International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

Advancing Circular Economy Through Product Design Strategies: A Comprehensive Framework

Allamsetti Yogesh[1], S.N. Padhi[2]
[1,2]Department of Mechanical Engineering, Koneru Lakshmaiah Education Foundation, Green Fields, Vaddeswaram, Guntur, Andhra Pradesh, India-522502
Email: 2301130001@kluniversity.in[1], s.n.padhi@kluniversity.in[2]

Abstract:
The transition to a circular economy presents multifaceted challenges for businesses, particularly in terms of product design and business model strategies. This paper introduces a comprehensive framework aimed at guiding designers and business strategists through this transition. Drawing upon Stahel's concepts of slowing, closing, and narrowing resource loops, the framework delineates a spectrum of product design and business model strategies essential for embracing a circular economy paradigm. By abolishing the notion of waste and emphasizing product and material reuse, the circular economy framework not only fosters economic sustainability but also minimizes environmental impact. Through a thorough literature review, the article distinguishes between eco-design and circular product design, introducing novel concepts such as pre-source and recovery horizon. Guided by Walter Stahel's Inertia Principle, the framework offers a typology of approaches for Design for Product Integrity, particularly focusing on durable consumer products. By providing practical strategies and examples, this framework serves as a roadmap for businesses seeking to transition towards a circular economy model, while also highlighting avenues for future research in this critical domain.
Keywords:*Circular Economy; Product Design; Business Model Strategies; Waste Reduction; Sustainability*

1. INTRODUCTION

The paper introduces a framework to guide businesses in transitioning to a circular economy, addressing challenges in product design and business models. It is a fully review based paper. It draws from Stahel's ideas of slowing, closing, and narrowing resource loops, emphasizing product and material reuse to minimize waste and environmental impact while promoting economic sustainability. Through a literature review, it distinguishes between eco-design and circular product design, introducing concepts like pre-source and recovery horizon. Guided by Stahel's Inertia Principle, the framework offers approaches for Design for Product Integrity, focusing on durable consumer products, with practical strategies and examples to aid businesses in this transition and suggesting avenues for further research.

Fig. 1: Journal cover page

2. Importance of Product Design

The importance of product Design in Circular Economy was :

- Resource Conservation

- Life Cycle Assessment
- Economic Resilience
- Consumer Engagement

The Resource Conservation :

- Efficient product design is essential in a circular economy as it prioritizes the conservation of raw materials and minimizes waste generation. By designing products with longevity and recyclability in mind, we can reduce the strain on natural resources and move towards a more sustainable future.

Life Cycle Assessment :

- Product design plays a pivotal role in conducting comprehensive life cycle assessments for goods. Understanding the environmental impact of products throughout their life cycle allows for informed decisions that promote resource efficiency and minimize negative ecological footprints.

Ecnomic Resilience :

- Well-designed products contribute to economic resilience by fostering efficient resource allocation, enhancing product value, and encouraging closed-loop systems. These strategies not only reduce production costs but also create new economic opportunities within a circular economy framework.

Consumer Engagement :

- Engaging product design captures consumer interest by highlighting the sustainable benefits of circular products. When products are thoughtfully designed with environmental considerations, consumers are more likely to support and advocate for circular economy initiatives.
-

3. Key Principles

The key principles of circular product design encompass a range of strategies aimed at minimizing environmental impact and maximizing the lifecycle of products. Designing for durability involves selecting materials and engineering techniques that enhance the longevity of the product, contributing to a more sustainable and resource-efficient production and consumption cycle. Optimizing material use is crucial in ensuring that products are manufactured with minimal waste and resource consumption. Embracing modularity enables the easy repair and upgrade of products, reducing overall waste and enhancing resource efficiency.

- **Design for Durability:** Creating products that are built to last, with robust and resilient materials to withstand wear and tear.
- **Optimize Material Use:** Minimizing resource consumption through efficient use of materials, reducing waste during production and use phase.
- **Embrace Modularity:** Designing products with interchangeable parts to facilitate repair and upgrade, extending their lifespan and reducing overall waste.

3.1. Design For Durability and longevity

The intentional process of creating products, systems, or structures that are built to withstand wear, usage, and environmental factors over an extended period of time. In essence, it involves crafting items with the capability to endure and remain functional for as long as possible, reducing the need for frequent repairs or replacements.

This approach encompasses various considerations throughout the design and manufacturing phases:

- Material Selection: Choosing materials known for their robustness and resilience against corrosion, degradation, or mechanical stress. This might involve using high-quality metals, reinforced plastics, or other durable substances.
- Structural Integrity: Ensuring that the design of the product or system is inherently strong and stable, capable of withstanding expected stresses and loads without succumbing to deformation or failure.
- Component Compatibility: Ensuring that all components and parts of the design work harmoniously together, reducing the likelihood of premature failure due to mismatched components or incompatible interfaces.
- Protective Measures: Incorporating features such as coatings, seals, or enclosures to shield vulnerable components from environmental factors like moisture, dust, or extreme temperatures that could accelerate deterioration.
- Maintenance Considerations: Designing with ease of maintenance in mind, including accessible components for inspection and replacement, as well as designing for modularization to facilitate repairs without extensive disassembly.

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 8, 2025
https://theaspd.com/index.php

- Testing and Validation: Conducting rigorous testing throughout the design and development process to identify and address any weaknesses or vulnerabilities before production, ensuring that the final product meets durability and longevity requirements.

3.2. Optimize Material Material Useage Efficiency

Implementing material efficiency strategies involves optimizing the use of industrial materials to minimize waste and maximize resource utilization. A modern industrial warehouse interior with ample natural lighting represents the integration of sustainable materials and efficient resource management. The use of innovative technologies and advanced manufacturing processes can further enhance material efficiency, ensuring that every material input is utilized effectively to reduce environmental impact. By adopting such strategies, companies can not only reduce their environmental footprint but also achieve significant cost savings and enhance overall operational efficiency.

Additionally, implementing material efficiency strategies can lead to the development of innovative products that are both environmentally friendly and economically sustainable. Through the adoption of circular economy principles, companies can create products that are designed with the end in mind, promoting the use of recycled or renewable materials and the minimization of waste throughout the product lifecycle. This approach aligns with the broader goals of sustainable development, creating a positive impact on both the environment and the economy.

3.3. Embrace Modularity

Embracing modular and repairable design is essential for advancing the principles of circular economy in product development. The concept involves creating products with components that can be easily disassembled, repaired, and replaced, extending the lifespan of the product and reducing waste. By incorporating modularity into design, products can be upgraded or repaired without the need to discard the entire unit.

Modular design enables seamless integration of new features, technology upgrades, or repairs, providing flexibility and longevity. Repairable design also emphasizes the use of easily accessible parts, clear repair instructions, and support for the repair ecosystem, empowering consumers to prolong the life of their products.

4. Incorporating Recycled and Renewable Materials

Incorporating recycled and renewable materials into manufacturing processes involves using substances that have been previously used or can be naturally replenished without exhausting finite resources. This approach supports sustainability by reducing reliance on new resources and diverting waste from landfills. Here's an overview:

- Recycled Materials:

These are materials obtained from post-consumer or post-industrial waste streams, such as plastics, metals, glass, paper, and textiles. They undergo processing to meet quality standards for reuse in new products, thereby extending their lifespan and lessening the demand for new resources.

- Renewable Materials:

These are sourced from natural, renewable sources that can be harvested or grown sustainably. Examples include bamboo, cork, sustainably harvested wood, natural fibers like cotton or hemp, and bio-based polymers from agricultural feedstocks. Using renewable materials reduces reliance on finite resources and lowers environmental impacts associated with their extraction and processing.

- Life Cycle Considerations:

It's crucial to assess the environmental impact of materials throughout their entire life cycle, from extraction or cultivation to disposal. Opting for recycled and renewable materials can lead to lower greenhouse gas emissions, reduced energy consumption, and decreased waste generation compared to conventional options.

- Design Compatibility:

Ensuring that recycled and renewable materials meet performance requirements and are suitable for the intended application. This might involve engineering solutions to address any limitations in strength, durability, or other properties compared to traditional materials.

- Supply Chain Management**:**

Building robust supply chains to source recycled and renewable materials reliably and sustainably. This includes collaborating with suppliers committed to ethical and environmentally responsible practices and implementing measures to trace and verify material origins throughout the supply chain.

5. Designing for Disassembly and End-of-Life Recycling

In the context of circular product design, it's essential to consider the end-of-life phase of products. Designing for disassembly is a key aspect, ensuring that products can be easily taken apart for recycling or refurbishment. The process involves a detailed product assessment to evaluate its disassembly potential, identifying recyclable materials and components, and engaging in efficient end-of-life recycling processes. This approach fosters a sustainable product life cycle and contributes to a circular economy by promoting the responsible end-of-ife management of products.

6. Case Studies

6.1. Renewable Material Innovation

One case study involves a company that successfully developed a new type of packaging material made from renewable resources. The material not only reduces the environmental impact but also provides a cost-effective solution for packaging needs. This case study showcases the power of innovation in creating sustainable products that align with circular economy principles.

6.2. Collaborative Design Processes

Another successful case study highlights the importance of collaboration in circular product design. By involving multiple stakeholders, including suppliers, manufacturers, and designers, the company was able to create a product with minimal waste and optimized material use. This collaborative approach emphasizes the significance of integrating diverse perspectives for sustainable design solutions.

6.3. Localized Production Models

An intriguing case study focused on the implementation of localized production models for consumer goods. By establishing small-scale manufacturing facilities closer to the target market, the company reduced transportation-related emissions and minimized the environmental footprint of their products. This localized approach exemplifies the potential of geographically conscious strategies in circular product design.

6.4. Circular Business Model Integration

A notable case study revolves around a company that not only designed circular products but also incorporated a comprehensive circular business model. This approach ensured that products remained in use for extended periods through repair, refurbishment, or remanufacturing, ultimately reducing the overall waste generated. The integration of circular principles into the business model marks a significant shift towards sustainable practices.

7. CONCLUSION AND CALL OF ACTION

Conclusion and the call of Action for the Advancing Circular Economy through Product Design Strategies

- Global Impact :

The transition to circular product design can significantly reduce waste and resource consumption, leading to a more sustainable future for our planet. By embracing innovative design strategies, businesses can contribute to a significant decrease in environmental impact

- Collaborative Engagement:

Encouraging collaboration among stakeholders, including designers, manufacturers, policymakers, and consumers, is essential. It fosters a collective responsibility towards sustainable practices and drives systemic change across industries and societies.

- **Economic Opportunities:**

The shift towards circular product design presents economic opportunities such as cost savings, new revenue streams, and job creation. This approach fosters a more resilient and adaptive economy, benefiting both businesses and communities.

- **Consumer Awareness and Empowerment:**

Empowering consumers through education and awareness can drive demand for circular products and exert pressure on brands to adopt sustainable practices. By making informed choices, individuals can actively contribute to the circular economy.

8. About Authors

REFERENCES:

[1] Aström, B. T., Manufacturing of Polymer Composites, Chapman & Hall, London, UK, (1997).
[2] Ayres, R. U., "Industrial metabolism; theory and policy," in B. R. Allenby and D. J. Richards (eds), The Greening of Industrial Ecosystems, National Academy Press, Washington, DC, 23–37 (1994).
[3] Ayres, R. and U. Simonis, eds. Industrial Metabolism: Restructuring for Sustainable Development, United Nations University Press, Tokyo (1994).
[4] Bakker, C., M. Den Hollander, E. van Hinte and Y. Zijlstra, Product that Last. Product Design for Circular Business Models, TU Delft Library, Delft (2014).
[5] Bakker, C. A., R. Wever, C. Teoh and S. De Clercq, "Designing cradle-to-cradle products: a reality check," International Journal of Sustainable Engineering, 3, 2–8 (2010).
[6] Bocken, N., M. Farracho, R. Bosworth and R. Kemp, "The front-end of eco-innovation for eco-innovative small and medium sized companies," Journal of Engineering and Technology Management, 31, 43–57 (2014).
[7] Bocken, N. and S. Short, "Towards a sufficiency-driven business model: Experiences and opportunities", Environ mental Innovation and Societal Transitions, 18, 41–61 (2016)
[8] Bocken, N., S. Short, P. Rana and S. Evans, "A literature and practice review to develop sustainable business model archetypes," Journal of Cleaner Production, 65, 42–56 (2014).
[9] Boulding, K. E., "The economics of the coming Spaceship Earth," in H. Jarrett (ed), Environmental Quality in a Growing Economy: Essays from the Sixth RFF Forum, John Hopkins University Press, Baltimore, MD, 3–14 (1966).
[10] Braungart, M., P. Bondesen, A. Kälin and B. Gabler, "Specific Public Goods for Economic Development: With a Focus on Environment." in British Standards Institution (eds),Public Goods for Economic Development. Compendium of Background papers, United Nations Industrial Development Organisation, Vienna, (2008).
[11] British Standard BS 8887-2. Design for Manufacture, Assembly, Disassembly and End-of-life Processing (MADE). Part 2: Terms and Definitions, BSI (2009).
[12] Carson, R., Silent Spring, Houghton Mifflin Company, New York, NY (2002).
[13] Chapman, J., Emotionally Durable Design; Objects, Expe riences and Empathy, Earthscan Publishing, London (2005).
[14]Chertow, M. R., "Industrial symbiosis: Literature and taxonomy," Annual Review of Energy and the Environment, 25, 313–337 (2000).
[15]Chesbrough, H., "Business model innovation: Opportuni ties and barriers," Long Range Planning, 43, 354–363 (2010).
[16]Chouinard, Y. and V. Stanley, The Responsible Company. Patagonia Books (1st ed.), Ventura, CA, (2012).
[17]Commoner, B., The Closing Circle. Nature, Man and Technology. Alfred A. Knopf, Inc., New York, NY (1971).
[18]Crowther, P., Design for Disassembly. BDP Environment Design Guide, November (1999).
[19]de Pauw, I., E. Karana and P. Kandachar, "Cradle to cradle in product development: A case study of closed loop design". in A. Y. C. Nee, B. Song and S.-K. Ong, Re-engineering manufacturing for sustainability, Springer, Singapore, 47–52 (2013).
[20]Druckman, A., M. Chitnis, S. Sorrell and T. Jackson, "Missing carbon reductions? Exploring rebound and backfire effects in UK households," Energy Policy, 39, 3572–3581 (2011).
[21] Interface, Innovation. Available online at: http://www.inter faceglobal.com/Sustainability/Products/Innovation.aspx (accessed December 2014).
[22] Koch, H. "Condemned to produce more". Atlantic Times, July 2010. Available online at: http://www.atlantic-time s.com/archive_detail.php?recordID=2226 (accessed June 2015
[23] Kumar, S., A. K. Panda and R. K. Singh, "A review on tertiary recycling of high-density polyethylene to fuel," Resources, Conservation and Recycling, 55, 893–910 (2011).
[24] Lee, S. G., S. W. Lye and M. K. Khoo, "A Multi-objective methodology for evaluating product end-of-life options and disassembly," The International Journal of Advanced Manufacturing Technology, 18, 148–156 (2001).
[25] Linton, J. D. and V. Jayaraman, "A framework for identi fying differences and similarities in the managerial compe tencies associated with different modes of product life extension," International Journal of Production Research, 43, 1807–1829 (2005).
[26]Lofthouse, V. and T. Bhamra, Design for Sustainability: A Practical Approach, Gower Publishing Ltd., Hampshire, UK, (2007).
[27] Lovins, A., M. Braungart and W. A. Stahel, A New Dynamic: Effective Business in a Circular Economy, Ellen MacArthur Foundation Publishing (2014), 172.
[28] Magretta, J., "Why business models matter," Harvard Business Review, 80, 86–92 (2002).
[29] McDonough, W. and M. Braungart, Cradle to Cradle: Remaking the Way We Make Things, North Point Press, New York, NY (2002).
[30] McDonough, W. and M. Braungart, The Upcycle: Beyond Sustainability– Designing for Abundance, North Point Press, New York, (2013), 227.
[31] Boschert, Stefan; Rosen, Roland (2016). Digital Twin—The Simulation Aspect. In Peter Hehenberger, David Bradley (Eds.): Mechatronic Futures. Cham: Springer International Publishing, pp. 59–74.

[32] Bottani, E.; Cammardella, A.; Murino, T.; Vespoli, S. (2017). From the Cyber-Physical System to the Digital Twin: the process development for behaviour modelling of a Cyber Guided Vehicle in M2M logic.
[33] Brenner, Beate; Hummel, Vera (2017). Digital Twin as Enabler for an Innovative Digital Shopfloor Management System in the ESB Logistics Learning Factory at Reutlingen - University. In Procedia Manufacturing, 9, pp. 198–205.
[34] Cai, Yi; Starly, Binil; Cohen, Paul; Lee, Yuan-Shin (2017). Sensor Data and Information Fusion to Construct Digital twins Virtual Machine Tools for Cyber-physical Manufacturing. In Procedia Manufacturing, 10, pp. 1031–1042.
[35] D'Addona, Doriana M.; Ullah, A. M. M. Sharif; Matarazzo, D. (2017). Tool-wear prediction and pattern-recognition using artificial neural network and DNA-based computing. In J Intell Manuf, 28 (6), pp. 1285–1301.
[36] Frazzon, Enzo Morosini; Albrecht, André; Hurtado, Paula Andrea (2016). Simulation-based optimization for the integrated scheduling of production and logistic systems. In IFAC-PapersOnLine, 49 (12), pp. 1050–1055.
[37] Friedemann Mattern, Christian Floerkemeier (2010). From the Internet of Computers to the Internet of Things.
[38]Friedrich, Christian; Lechler, Armin; Verl, Alexander (2014). Autonomous Systems for Maintenance Tasks – Requirements and Design of a Control Architecture. In Procedia Technology, 15, pp. 595–604.
[39] Garetti, Marco; Rosa, Paolo; Terzi, Sergio (2012). Life Cycle Simulation for the design of Product–Service Systems. In Computers in Industry, 63 (4), pp. 361–369.
[40] GE Power Digital Solutions (2016). GE Digital Twin. Glaessgen, E. H.; Stargel, D. S. (2012). The Digital Twin Paradigm for Future NASA and U.S. Air Force Vehicles. In 53rd Struct. Dyn. Mater. Conf. Special Session: Digital Twin, Honolulu, HI, US.
[41] Grieves, Michael; Vickers (2017). Digital Twin: Mitigating Unpredictable, Undesirable Emergent Behavior in Complex Systems.
[42] Gyulai, Dávid; Pfeiffer, András; Kádár, Botond; Monostori, László (2016). Simulation-based Production Planning and Execution Control for Reconfigurable Assembly Cells. In Procedia CIRP, 57, pp. 445–450.
[43] Tao F, Qi Q, Liu A, Kusiak A. Data-driven smart manufacturing. J Manuf Syst 2018;48:157–69. https://doi.org/10.1016/j.jmsy.2018.01.006.
[44] Wang J, Ma Y, Zhang L, et al. Deep learning for smart manufacturing: methods and applications. J Manuf Syst 2018;48:144–56.
[45] Wang L, Haghighi A. Combined strength of holons, agents and function blocks in cyber-physical systems. J Manuf Syst 2016;40:25–34.
[46] Shafto M, et al. DRAFT modeling, simulation, information technology & processing roadmap. Technol Area 2010;11.
[47]Glaessgen E, Stargel D. The digital twin paradigm for future NASA and US air force vehicles. 53rd AIAA/ASME/ASCE/AHS/ASC Structures, Structural Dynamics Materials Conf. 2012. p. 1–14.
[48] Li C, Mahadevan S, Ling Y, Choze S, Wang L. Dynamic Bayesian network for aircraft wing health monitoring digital twin. AIAA J 2017;55(3):930–41. Jan.
[49] Tuegel E. The airframe digital twin: some challenges to realization. 53rd AIAA/ ASME/ASCE/AHS/ASC Structures, Structural Dynamics Materials Conf. 1812.
[50] Ríos J, Hernández JC, Oliva M, Mas F. Product avatar as digital counterpart of a physical individual product: literature review and implications in an aircraft. 22nd ISPE Int. Conf. Concurrent Eng. (CE2015). 2015. p. 657–66.
[51] Prabhkar GVNB, Babu BK, Prasad KD. Digital twin and triple spark ignition in four stroke internal combustion engines of two-wheelers. IJIET 2014;4(4):293–8. Dec.
[52] Tao F, et al. Digital twin-driven product design framework. Int J Prod Res 2018:1–19. Feb.
[53] Qi Q, Tao F. Digital twin and big data towards smart manufacturing and industry 4.0: 360 degree comparison. IEEE Access 2018;6:3585–93. Jan.
[54] Tao F, et al. Digital twin-driven product design, manufacturing and service with big data. Int J Adv Manuf Technol 2018;94(9):3563–76. Feb.
[55] Feng Y, et al. Target disassembly sequencing and scheme evaluation for CNC ma chine tools using improved multiobjective ant colony algorithm and fuzzy integral. IEEE Trans Syst Man CY-S 2018;49(12):2438–51. Jul.
[56] Lee J, Lapira E, Bagheri B, Kao H-A. Recent advances and trends in predictive manufacturing systems in big data environment. Manuf Lett 2013;1(1):38–41. Oct.
[57] Tao F, Zhang M. Digital twin shop-floor: a new shop-floor paradigm towards smart manufacturing. IEEE Access 2017(5):20418–27. Sept.
[58] Zhuang C, Liu J, Xiong H. Digital twin-based smart production management and control framework for the complex product assembly shop-floor. Int J Adv Manuf Technol 2018;96(1):1149–63. Apr.
[59] Coronado PDU, Lynn R, Louhichi W, Parto M, Wescoat E, Kurfess T. Part data in tegration in the Shop Floor Digital Twin: mobile and cloud technologies to enable a manufacturing execution system. J Manuf Syst 2018;48:25–33.
[60] Lu YQ, Xu X. Resource virtualization: a core technology for developing cyberphy sical production systems. J Manuf Syst 2018;47:128–40.
[61] Tao F, Zhang H, Liu A, Nee AYC. Digital twin in industry: state-of-the art. IEEE Trans Ind Inform 2018:1–11. Oct.
[62]Knights, M. I. Y. A. (2007). Web 2.0 [web technologies]. Communications Engineer, 5(1):30–35
[63] Gantz JF (2007) The expanding digital universe: a forecast of worldwide information growth through 2010. IDC
[64] Bryant R, Katz RH, Lazowska ED (2008) Big-Data computing: creating revolutionary breakthroughs cn Commerce, science and society. http://www.datascienceassn.org/sites/default/files/Big% 20Data%20Computing%202008%20Paper.pdf
[65] Gupta R, Gupta H, Mohania M (2012) Cloud computing and "Big Data" analytics: what is new from databases perspective? "Big Data" analytics. Springer, Berlin, pp 42–61
[66]M. Graen (1999) Technology in manufacturer/retailer integration: Wal-Mart and Procter & Gamble. Private communication
[67]ShawMJ,SubramaniamC,TanGW,WelgeME(2001)Knowledge management and data mining for marketing. Decis Support Syst 31(1):127–137
[68] LiuC,Arnett KP(2000) Exploring the factors associated with Web site success in the context of electronic commerce. Inform Manag 38(1):23–33

[69] StrahonjaV(2002)Complexitymetricofdataenquiry functionsfor public registers and electronic commerce. Inf Technol Interfaces : 63–68
[70] Wei FF (2013) ECL Hadoop: "Big Data" processing based on Hadoop strategy in effective e-commerce logistics. Comput Eng Sci 35(10):65–71
[71] Preis T, Moat HS,Stanley HE (2013) Quantifying trading behavior in financial markets using Google Trends. Sci Rep 3:1684
[72] Moat HS, Curme C, Avakian A, Kenett DY, Stanley HE, Preis T (2013) Quantifying Wikipedia usage patterns before stock market moves. Sci Rep 111(32):11600–11605
[73] Fuhrer E (2000) System for enhanced financial trading support: U.S. Patent 6,105,005[P]
[74]. BughinJ,ChuiM,ManyikaJ(2010)Clouds,"BigData",andsmart assets: ten tech-enabled business trends to watch. McKinsey Q 56(1):75–86
[75]MurdochTB,DetskyAS(2013)Theinevitable application of "Big Data" to health care [J]. JAMA 309(13):1351–1352
[76]Steinbrook R (2008) Personally controlled online health data-the next big thing in medical care. N Engl J Med 358(16):1653
[77] Groves P, Kayyali B, Knott D, Van Kuiken S (2013) The "Big Data" revolution in healthcare. McKinsey Q http://www. pharmatalents.es/assets/files/Big_Data_Revolution.pdf
[78] WeissGM(2005)Dataminingintelecommunications.Datamining and knowledge discovery handbook. Springer, US, pp 1189–1201
[79] Kļevecka I, Lelis J (2008) Pre-processing of input data of neural networks: the case of forecasting telecommunication network traf fic. Riga Tech Univ 104:168–178
[80] Stark J (2011) Product lifecycle management. Springer, London
[81] Jun HB, Shin JH, Kim YS, Kiritsis D, Xirouchakis P (2009) A framework for RFIDapplications in product lifecycle management. Int J Comput Integr Manuf 22(7):595–615
[82] Shehab E, Roy R (2011) Guest editorial: IJAMT special issue on: product-service systems. Int J Adv Manuf Technol 52(9):1115 1116
[83] Platt, D., Biodegradable polymers, market report. Smithers Rapra Ltd., Shawbury (2006).
[84] Prahalad, C. K. and R. Bettis, "The dominant logic: Retrospective and extension," Strategic Management Journal, 16, 5–14 (1995).
[85] Rodenburg Biopolymers, What is Solanyl. Available online at: www.biopolymers.nl/rodenburg_biopolymers solanyl (accessed June 2015)
[86] Short, S., N. Bocken, C. Barlow and M. Chertow, "From refining sugar to growing tomatoes. Industrial ecology and business model evolution," Journal of Industrial Ecology., 18, 603–618 (2014).
[87] Solanyl, Biopolymer biodegradability. Available online at: www.solanyl.ca/biopolymer-biodegradability.asp, informa tion retrieved (accessed June 2015).
[88] Stahel, W., "The product-life factor," in S. Grinton Orr (eds), AnInquiry into the Nature of Sustainable Societies: The Role of the Private Sector, HARC, Houston, TX, 72– 96 (1981).
[89] Stahel, W. R., "The utilization focused service economy: Resource efficiency," in B. R. Allenby and D. J. Richards (eds), The Greening of Industrial Ecosystems, National Academy Press, Washington, DC, 178–190 (1994).
[90]Stahel, W. R., The Performance Economy, Palgrave Macmillan Hampshire, Hampshire UK, (2010).
[91] Su, B. W., A. Heshmati, Y. Geng and X. M. Yu, "A review of the circular economy in China," Journal of Cleaner Production, 42, 215–227 (2013).
[92] Teece, D., "Business models, business strategy and innovation," Long Range Planning, 43, 172–194 (2010).
[93] Tukker, A., "Eight types of product–service system: Eight ways to sustainability? Experiences from SusProNet," Business Strategy and the Environment, 13, 246–260 (2004).
[94] Vert, M., Y. Doi, K. Hellwich, M. Hess, P. Hodge, P. Kubisa, M. Rinaudo and F. Schué, "Terminology for biorelated polymers and applications," Pure Applied Chemistry, 84, 377–410 (2012).
[95] von Weizsäcker, E., A. B. Lovins and L. H. Lovins, Factor Four; Doubling Wealth– Halving Resource Use. The New Report to the Club of Rome, Earthscan Publications, London. (1998).
[96] Wells, P. and M. Seitz, Business models and closed-loop supply chains: A typology. Supply Chain Management: An International Journal, 10 (4). 249–251(2005).
[97] World Business Council for Sustainable Development (WBCSD). Vision 2050: The new agenda for business. Available online at: http://www.wbcsd.org/pages/edocu ment/edocumentdetails.aspx?id=219&nosearchcontextkey= true (accessed December 2014)
[98] Yunus, M., B. Moingeon and L. Lehmann-Ortega, "Building social business models: Lessons from the grameen Experience," Long Range Planning, 43, 308–325 (2010).
[99] Zhu, Q., et al., "Industrial symbiosis in China: A case study of the guitang group," Journal of Industrial Ecology, 11, 31–42 (2007)