Conference Innovative Product Creation

Volume 35
pp. 1-100 (2015)
MIC2015 – 15th Machining Innovations Conference for Aerospace Industry

Volume 34
pp. 1-284 (2015)
9th International Conference on Axiomatic Design (ICAD 2015)

Volume 33
pp. 1-598 (2015)
9th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '14

Volume 32
pp. 1-156 (2015)
5th Conference on Learning Factories

Volume 31
pp. 1-568 (2015)
15th CIRP Conference on Modelling of Machining Operations (15th CMMO)

Volumes 21 - 30 (2014 - 2015)

Volumes 11 - 20 (2013 - 2014)

Volumes 1 - 10 (2012 - 2013)

< Previous vol/iss | Next vol/iss >

No prev art. 1 - 100 of 122 Next ▸

Download PDFs | Export | Open Access articles

## Session 1: Processes

Utilization of Thermal Energy to Compensate Quasi-static Deformations in Modular Machine Tool Frames Original Research Article — Open Access
*Pages 1-6*
Eckart Uhlmann, Mihir Saoji, Bernd Peukert
Abstract | PDF (254 K)

The Adoption of Additive Manufacturing Technology in Sweden Original Research Article — Open Access
*Pages 7-12*
Babak Kianian, Sam Tavassoli, Tobias C. Larsson, Olaf Diegel
Abstract | PDF (254 K)

Using Sustainable Manufacturing Process to Produce Solid Shaft from Al - Zn Alloys Chips and Copper Chips without Melting Original Research Article — Open Access
*Pages 13-17*
Ahmad K. Jassim
Abstract | PDF (429 K)

Challenges and Approaches for a Continuous Cable Production Original Research Article — Open Access
*Pages 18-23*
Mustafa Severengiz, Tobias Sprenger, Günther Seliger
Abstract | PDF (353 K)

The Challenges for Energy Efficient Casting Processes Original Research Article — Open Access
*Pages 24-29*
Konstantinos Salonitis, Binxu Zeng, Hamid Ahmad Mehrabi, Mark Jolly
Abstract | PDF (202 K)

A Novel Technique to Achieve Sustainable Machining System Original Research Article — Open Access
*Pages 30-34*
Rakesh Kumar Gunda, Narala Suresh Kumar Reddy, H.A. Kishawy
Abstract | PDF (287 K)

## Session 2: Energy

Contribution to Exemplary In-House Wastewater Heat Recovery in Berlin, Germany Original Research Article — Open Access
*Pages 35-40*
Samir Alnahhal, Ernesto Spremberg
Abstract | PDF (471 K)

Analysis of Prospects of Using Solar Energy in Russian Federation Economy Original Research Article — Open Access
*Pages 41-45*
Lyudmila Serga, Ekaterina Chemezova, Elena Makaridina, Nataliya Samotoy
Abstract | PDF (302 K)

Greenhouse Gas Emission from Freight Transport-Accounting for the Rice Supply Chain in Vietnam Original Research Article — Open Access
*Pages 46-49*
N.T. Binh, V.A. Tuan
Abstract | PDF (210 K)

Keeping a Factory in an Energy-optimal State Original Research Article — Open Access
*Pages 50-55*
Sylvia Wahren, Eduardo Colangelo, Alexander Sauer, Jörg Mandel, Jörg Siegert

Abstract | PDF (226 K)

Adaptation of Biomass Based Thermal Energy Generation of Sri Lankan Manufacturing Sector: Paragon for Policy Development Original Research Article — Open Access
*Pages 56-61*
Supun S. Punchihewa, Chanjief Chandrakumar, Asela K. Kulatunga
Abstract | PDF (173 K)

Analysis of Energy Utilization in 3D Printing Processes Original Research Article — Open Access
*Pages 62-67*
Tao Peng
Abstract | PDF (121 K)

## Session 3: Life Cycle

Contribution for Product Analyses to Quantify and Predict Similar or Diverse Eco-related Product Perception in the Usage Phase Original Research Article — Open Access
*Pages 68-72*
Stefan Bracke, Christoph Rosebrock
Abstract | PDF (274 K)

Rice Husk Based Bioelectricity vs. Coal-fired Electricity: Life Cycle Sustainability Assessment Case Study in Vietnam Original Research Article — Open Access
*Pages 73-78*
Le Quyen Luu, Anthony Halog
Abstract | PDF (62 K)

Quantitative Analysis of Material Flow of Used Mobile Phones in Japan Original Research Article — Open Access
*Pages 79-84*
Kimitaka Sugiyama, Osamu Honma, Nozomu Mishima
Abstract | PDF (295 K)

Dynamic Modularization throughout System Lifecycle Using Multilayer Design Structure Matrices Original Research Article — Open Access
*Pages 85-90*
Shraga Shoval
Abstract | PDF (196 K)

Adapting Ergonomic Assessments to Social Life Cycle Assessment Original Research Article — Open Access
*Pages 91-96*
Ya-Ju Chang, The Duy Nguyen, Matthias Finkbeiner, Jörg Krüger
Abstract | PDF (106 K)

Environmentally Sound Desludging Concept for Hoan Kiem Lake in Hanoi Vietnam Original Research Article — Open Access
*Pages 97-102*
Le Hung Anh, Celia Hahn, Peter Werner, Dang Dinh Kim, Christian Richter, Frank Panning, Lothar Paul, Leonhard Fechter
Abstract | PDF (376 K)

Technological Elements of Circular Economy and the Principles of 6R-Based Closed-loop Material Flow in Sustainable Manufacturing Original Research Article — Open Access
*Pages 103-108*
I.S. Jawahir, Ryan Bradley
Abstract | PDF (826 K)

## Session 4: Processes

Energy-efficiency in a Hybrid Process of Sheet Metal Forming and Polymer Injection Moulding Original Research Article — Open Access
*Pages 109-114*
D. Landgrebe, V. Kräusel, A. Rautenstrauch, A. Albert, R. Wertheim
Abstract | PDF (394 K)

Application of Modal Analysis for Commissioning of Drives on Machine Tools Original Research Article — Open Access
*Pages 115-120*
T.D. Tran, H. Schlegel, R. Neugebauer
Abstract | PDF (377 K)

Achieving Environmental Performance through Design for Environment (DFE) Process in Foundry Operations Original Research Article — Open Access
*Pages 121-126*
Ignatio Madanhire, Charles Mbohwa
Abstract | PDF (318 K)

Sustainable Welding Process Selection Based on Weight Space Partitions Original Research Article — Open Access
*Pages 127-132*
Gunther Sproesser, Sebastian Schenker, Andreas Pittner, Ralf Borndörfer, Michael Rethmeier, Ya-Ju Chang, Matthias Finkbeiner

Abstract | PDF (155 K)

Single Roll Melt Spinning Technique Applied as a Sustainable Forming Process to Produce Very Thin Ribbons of 5052 and 5083 Al-Mg Alloys Directly from Liquid State Original Research Article — Open Access
*Pages 133-137*
Ahmad K. Jassim, Ali S. Hammood
Abstract | PDF (625 K)

Measurement and Analysis of Surface Roughness in $WS_2$ Solid Lubricant Assisted Minimum Quantity Lubrication (MQL) Turning of Inconel 718 Original Research Article — Open Access
*Pages 138-143*
Uma Maheshwera Reddy Paturi, Yesu Ratnam Maddu, Ramalinga Reddy Maruri, Suresh Kumar Reddy Narala
Abstract | PDF (211 K)

## Session 5: End of Life

A Decision Support Tool for Product Design for Remanufacturing Original Research Article — Open Access
*Pages 144-149*
S.S. Yang, S.K. Ong, A.Y.C. Nee
Abstract | PDF (141 K)

Sustainability Assessment of Remanufactured Computers Original Research Article — Open Access
*Pages 150-155*
Yun Arifatul Fatimah, Wahidul Karim Biswas
Abstract | PDF (206 K)

Towards a Sustainable Disassembly/Dismantling in Aerospace Industry Original Research Article — Open Access
*Pages 156-161*
Mahdi Sabaghi, Yongliang Cai, Christian Mascle, Pierre Baptiste
Abstract | PDF (150 K)

Analysis of Environmental and Economic Disassembly Parts Selection by Goal Programming Original Research Article — Open Access
*Pages 162-167*
Yuki Kinoshita, Tetsuo Yamada, Surendra M. Gupta, Aya Ishigaki, Masato Inoue
Abstract | PDF (174 K)

Advanced Airframe Disassembly Alternatives; An Attempt to Increase the Afterlife Value Original Research Article — Open Access
*Pages 168-173*
Hamidreza Zahedi, Christian Mascle, Pierre Baptiste
Abstract | PDF (123 K)

Add-on Error Compensation Unit as Sustainable Solution for Outdated Milling Machines Original Research Article — Open Access
*Pages 174-178*
K. Kianinejad, S. Thom, S. Kushwaha, E. Uhlmann
Abstract | PDF (224 K)

## Session 6: Life Cycle

Contribution for Analysing, Saving and Prioritising of Lessons Learned Issues Regarding Product Improvement and Future Product Generations Original Research Article — Open Access
*Pages 179-184*
Stefan Bracke, Masato Inoue, Berna Ulutas
Abstract | PDF (118 K)

The Effect of Consumer Behaviour on the Life Cycle Assessment of Energy Efficient Lighting Technologies Original Research Article — Open Access
*Pages 185-190*
Zhe Ying Yu, Vi Kie Soo, Matthew Doolan
Abstract | PDF (151 K)

The Development of a Sustainable Resort and Indicators Original Research Article — Open Access
*Pages 191-196*
Komet Kulkajonplun, Vorapoch Angkasith, Dhiranantha Rithmanee
Abstract | PDF (239 K)

Condition Monitoring of Rack and Pinion Drive Systems: Necessity and Challenges in Production Environments Original Research Article — Open Access
*Pages 197-201*
Christopher Ehrmann, Philippe Isabey, Jürgen Fleischer
Abstract | PDF (383 K)

Life Cycle Assessment Tool in Product Development: Environmental Requirements in Decision Making Process Original Research Article — Open Access
*Pages 202-208*
Rossella Luglietti, Paolo Rosa, Sergio Terzi, Marco Taisch
Abstract | PDF (277 K)

Environmental Impact Analysis of Primary Aluminium Production at Country Level Original Research Article — Open Access
*Pages 209-213*
Dimos Paraskevas, Karel Kellens, Alexander Van de Voorde, Wim Dewulf, Joost R Duflou
Abstract | PDF (309 K)

### Session 7: ICT

Factory Eco-Efficiency Modelling: Framework Application and Analysis Original Research Article — Open Access
*Pages 214-219*
Aanand Davé, Konstantinos Salonitis, Peter Ball, Mark Adams, David Morgan
Abstract | PDF (344 K)

Cloud Management Tools for Sustainable SMEs Original Research Article — Open Access
*Pages 220-224*
Luis Rocha, Andrés Gomez, Nuno Araújo, Carmen Otero, David Rodrigues
Abstract | PDF (359 K)

Enterprise Resource Planning (ERP) in Improving Operational Efficiency: Case Study Original Research Article — Open Access
*Pages 225-229*
Ignatio Madanhire, Charles Mbohwa
Abstract | PDF (237 K)

New Method for the Development of Sustainable STEP-Compliant Open CNC System Original Research Article — Open Access
*Pages 230-235*
Kamran Latif, Yusri Yusof
Abstract | PDF (337 K)

Online Fault-monitoring in Machine Tools Based on Energy Consumption Analysis and Non-invasive Data Acquisition for Improved Resource-efficiency Original Research Article — Open Access
*Pages 236-243*
Soner Emec, Jörg Krüger, Günther Seliger
Abstract | PDF (339 K)

Energy Supply Orientation in Production Planning Systems Original Research Article — Open Access
*Pages 244-249*
Fabian Keller, Gunther Reinhart
Abstract | PDF (297 K)

### Session 8: End of Life

Business Models for Sustainability: The Case of Second-life Electric Vehicle Batteries Original Research Article — Open Access
*Pages 250-255*
Na Jiao, Steve Evans
Abstract | PDF (285 K)

Evolutionary in Solid State Recycling Techniques of Aluminium: A review Original Research Article — Open Access
*Pages 256-261*
Shazarel Shamsudin, MA Lajis, Z.W. Zhong
Abstract | PDF (124 K)

An Integrated Approach for Product Remanufacturing Assessment and Planning Original Research Article — Open Access
*Pages 262-267*
H.C. Fang, S.K. Ong, A.Y.C. Nee
Abstract | PDF (230 K)

Life Cycle Assessment of Filtration Systems of Reverse Osmosis Units: A Case Study of a University Campus Original Research Article — Open Access
*Pages 268-273*
Vikrant Bhakar, D.N.S. Hemanth Kumar, Nitin Krishna Sai, Kuldip Singh Sangwan, Smita Raghuvanshi
Abstract | PDF (277 K)

A Study on Separating Characteristics of Metals towards Remote Recycling Original Research Article — Open Access
*Pages 274-279*
Jun Oki, Kenta Torihara, Yuta Kadowaki, Nozomu Mishima
Abstract | PDF (458 K)

Comparative Analysis on Cross-national System to Enhance the Reliability of Remanufactured Products Original Research Article — Open Access
*Pages 280-284*
Hong-Yoon Kang, Yong-Sung Jun, Young-Chun Kim, Hyun-Jung Jo
Abstract | PDF (93 K)

### Session 9: Supply Chain

Feasibility of Cleaner Production for Vietnam Rice Processing Industry Original Research Article — Open Access
*Pages 285-288*
Tran Quoc Cong, Do Ngoc Hien
Abstract | PDF (279 K)

Optimizing Facility Location Decisions Considering Health Impact on Local Population Original Research Article — Open Access
*Pages 289-294*
Thi Truong Nguyen, Sun Olapiriyakul
Abstract | PDF (380 K)

Topological Complexity Measures of Supply Chain Networks Original Research Article — Open Access
*Pages 295-300*
Vladimir Modrak, Slavomir Bednar
Abstract | PDF (284 K)

Incorporate LEAN and Green Concepts to Enhance the Productivity of Transshipment Terminal Operations Original Research Article — Open Access
*Pages 301-306*
Chanjief Chandrakumar, Jeyanthinathasarma Gowrynathan, Asela K. Kulatunga, Nadarasa Sanjeevan
Abstract | PDF (516 K)


## Session 10: Strategies


Consideration of Market Demand Volatility Risks, when Making Manufacturing System Investments Original Research Article — Open Access
*Pages 307-311*
Anders Johansson, Lars Pejryd, Linn Gustavsson Christiernin
Abstract | PDF (275 K)

Sustainable Urban Mobility through the Perspective of Overcompliance Original Research Article — Open Access
*Pages 312-317*
Mehmet Çağrı Köse, Jón Garðar Steingrímsson, Julia Schmid, Roel van Veldhuizen, Dorothea Kübler, Günther Seliger
Abstract | PDF (256 K)

Application of 6R Principles in Sustainable Supply Chain Design of Western Australian White Goods Original Research Article — Open Access
*Pages 318-323*
Chloe Rosenthal, Yun Arifatul Fatimah, Wahidul K. Biswas
Abstract | PDF (159 K)

Clusterization Economy as a Way to Build Sustainable Development of the Region Original Research Article — Open Access
*Pages 324-328*
Vladimir Glinskiy, Lyudmila Serga, Ekaterina Chemezova, Kirill Zaykov
Abstract | PDF (103 K)

Decision Support System for Industrial Social Performance Original Research Article — Open Access
*Pages 329-334*
Ahmed Abu Hanieh, Sadiq AbdElall, Afif Hasan
Abstract | PDF (273 K)

Integrated Evaluation System for the Strategic Management of Innovation Initiatives in Manufacturing Industries Original Research Article — Open Access
*Pages 335-340*
H. Kohl, R. Orth, O. Riebartsch, F. Hecklau
Abstract | PDF (315 K)


## Session 11: Awareness


Sustainable Manufacturing in Vietnamese Engineering Education – Approaches from the Vietnamese-German University Original Research Article — Open Access
*Pages 341-346*
Carsten Reise, Luan Phan
Abstract | PDF (219 K)

A Comparison of Obstacles in Emerging and Developed Nation Dry Waste Recovery Original Research Article — Open Access
*Pages 347-352*
Brendan Moloney, Matthew Doolan
Abstract | PDF (137 K)

Simulation-games for Learning Conducive Workplaces: A Case Study for Manual Assembly Original Research Article — Open Access
*Pages 353-358*
Bastian C. Müller, Carsten Reise, Bui Minh Duc, Günther Seliger
Abstract | PDF (329 K)

How to Awareness Make People Make a Change – Using Social Labelling for Raising — Open Access

Sustainable Manufacturing on Original Research Article
Pages 359-364
M.A. Ina Roeder, M.A. Matthias Scheibleger, Rainer Stark
Abstract | PDF (269 K)

Competencies to Move beyond Eco-efficiency Original Research Article — Open Access
Pages 365-371
Lloyd Fernando, Steve Evans
Abstract | PDF (202 K)

Manufacturing Resilience via Inventory Management for Domestic Food Waste Original Research Article — Open Access
Pages 372-377
E. Woolley, G. Garcia-Garcia, R. Tseng, S. Rahimifard
Abstract | PDF (313 K)

## Session 12: Technology

Supporting Manufacturing Technology Definition through Multi-level Resource Consumption Analysis Original Research Article — Open Access
Pages 378-383
Dirk Bähre, Martin Swat, Kirsten Trapp, Michael Vielhaber
Abstract | PDF (298 K)

Online on-board Optimization of Cutting Parameter for Energy Efficient CNC Milling Original Research Article — Open Access
Pages 384-389
Nikolaos Tapoglou, Jörn Mehnen, Jevgenijs Butans, Nicolau Iralal Morar
Abstract | PDF (433 K)

A Heuristic Approach to Schedule Mobile Robots in Flexible Manufacturing Environments Original Research Article — Open Access
Pages 390-395
Quang-Vinh Dang, Lam Nguyen
Abstract | PDF (216 K)

Simulation-based Assessment and Optimization of the Energy Consumption in Multi Variant Production Original Research Article — Open Access
Pages 396-401
Andreas Kruse, Thomas H.-J. Uhlemann, Rolf Steinhilper
Abstract | PDF (435 K)

Optimization of Patient-Specific Design of Medical Implants for Manufacturing Original Research Article — Open Access
Pages 402-406
Matthew Chin Heng Chua, Chee-Kong Chui
Abstract | PDF (154 K)

Using Adaptive Model Predictive Technique to Control Underactuated Robot and Minimize Energy Consumption Original Research Article — Open Access
Pages 407-412
Ahmad Albalasie, Guenther Seliger, Ahmed Abu Hanieh
Abstract | PDF (474 K)

## Session 13: Design

Principles for Interconnection of Modular Machine Tool Frames Original Research Article — Open Access
Pages 413-418
Eckart Uhlmann, Mihir Saoji, Bernd Peukert
Abstract | PDF (1424 K)

Membrane Bioreactor and Promising Application for Textile Industry in Vietnam Original Research Article — Open Access
Pages 419-424
Tan Vu. Luong, S. Schmidt, S.A. Deowan, J. Hoinkis, A. Figoli, F. Galiano
Abstract | PDF (389 K)

A New Model to Select Fasteners in Design for Disassembly Original Research Article — Open Access
Pages 425-430
Thomas Jeandin, Christian Mascle
Abstract | PDF (100 K)

Requirements for Design Methodology for Local Oriented Manufacturing in Developing Countries Original Research Article — Open Access
Pages 431-436
Tomoyuki Tamura, Hideki Kobayashi, Yasushi Umeda
Abstract | PDF (396 K)

Lean Line Balancing for an Electronics Assembly Line Original Research Article — Open Access
Pages 437-442
Nguyen Thi Lam, Le Minh Toi, Vu Thi Thanh Tuyen, Do Ngoc Hien

Abstract | PDF (462 K)

CFD-Simulations in the Early Product Development Original Research Article — Open Access
*Pages 443-448*
Krotil Stefan, Reinhart Gunther
Abstract | PDF (302 K)

## Session 14: Assessment

A Measurement Scale to Evaluate Sustainable Innovation Performance in Manufacturing Organizations Original Research Article — Open Access
*Pages 449-454*
E. Calik, F. Bardudeen
Abstract | PDF (225 K)

Improving Material Efficiency for Ultra-efficient Factories in Closed-loop Value Networks Original Research Article — Open Access
*Pages 455-462*
Erin Sheehan, Anja-Tatjana Braun, Timm Kuhlmann, Alexander Sauer
Abstract | PDF (395 K)

A Study on Reaction of Residents to Wind Turbines to Promote Local Economy Original Research Article — Open Access
*Pages 463-468*
Kazuki Abe, Toru Saito, Masaya Taguchi, Nozomu Mishima
Abstract | PDF (427 K)

Evaluation of Indicators Supporting the Sustainable Design of Electronic Systems Original Research Article — Open Access
*Pages 469-474*
Eduard Wagner, Stephan Benecke, Janis Winzer, Nils F. Nissen, Klaus-D. Lang
Abstract | PDF (105 K)

Evaluating Sustainable Development from a Child's Perspective - A Proposal of Sustainable Child Development Index (SCDI) Original Research Article — Open Access
*Pages 475-480*
Ya-Ju Chang, Matthias Finkbeiner
Abstract | PDF (104 K)

## Session 15: Machining

Improving Performance of Turn-milling by Controlling Forces and Thermally Induced Tool-center Point (TCP) Displacement Original Research Article — Open Access
*Pages 481-485*
M. Putz, S. Ihlenfeldt, U. Karaguzel, U. Semmler, E. Budak, M. Bakkal, R. Wertheim
Abstract | PDF (385 K)

Sustainable Cutting Process for Milling Operation using Disturbance Observer Original Research Article — Open Access
*Pages 486-491*
Z. Jamaludin, J. Jamaludin, T.H. Chiew, L. Abdullah, N.A. Rafan, M. Maharof
Abstract | PDF (320 K)

Determination of Displacements on a Cutting Disc During Sawing Process Original Research Article — Open Access
*Pages 492-497*
Ismail Ucun, Fatih Onur Hocaoglu, Sukru Gorgulu
Abstract | PDF (810 K)

Sustainability Improvement in Milling Operation Through Improved Tool Design and Optimized Process Parameters-an Industrial Case Study Original Research Article — Open Access
*Pages 498-503*
O.O. Owodunni, D. Pinder
Abstract | PDF (450 K)

The Effect of Tribology Behavior on Machining Performances When Using Bio-based Lubricant as a Sustainable Metalworking Fluid Original Research Article — Open Access
*Pages 504-508*
N. Talib, E.A. Rahim
Abstract | PDF (152 K)

Thermal Aspects of Environmentally Friendly-MQL Grinding Process Original Research Article — Open Access
*Pages 509-515*
Mohammadjafar Hadad, Alireza Sharbati
Abstract | PDF (647 K)

## Session 16: Value Creation

A Novel Framework for Achieving Sustainable Value Creation Through Industrial Engineering Principles Original Research Article — Open Access

*Pages 516-523*
Pinar Bilge, Günther Seliger, Fazleena Badurdeen, I.S. Jawahir
Abstract | PDF (135 K)

Sustainable Product Service Systems – From Concept Creation to the Detailing of a Business Model for a Bicycle Sharing System in Berlin Original Research Article — Open Access
*Pages 524-529*
Ana Paula Barquet, Johannes Seidel, Tom Buchert, Mila Galeitzke, Sabrina Neugebauer, Nicole Oertwig, Henrique Rozenfeld, Günther Seliger
Abstract | PDF (280 K)

Decision Support for Energy Efficient Production in Product and Production Development Original Research Article — Open Access
*Pages 530-535*
Pascal Stoffels, Michael Vielhaber
Abstract | PDF (416 K)

Opportunities of Sustainable Manufacturing in Industry 4.0 Original Research Article — Open Access
*Pages 536-541*
T. Stock, G. Seliger
Abstract | PDF (691 K)

A Collection of Tools for Factory Eco-efficiency Original Research Article — Open Access
*Pages 542-546*
Mélanie Despeisse, Aanand Davé, Lampros Litos, Simon Roberts, Peter Ball, Steve Evans
Abstract | PDF (525 K)

Sustainable Technology for Using Bio-Waste in Rural and Urban Regions in South- and South-East-Asia Original Research Article — Open Access
*Pages 547-550*
Michael H. Böhme, Le Hung Anh
Abstract | PDF (206 K)

**Session 17: Processes**

Novel Ag/Au Nanocubes Modified the Negative/Positive Charge on the Surface and Their Application in Surface-Enhanced Raman Scattering Original Research Article — Open Access
*Pages 551-556*
Tran Thi Bich Quyen, Bing-Joe Hwang
Abstract | PDF (412 K)

Wood as a Technical Material for Structural Vehicle Components Original Research Article — Open Access
*Pages 557-561*
Daniel Kohl, Philipp Link, Stefan Böhm
Abstract | PDF (250 K)

Enhancement of Productivity of Traditional Brass Manufacturing Industry Using Sustainable Manufacturing Concept Original Research Article — Open Access
*Pages 562-567*
H.M.M.M Jayawickrama, M. Dharmawardana, A.K Kulatunga, K.G.S.P Karunarathna, S.A.U. Osadith
Abstract | PDF (334 K)

Sustainable Machining of Metal Matrix Composites Using Liquid Nitrogen Original Research Article — Open Access
*Pages 568-573*
Sravan Kumar Josyula, Suresh Kumar Reddy Narala, E. Guru Charan, H.A. Kishawy
Abstract | PDF (891 K)

**Session 18: Utilization**

Sustainable Manufacturing Through Energy Efficient Handling Processes Original Research Article — Open Access
*Pages 574-579*
Jürgen Fleischer, Frederic Förster, Johannes Gebhardt
Abstract | PDF (370 K)

Application of Statistical Process Control (SPC) in Manufacturing Industry in a Developing Country Original Research Article — Open Access
*Pages 580-583*
Ignatio Madanhire, Charles Mbohwa
Abstract | PDF (103 K)

ScienceDirect Journals Books Sign in Help

Search all fields | Author name | --This Journal/Book-- | Volume | Issue | Page | Advanced search

# Procedia CIRP

Open Access | About this Journal | Submit your Article

Get new article feed
Subscribe to new volume alerts
Add to Favorites

CIRP



Procedia CIRP
Volume 40, Pages 1-716 (2016)
**13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use**
Edited by Günther Seliger, Holger Kohl and Jürgen Mallon

< Previous vol/iss | Next vol/iss >

◂ Prev art. **101 - 122** of **122** No next


**Volume 41 (2016)**

**Volumes 31 - 40 (2015 - 2016)**

**Volume 40**
pp. 1-716 (2016)
13th Global Conference on Sustainable Manufacturing – Decoupling Growth from Resource Use

Volume 39
pp. 1-230 (2016)
Structured Innovation with TRIZ in Science and Industry: Creating Value for Customers and Society

Volume 38
pp. 1-288 (2015)
Proceedings of the 4th International Conference on Through-life Engineering Services

Volume 37
pp. 1-270 (2015)
CIRPe 2015 - Understanding the life cycle implications of manufacturing

Volume 36
pp. 1-290 (2015)
CIRP 25th Design Conference Innovative Product Creation

Volume 35
pp. 1-100 (2015)
MIC2015 – 15th Machining Innovations Conference for Aerospace Industry

Volume 34
pp. 1-284 (2015)
9th International Conference on Axiomatic Design (ICAD 2015)

Volume 33
pp. 1-598 (2015)
9th CIRP Conference on Intelligent Computation in Manufacturing Engineering - CIRP ICME '14

Volume 32
pp. 1-156 (2015)
5th Conference on Learning Factories

Volume 31
pp. 1-568 (2015)
15th CIRP Conference on Modelling of Machining Operations (15th CMMO)

**Volumes 21 - 30 (2014 - 2015)**

**Volumes 11 - 20 (2013 - 2014)**

**Volumes 1 - 10 (2012 - 2013)**


< Previous vol/iss | Next vol/iss >

Download PDFs | Export | Open Access articles


## Session 18: Utilization

Waste Reduction by Product-quality based Scheduling in Food Processing Original Research Article — Open Access
*Pages 584-590*
Marcel Wagner, Stefan Kaluschke, Fabian Keller, Gunther Reinhart
Abstract | PDF (286 K)

Re-engineering Assembly Line with Lean Techniques Original Research Article — Open Access
*Pages 591-596*
Minh-Nhat Nguyen, Ngoc-Hien Do
Abstract | PDF (1397 K)

Design of a Footwear Assembly Line Using Simulation-based ALNS Original Research Article — Open Access
*Pages 597-602*
Quang-Vinh Dang, Khoa Pham
Abstract | PDF (365 K)

## Session 19: Performance

"Made in Vietnam" Lean Management Model for Sustainable Development of Vietnamese Enterprises Original Research Article — Open Access
*Pages 603-608*
Nguyen Dang Minh, Nguyen Thi Van Ha
Abstract | PDF (419 K)

Development of Sustainable Manufacturing Performance Evaluation Expert System for Small and Medium Enterprises Original Research Article — Open Access
*Pages 609-614*
Sujit Singh, Ezutah Udoncy Olugu, Siti Nurmaya Musa
Abstract | PDF (219 K)

Fuzzy Neural Networks in the Assessment of Environmental Safety Original Research Article — Open Access
*Pages 615-619*
Vladimir Glinskiy, Lyudmila Serga, Mariya Khvan, Kirill Zaykov
Abstract | PDF (135 K)

A Fuzzy Multi Criteria Approach for Sustainable Manufacturing Evaluation in Cement Industry Original Research Article — Open Access
*Pages 620-625*
Elita Amrina, Chintia Ramadhani, Annike Lutfia Vilsi
Abstract | PDF (257 K)

Assessment of Environmental Parameters Impact on the Level of Sustainable Development of Territories Original Research Article — Open Access
*Pages 626-631*
Vladimir Glinskiy, Lyudmila Serga, Mariya Khvan
Abstract | PDF (116 K)

## Session 20: Processes

Investigation of Turning Elastomers Assisted with Cryogenic Cooling Original Research Article — Open Access

Pages 632-637
M. Putz, M. Dix, M. Neubert, G. Schmidt, R. Wertheim
Abstract | PDF (815 K)

Experimental Investigation of Supercritical Carbon Dioxide ($SCCO_2$) Performance as a Sustainable Cooling Technique Original Research Article — Open Access
Pages 638-642
E.A. Rahim, A.A. Rahim, M.R. Ibrahim, Z. Mohid
Abstract | PDF (406 K)

Increasing Performance and Energy Efficiency of Gas Metal Arc Welding by a High Power Tandem Process Original Research Article — Open Access
Pages 643-648
Gunther Sproesser, Andreas Pittner, Michael Rethmeier
Abstract | PDF (272 K)

Environmental Generation of Cold Air for Machining Original Research Article — Open Access
Pages 649-653
Yogie Rinaldy Ginting, Brian Boswell, Wahidul K. Biswas, Mohammad Nazrul Islam
Abstract | PDF (300 K)

Dry Rotary Swaging with Structured Tools Original Research Article — Open Access
Pages 654-659
Marius Herrmann, Christian Schenck, Bernd Kuhfuss
Abstract | PDF (679 K)

## Session 21: Entrepreneurship

Sustainable Business Model Innovation: Exploring Evidences in Sustainability Reporting Original Research Article — Open Access
Pages 660-668
Sandra Naomi Morioka, Steve Evans, Marly Monteiro de Carvalho
Abstract | PDF (399 K)

A Proposal for the Evaluation of Craftsmanship in Industry Original Research Article — Open Access
Pages 669-674
Giampaolo Campana, Barbara Cimatti, Francesco Melosi
Abstract | PDF (163 K)

Process-oriented Design Methodology for the (Inter-) Organizational Intellectual Capital Management Original Research Article — Open Access
Pages 675-680
Mila Galeitzke, Nicole Oertwig, Ronald Orth, Holger Kohl
Abstract | PDF (390 K)

The Effect of Culture on Enterprise's Perception of Corporate Social Responsibility: The Case of Vietnam Original Research Article — Open Access
Pages 681-687
My Nguyen, Minh Truong
Abstract | PDF (124 K)

## Session 22: Maintenance

Concept for a Sustainable Industrial Product Service Systems based on Field Data Original Research Article — Open Access
Pages 688-693
M. Mamrot, J.-P. Nicklas, N. Schlüter, P. Winzer, A. Lindner, M. Abramovici
Abstract | PDF (223 K)

How Additive Manufacturing Enables more Sustainable End-user Maintenance, Repair and Overhaul (MRO) Strategies Original Research Article — Open Access
Pages 694-699
Wessel W. Wits, J. Roberto Reyes García, Juan M. Jauregui Becker
Abstract | PDF (599 K)

Control and Evaluation Concept for Smart MRO Approaches Original Research Article — Open Access
Pages 700-705
Annett Bierer, Uwe Götze, Susann Köhler, Romy Lindner
Abstract | PDF (341 K)

The Development of Compressor Noise Barrier in the Assembly Area (Case Study of PT Jawa Furni Lestari) Original Research Article — Open Access
Pages 706-711
Nur Indrianti, Nandyan Banyu Biru, Tri Wibawa
Abstract | PDF (176 K)

Evaluation and Benchmarking of Maintenance Organization and Planning/Scheduling at — Open Access

Automotive Industries of Pakistan Original Research Article
*Pages 712-716*
Javeria Younus, Muhammad Fahad, Maqsood A. Khan
Abstract | PDF (311 K)

◂ Prev art. 101 - 122 of 122 No next

Available online at www.sciencedirect.com

ScienceDirect

Procedia CIRP 40 (2016) 620 – 625

www.elsevier.com/locate/procedia

13th Global Conference on Sustainable Manufacturing - Decoupling Growth from Resource Use

# A Fuzzy Multi Criteria Approach for Sustainable Manufacturing Evaluation in Cement Industry

Elita Amrina*, Chintia Ramadhani, Annike Lutfia Vilsi

*Department of Industrial Engineering, Andalas University, Padang 25163, Indonesia*

* Corresponding author. Tel.: +62-751-72497; fax: +62-751-72566.*E-mail address:*elita@ft.unand.ac.id

**Abstract**

The cement industry has remarked as an intensive consumer of natural raw materials, fossil fuels, energy, and a major source of multiple pollutants. Therefore, it is a need to evaluate sustainable manufacturing in this industry. This paper aims to propose a fuzzy multi criteria approach for evaluating sustainable manufacturing in cement industry which integrated the Interpretive Structural Modeling (ISM) and the Fuzzy Analytic Network Process (FANP) methodology. The network relationship model is constructed using ISM methodology. Importance weights of indicators are assigned by pairwise comparisons and calculated using fuzzy ANP methodology. A case study is also presented to demonstrate implementation of the evaluation model. The results show the existing performance level on company's strengths and weaknesses, and where improvements need to be made. It is hoped the proposed evaluation model can aid the cement industry to achieve the higher performance in sustainable manufacturing.

Peer-review under responsibility of the International Scientific Committee of the 13th Global Conference on Sustainable Manufacturing
*Keywords:* analytic network process; cement industry; fuzzy; evaluation; interpretive structure modeling; sustainable manufacturing

## 1. Introduction

Sustainable manufacturing has became a critical issue in the cement industry. Cement is an indispensable industrial product for economic development, but its production is extremely energy-intensive and leads to excessive pollution [1]. The cement industry has regarded as one of the most energy intensive consumers amongst industries in the world [2]. Furthermore, cement plants are characterised as an intensive consumer of natural raw materials and fossil fuels, and has remarked as emitters of pollutants [3, 4]. The cement companies are under intense pressure to reduce the environmental impacts of their products and operations. Thus, it is important to implement sustainable manufacturing in this industry.

The US Department of Commerce defined sustainable manufacturing as the creation of manufactured products that minimize negative environmental impacts, conserve energy and natural resources, are safe for employees, communities and consumers and are economically sound [5]. According to the definitions, sustainable manufacturing must address the integration all the three indicators of environmental, social, and economic, known as the triple bottom line of sustainability. Therefore, sustainable manufacturing should be evaluated with respect to those three indicators.

Sustainable manufacturing is currently a very important issue for governments and industries worldwide [6]. Achieving sustainability in manufacturing activities have been recognized as a critical need due to diminishing non-renewable resources, stricter regulations related to environment and occupational safety, and growing consumer preference for environmentally-friendly products [7]. Sustainable manufacturing must respond to [8]: (i) economical challenges, by producing wealth and new services ensuring development and competitiveness through time; (ii) environmental challenges, by promoting minimal use of natural resources (in particular non-renewable) and managing them in the best possible way while reducing environmental impact; and (iii) social challenges, by promoting social development and improved quality of life through renewed quality of wealth and jobs. It has been suggested that sustainable manufacturing has to be evaluated based on triple bottom line of economic, environmental, and social performance [9] as well as to consider their interdependencies [10].


Peer-review under responsibility of the International Scientific Committee of the 13th Global Conference on Sustainable Manufacturing
doi:10.1016/j.procir.2016.01.144

This research proposes a fuzzy multi criteria approach for evaluating sustainable manufacturing in cement industry which integrated the Interpretive Structural Modeling (ISM) and the Fuzzy Analytic Network Process (FANP) methodology. The ISM methodology is utilized to determine the structural relationships and interrelationships amongst all the evaluation indicators, while the Fuzzy ANP methodology is applied to arrange the appropriate weights to each of the indicators in the evaluation model. A case study is then conducted to demonstrate implementation of the evaluation model.

## 2. Research method

### *2.1. Interpretive Structural Modeling (ISM)*

Interpretive Structural Modeling (ISM) was proposed by Warfield in 1973 as computer assisted methodology [12]. ISM is an interactive learning process that enables one to develop a map of the complex relationships among many elements involved in a complex problem [12]. It helps build an interaction map to identify the interrelationships among system variables. ISM provides a better understanding of a system structure and draws up a useful guideline in generating a graphical representation of the structure [13]. ISM is interpretive as the judgment of the experts decides whether and how the system variables are related. It is structural as on the basis of relationship and overall structure is extracted from the complex set of system variables. The first step of ISM is to identify the variables relevant to the problem. A structural self interaction matrix (SSIM) is then developed based on a pair-wise comparison of variables. SSIM is then converted into a reachability matrix. Noted that the reachability matrix is under Boolean operations. Its transitivity is then checked. The transitivity is a basic assumption of ISM methodology, which stated that if variable-A related to variable-B and variable-B related to variable-C, then variable-A necessarily related to variable-C [12].

### *2.2. Fuzzy Analytic Network Process (FANP)*

Analytic Network Process (ANP) method introduced by Thomas L. Saaty in 1996 is an extension of the Analytic Hierarchy Process (AHP) method. AHP decomposes a problem into a hierarchical structure where each decision element is assumed to be independent. ANP is designed to deal with complex decisions that involve dependency and feedback [14]. Because of its consideration to the interdependence of each element, ANP could establish a better understanding of the complex relationships between elements in decision making and thus, improve the reliability of decision making [15]. ANP method is capable of handling interdependence among elements by obtaining the composite weights through the development of a supermatrix [16].

It is the fact that human perception always contains a certain degree of vagueness and ambiguity, and traditional ANP fails to perceive these traits. Thus, fuzzy set theory is applied in dealing with uncertainty and imprecision associated with information concerning various parameters, and to cope with situations in which only partial information is available. Fuzzy logic has been described as a problem solving method which provides definite conclusions from imprecise, vague, and uncertain information [17]. Generally, a fuzzy set is defined by its membership function, which represents the grade of any element $x$ of $X$ that have the partial membership to $M$. The degree to which an element belongs to a set is defined by the value ranging between zero and one [18]. If an element $x$ belongs to M, $\mu_M(x) = 1$ and clearly not $\mu_M(x) = 0$.

A triangular fuzzy number (TFN) is defined as ($l$, $m$, $u$), where $l \leq m \leq u$. The parameters $l$, $m$ and $u$, respectively, denote the smallest possible value, the most promising value, and the largest possible value that describe a fuzzy event. Each TFN has linear representations on its left and right side such that its membership function can be defined as:

$$\mu_M(x) = \begin{cases} (x-l)/(m-l) & 1 \leq x \leq m \\ (u-x)/(u-m) & m \leq x \leq u \\ 0 & otherwise \end{cases} \quad (1)$$

## 3. Fuzzy multi criteria approach

This study provides decision makers with a fuzzy multi criteria approach for evaluating sustainable manufacturing in the cement industry. The methodology has three main stages. First, establish the KPIs for sustainable manufacturing evaluation in cement industry. Second, determine the interrelationships of KPIs using Interpretive Structural Modeling (ISM) method. Finally, calculate the importance weight of KPIs using Fuzzy Analytic Network Process (FANP) method.

### *3.1. Establishing KPIs*

This study starts with the development of initial Key Performance Indicators (KPIs) for sustainable manufacturing evaluation in cement industry through literature review. The initial KPIs have been constructed by adopting the triple bottom line of sustainability consisting of environmental, economic, and social factors. As a result, the initial KPIs consist of three factors divided into nineteen indicators were developed. The initial KPIs were then validated by conducting interviews to a total of 12 managers in a cement manufacturing company located in Padang, Indonesia. Established in 1910, the company is the first cement manufacturing plant in Indonesia. Currently, the company has four plants with a total of production capacity of 5,240,000 tons per year. The company has been certified by ISO 9001, ISO 14001, and OHSAS 18001. Based on the results, the initial KPIs of sustainable manufacturing evaluation in cement industry have been modified. Based on the results, the initial KPIs of sustainable manufacturing evaluation in cement industry have been modified. Due to the less importance, six indicators were removed from the initial KPIs. Finally, three factors with a total of thirteen indicators have been proposed as the KPIs for sustainable manufacturing evaluation in cement industry [19] as shown in Table 1.

Table 1. Proposed KPIs.

| Factors | Indicators |
|---|---|
| 1. Economic | 1. Inventory cost |
| | 2. Labor cost |
| | 3. Material cost |
| | 4. Product delivery |
| | 5. Raw material substitution |
| 2. Environmental | 6. Air emission |
| | 7. Energy consumption |
| | 8. Fuel consumption |
| | 9. Material consumption |
| 3. Social | 10. Accident rate |
| | 11. Labor relationship |
| | 12. Occupational health and safety |
| | 13. Training and education |

### 3.2. Determining the interrelationships of KPIs

Since the evaluation systems are complex, it is not appropriate to assume the indicators within the system are independent. Therefore, it is required to determine the relationships among the indicators. For that purpose, Interpretive Structural Modeling (ISM) method was applied. An ISM survey was conducted to develop a network structure model of the KPIs for sustainable manufacturing evaluation in cement industry. A questionnaire was then designed and sent to 15 managers from the cement manufacturing company in Padang, Indonesia. Those managers were carefully selected based on their experience in cement industry. Through the ISM survey, the experts were consulted to identify the relationships amongst the KPIs of sustainable manufacturing evaluation in cement industry. Answers to the questions from the experts were averaged. The results indicated a total of 30 direct relationships amongst the KPIs [20]. The Structural self-interactive modeling (SSIM) of the KPIs is presented in Table 2.

Table 2. Structural self-interactive matrix (SSIM) of KPIs.

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | - | O | O | A | A | O | O | A | A | O | O | O | O |
| 2 | | - | O | O | O | O | O | O | O | A | O | A | A |
| 3 | | | - | A | A | O | A | A | A | O | O | O | O |
| 4 | | | | - | A | O | O | O | O | O | O | O | O |
| 5 | | | | | - | O | X | A | X | O | O | O | O |
| 6 | | | | | | - | A | O | O | O | O | V | O |
| 7 | | | | | | | - | X | A | O | O | O | O |
| 8 | | | | | | | | - | O | O | O | O | O |
| 9 | | | | | | | | | - | O | O | O | O |
| 10 | | | | | | | | | | - | A | X | A |
| 11 | | | | | | | | | | | - | V | A |
| 12 | | | | | | | | | | | | - | A |
| 13 | | | | | | | | | | | | | - |

Four symbols are used to denote the direction of relationship between the indicators (*i* and *j*) where V for the relation from *i* to *j*, A for the relation from *j* to *i*, X for both directions, relations from *i* to *j* and *j* to *i*, and O if the relation between the indicators does not appear valid. The SSIM is then transformed into the initial reachability matrix by substituting the symbols of V, A, X, and O into a binary matrix of 1 and 0, where 1 means there is relationship between the indicators and otherwise, 0 means there is no relationship between the indicators. The initial reachability matrix of the KPIs for sustainable manufacturing evaluation in cement industry is shown in Table 3.

Table 3. Initial reachability matrix of KPIs.

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1 | 0 | 1 | 1 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 6 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 1 | 0 |
| 7 | 0 | 0 | 1 | 0 | 1 | 1 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 8 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 |
| 9 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 1 | 0 | 0 | 0 | 0 |
| 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 11 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 13 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

The final reachability matrix is developed from the initial reachability matrix by incorporating the transitivities. The final reachability matrix of the KPIs [20]is shown in Table 4.

Table 4. Final reachability matrix of KPIs.

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 2 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 3 | 0 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 4 | 1 | 0 | 1 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 5 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 6 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 7 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 8 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 9 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 1 | 0 |
| 10 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 11 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 0 |
| 12 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 0 | 1 | 0 |
| 13 | 0 | 1 | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 1 | 1 |

Finally, an ISM-based network model [20] is then generated based on the relationships of indicators given in the final reachability matrix as shown in Fig. 1. It can be concluded that raw material substitution is regarded as the most influencing indicator for sustainable manufacturing evaluation in the cement industry.

### 3.3. Determining the importance weight of KPIs

Once the network model has been constructed, the importance weight of KPIs should be calculated. For that purpose, Fuzzy Analytic Network Process (ANP) method was applied. A pairwise comparison questionnaire was then designed and sent to the same managers of the ISM survey to determine the importance weights of KPIs of sustainable manufacturing evaluation. The managers were asked to make pairwise comparisons of the indicators with respect to their relative importance toward their control indicator. A Saaty' scale of 1 to 9 (1 = equally, 3 = moderate, 5 = strong, 7 = very strong, 9 = extreme) was used to reflect these preferences. A reciprocal value is automatically assigned to the reverse comparison within the matrix. The comparisons values are represented as an interval ($l$, $m$, $u$). An example of the pairwise comparison matrix under raw material substitution is shown in Table 5.

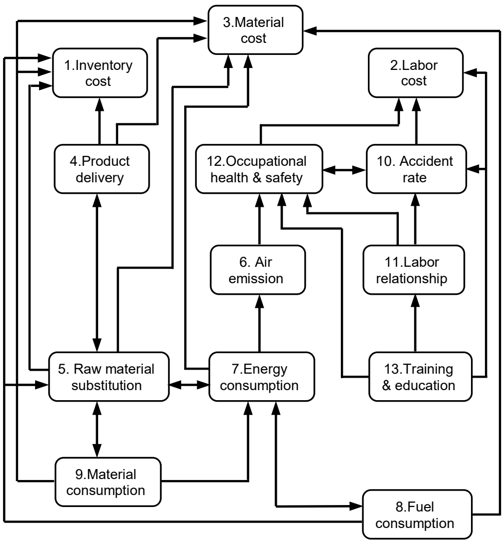



Fig. 1. ISM model of KPIs

Table 5. Fuzzy comparisons matrix under raw material substitution.

| Indicators | Fuel consumption | Energy consumption | Material consumption |
|---|---|---|---|
| Fuel consumption | 1 | (1, 1, 3) | (1/7, 1/5, 1/3) |
| Energy consumption | (1, 1, 1/3) | 1 | (1/7, 1/5, 1/3) |
| Material consumption | (7, 5, 3) | (7, 5, 3) | 1 |

Answers to each question were then geometrically averaged before calculating the importance weight. Consistency ratio (CR) was checked for each pairwise comparison. Then the supermatrix is constructed based on the network relationship model from the ISM stage. The supermatrix is composed by many sub-matrices which obtained from the pairwise comparisons matrix. If there is no relationship between the KPIs, the value for the supermatrix is set equal to zero. Table 6 shows the unweighted supermatrix of the KPIs. The unweighted supermatrix is then multiplied by the importance weight of corresponding influencing factors and obtained the weighted supermatrix as shown in Table 7. The weighted supermatrix should be column stochastic (the total column equal to one). Finally, the weighted supermatrix then converged into the limit supermatrix by raising the supermatrix to the power $M^{2k+1}$, where k is an arbitrarily large number. In this case, the convergence was reached at $M^{12}$. The limit supermatrix is shown in Table 8. The value in each row of the limit supermatrix represents the importance weight of each indicator.

The importance weight of the four indicators of raw material substitution, energy consumption, fuel consumption, and material consumption are obtained directly from the limit supermatrix. Since the limit supermatrix gave zero values for the other nine indicators, then their importance weights were obtained using Fuzzy Analytic Hierarchy Process (FAHP) method. A pairwise comparisons questionnaire was then designed and the thirteen managers were consulted to establish the importance weights of KPIs of sustainable manufacturing evaluation. The pairwise comparisons were determined between factors, and indicators within each factor using Saaty's scale of 1 to 9. The pairwise comparisons are determined to indicate how much more one factor or indicator is important than other factors or indicators.

Table 6. Unweighted supermatrix

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Inventory cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2. Labor cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| 3. Material cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4. Product delivery | 0.446 | 0.000 | 0.348 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5. Raw material substitution | 0.554 | 1.000 | 0.652 | 1.000 | 0.000 | 1.000 | 1.000 | 1.000 | 1.000 | 1.000 | 0.000 | 1.000 | 0.000 |
| 6. Air emission | 0.000 | 0.239 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.293 | 0.000 | 0.348 | 0.000 |
| 7. Energy consumption | 0.313 | 0.327 | 0.396 | 0.444 | 0.368 | 0.406 | 0.000 | 0.670 | 0.471 | 0.220 | 0.000 | 0.200 | 0.000 |
| 8. Fuel consumption | 0.322 | 0.172 | 0.244 | 0.272 | 0.319 | 0.308 | 0.629 | 0.000 | 0.529 | 0.277 | 0.000 | 0.253 | 0.000 |
| 9. Material consumption | 0.364 | 0.263 | 0.360 | 0.284 | 0.313 | 0.286 | 0.371 | 0.330 | 0.000 | 0.209 | 0.000 | 0.198 | 0.000 |
| 10. Accident rate | 0.000 | 0.175 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.347 | 0.000 |
| 11. Labor relationship | 0.000 | 0.122 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.174 | 0.000 | 0.193 | 0.000 |
| 12. Occup. health & safety | 0.000 | 0.364 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.401 | 0.000 | 0.000 | 0.000 |
| 13. Training and education | 0.000 | 0.339 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.425 | 1.000 | 0.460 | 0.000 |

Table 7. Weighted supermatrix

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Inventory cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2. Labor cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 1.000 |
| 3. Material cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4. Product delivery | 0.223 | 0.000 | 0.174 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5. Raw material substitution | 0.277 | 0.333 | 0.326 | 0.500 | 0.000 | 0.500 | 0.500 | 0.500 | 0.500 | 0.333 | 0.000 | 0.333 | 0.000 |
| 6. Air emission | 0.000 | 0.080 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.098 | 0.000 | 0.116 | 0.000 |
| 7. Energy consumption | 0.157 | 0.109 | 0.198 | 0.222 | 0.368 | 0.203 | 0.000 | 0.335 | 0.236 | 0.073 | 0.000 | 0.067 | 0.000 |
| 8. Fuel consumption | 0.161 | 0.057 | 0.122 | 0.136 | 0.319 | 0.154 | 0.315 | 0.000 | 0.265 | 0.092 | 0.000 | 0.084 | 0.000 |
| 9. Material consumption | 0.182 | 0.088 | 0.180 | 0.142 | 0.313 | 0.143 | 0.186 | 0.165 | 0.000 | 0.070 | 0.000 | 0.066 | 0.000 |
| 10. Accident rate | 0.000 | 0.058 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.116 | 0.000 |
| 11. Labor relationship | 0.000 | 0.041 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.058 | 0.000 | 0.064 | 0.000 |
| 12. Occup. health & safety | 0.000 | 0.121 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.134 | 0.000 | 0.000 | 0.000 |
| 13. Training and education | 0.000 | 0.113 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.142 | 1.000 | 0.153 | 0.000 |

Table 8. Limited supermatrix

| Indicators | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 | 11 | 12 | 13 |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1. Inventory cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 2. Labor cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 3. Material cost | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 4. Product delivery | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 5. Raw material substitution | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 | 0.333 |
| 6. Air emission | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 7. Energy consumption | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 | 0.245 |
| 8. Fuel consumption | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 | 0.233 |
| 9. Material consumption | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 | 0.188 |
| 10. Accident rate | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 11. Labor relationship | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 12. Occup. health & safety | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |
| 13. Training and education | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 | 0.000 |

Table 9 shows a summary of the importance weights for the KPIs of sustainable manufacturing evaluation in the cement industry. The importance weights were then normalized to yield a sum of up to one. The table shows which indicator is regarded as being more important relative to other indicators. The results indicate that the most important indicator for sustainable manufacturing performance evaluation is raw material substitution with an importance weight of 0.191 which included in economic factor of KPIs. It followed by energy consumption (0.140), fuel consumption (0.134), and material consumption (0.108). These three are indicators in enviromental factor of KPIs. Based on the results, it can be concluded that those four indicators are regarded as the key indicators for evaluating sustainable manufacturing in cement industry. The least important indicator is labor relationship with an importance weight of 0.029.

Table 9. Importance weights of KPIs.

| Indicators | Importance Weight | |
|---|---|---|
| | Calculated | Normalized |
| 1. Inventory cost | 0.089 | 0.051 |
| 2. Labor cost | 0.119 | 0.068 |
| 3. Material cost | 0.134 | 0.077 |
| 4. Product delivery | 0.096 | 0.055 |
| 5. Raw material substitution | 0.333 | 0.191 |
| 6. Air emission | 0.074 | 0.042 |
| 7. Energy consumption | 0.245 | 0.140 |
| 8. Fuel consumption | 0.233 | 0.134 |
| 9. Material consumption | 0.188 | 0.108 |
| 10. Accident rate | 0.034 | 0.019 |
| 11. Labor relationship | 0.051 | 0.029 |
| 12. Occupational health and safety | 0.066 | 0.038 |
| 13. Training and education | 0.083 | 0.048 |

## 4. Case study results

A case study was then conducted to a cement manufacturing company in Padang, Indonesia. The managers scored all the KPIs to evaluate their three plants using 1 to 10 rating scale. Plant-1 begins its operation in 1983 and has a total production capacity of 1,320,000 tons/year. Plant-2 operates in 1987 with a total production capacity of 1,620,000 tons/year. While Plant-3 begins its production in 1998 and has a total production capacity of 2,300,000 tons/year. The scores were calculated as the product sum of scores and importance weights over all KPIs. The overall score of the three plants compared is presented in Fig. 2. It can be seen that plant-3 has attained the highest performance with overall score of 8.083. It followed by plant-2 (7.495) and lastly, plant-1 (7.249) which has the lowest overall score. It is suggested from the results that sustainable manufacturing performance of plant-3 should improve in order to improve the overall company's performance.

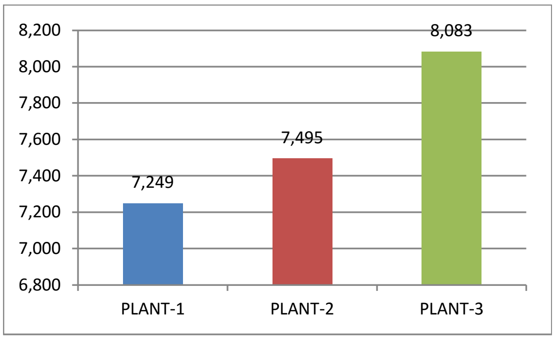



Fig. 2

## 5. Conclusions

This paper has proposed a fuzzy multi criteria approach for sustainable manufacturing evaluation in cement industry developed using interpretive structural model (ISM) and fuzzy analytic network process (FANP) method. The network relationship model is constructed using ISM method. Importance weights of the KPIs were assigned by pairwise comparisons and calculated using FANP method. Integration of ISM and FANP method will give a better understanding of the interrelationships amongst the KPIs and help to solve a complex evaluation problem, so that it can enhance the quality of decision making. A case study has also presented. The model enables and assists companies to know and understand their existing performance level on their strengths and weaknesses. It provides informative suggestions and directions for companies to take appropriate actions in improving their sustainable manufacturing performance. The model aids companies in achieving the higher performance and so as to compete in a much more sustainable manner. Future work will develop a sustainable manufacturing evaluation tool for the cement industry.

## Acknowledgements

The authors would like to thanks to Andalas University, Padang, Indonesia for the research funding and Directorate General of Higher Education, Indonesia.

## References

[1] Uwasu M, Hara K, Yabar H. World cement production and environmental implications. Environmental Development 2014;10:36-47.
[2] Uson AA, Lopez-Sabiron AM, Ferreira G, Sastresa EL. Uses of alternative fuels and raw materials in the cement industry as sustainable waste management options. Renewable and Sustainable Energy Reviews 2013; 23:242–60.
[3] Ali MB, Saidur R, Hossain MS. A review on emission analysis in cement industries. Renewable and Sustainable Energy Reviews 2011;15:2252-61.
[4] Pardo N, Moya JA, Mercier A. Prospective on the energy efficiency and CO2 emissions in the EU cement industry. Energy 2011; 36:3244–54.
[5] US Department of Commerce. Sustainable manufacturing initiative. Proceedings of the 2nd Annual Sustainable Manufacturing Summit 2009.
[6] Seliger G, Kim H-J, Kernbaum S, Zettl M. Approaches to sustainable manufacturing. International Journal of Sustainable Manufacturing 2008; 1(1/2): 58-77.
[7] Jayal AD, Badurdeen F, Dillon Jr. OW, Jawahir IS. Sustainable manufacturing: modeling and optimization challenges at the product, process and system levels. CIRP Journal of Manufacturing Science and Technology 2010;2(3):144–152.
[8] Jovane F, Yoshikawa H, Alting L, Boer CR, Westkamper E, Williams D, Tseng M, Seliger G, Paci AM. The incoming global technological and industrial revolution towards competitive sustainable manufacturing. CIRP Annals - Manufacturing Technology 2008;57(2):641–659.
[9] Bakshi BR., Fiksel J. The quest for sustainability: challenges for process systems engineering. AIChE Journal 2003;49(6):1350-1358.
[10] Gasparatos A, El-Haram M, Horner M. A critical review of reductionist approaches for assessing the progress towards sustainability. Environmental Impact Assessment Review 2008;28:286–311.
[11] Agarwal A, Shankar R, Tiwari MK. Modeling agility of supply chain. Industrial Marketing Management 2007;36(4):443-457.
[12] Kannan G, Pokharel S, Kumar PS. A hybrid approach using ISM and fuzzy TOPSIS for the selection of reverse logistics provider. Resources, Conservation and Recycling 2009;54:28-36.
[13] Chen SP, Wu WY. A systematic procedure to evaluate an automobile manufacturer-distributor partnership. European Journal of Operational Research 2010;205:687-698.
[14] Saaty TL. The analytic hierarchy and analytic network measurement processes: application to decisions under risk. European Journal of Pure and Applied Mathematics 2008;1(1):122-196.
[15] Jharkharia S, Shankar R. Selection of logistics service provider: An analytic network process (ANP) approach. Omega: The International Journal of Management Science 2007;35:274-289.
[16] Buyukozkan G, Cifci G. A novel fuzzy multi-criteria decision framework for sustainable supplier with incomplete information. Computers in Industry 2011;62:164-174.
[17] Dweiri FT, Kablan MM. Using fuzzy decision making for the evaluation of project management internal efficiency. Decision Support Systems 2006;42(2):712-726.
[18] Kahraman C, Ruan D, Dogan I. Fuzzy group decision making for facility location selection. Information Sciences 2003;157:135-153.
[19] Amrina E, Vilsi AL. Key performance indicators for sustainable manufacturing evaluation in cement industry. Procedia CIRP 2015;26C:19-23.
[20] Amrina E, Vilsi AL. Interpretive structural model of key performance indicators for sustainable manufacturing evaluation in cement industry. Proceedings of the IEEE International Conference on Industrial Engineering and Engineering Management 2014: 1111-1115.