친환경 제품 개발 방법 및 전략 조사

A Survey of Eco Product Development Methods and Strategies

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Contents

- **Introduction**
  - ✓ Background
  - ✓ Objectives of study
- **Literature Survey Method**
- **Eco Product Development Methods and Strategies**
- **Discussion**

친환경 제품 개발의 필요성

- 환경 보존, 국제 환경 규제 강화, 기업의 지속 가능한 성장에 대한 관심 증대
- 제품, 서비스, 시스템의 친환경성, 품질, 사용성, 가치 등에 대한 고객 요구사항 증대

국제 환경 규제

RoHS Compliant

Energy Saving! EuP Ready

WEEE

기업

환경 보존,
자원•에너지 절약

환경 규제,
사회적 책임

친환경성,
건강, 안전

품질, 사용성,
가치, 적정가격

고객

국제 환경 규제 대응

비용 절감

제품 경쟁력 유지

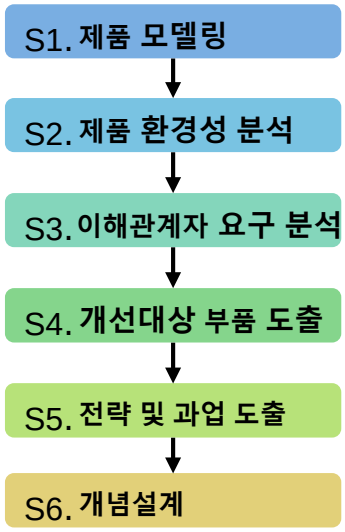
친환경 제품 개발

지속 가능한 성장

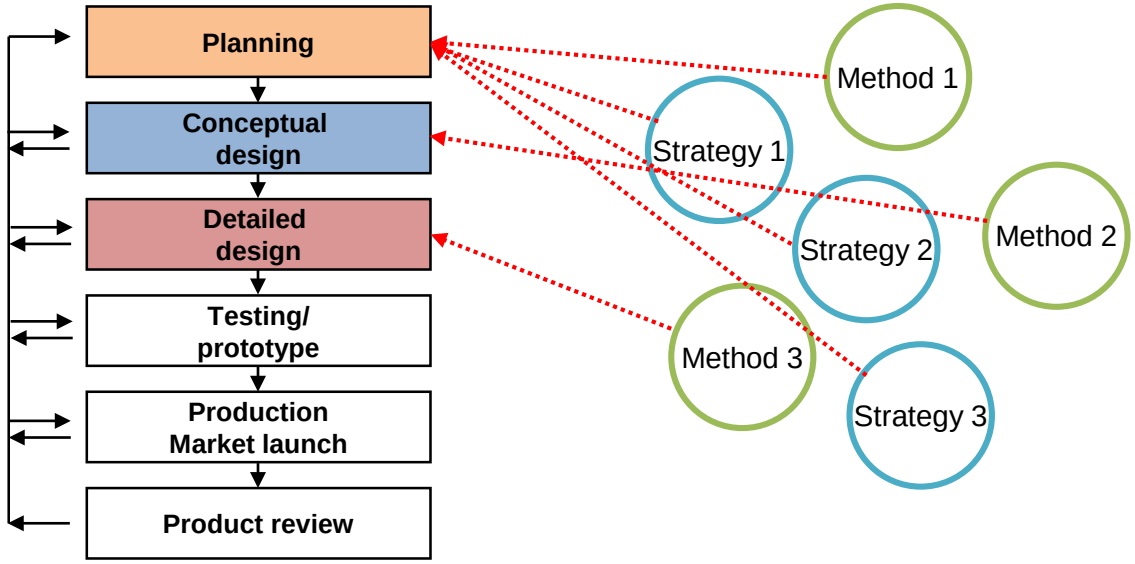
친환경 제품 개발 프로세스

- 환경산업기술원(2010): 기존 제품에 대해 환경성 및 이해관계자 요구사항을 분석하여 환경친화적 제품 설계 및 개선 과정
- ISO 14062(2002): 제품 개발 과정에서 환경 측면을 비용, 품질 등의 요소와 함께 통합적으로 고려하여 환경·경제적으로 우수한 제품 개발 과정

  ⇒ 각 단계에 적용할 수 있는 eco design 방법과 전략에 대한 조사 필요



환경산업기술원(2010)



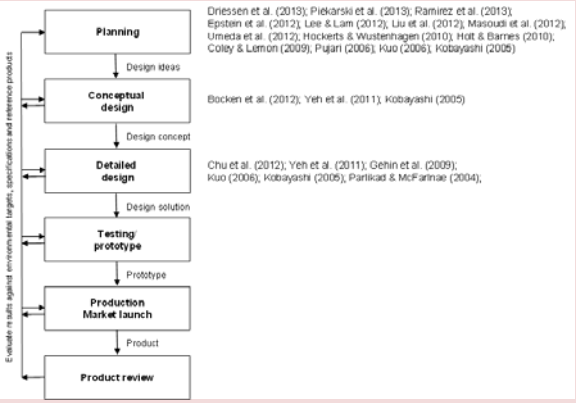
ISO 14062(2002)

연구 목표

친환경 제품 개발에 적용 가능한
방법 및 전략 분석과 단계별 **Mapping**

1 체계적 literature review를 통한
친환경 제품 개발 방법 및 전략 탐색

2 친환경 제품 개발 단계별
mapping 및 활용방안 제시



문헌 조사 절차

S1. 친환경 제품 개발 프로세스 관련 keyword 선정

- Keyword: eco product design process, innovation, sustainability, life cycle assessment, strategy, new product development

S2. 유관 논문 검색(600건) 및 선별

- 문헌 조사 site: http://www.hub.sciverse.com/
- 검색 조건
  - ✓ Title, abstract, and keyword search
  - ✓ Conference proceedings 제외

S2-1. Title screening **198 건**

S2-2. Abstract screening **74 건**

S2-3. 관련도에 따른 분류 **20 건**

- 유관 논문 선별: 연구자 4인의 cross-filtering
- 연구 관련도 및 중요도에 따라 선정된 문헌 분류

S3. 제품 개발 프로세스에 mapping

- ISO 14062의 제품 개발 단계에 mapping

유관 논문 선별

No.	Category	Authors(year)	Title	*Journal, Vol.*, Pages
1	Method	Bocken et al. (2012)	Development of a tool for rapidly assessing the implementation difficulty and emissions benefits of innovations	Technovation, 32(1), pp.19–31
2	Method	Chu et al. (2012)	A concurrent approach to reducing environmental impact of product development at the system design stage	IEEE Transactions on Automation Science & Engineering, 9(3), pp.482-495
3	Method	Yeh et al. (2011)	Integration of four-phase QFD and case study	Research in Engineering Design, 22(3), pp.125–141
4	Method	Gehin et al. (2009)	Integrated design of product lifecycles: The fridge case study	CIRP Journal of Manufacturing Science and Technology, 1(4), pp.214-220
5	Method	Dufulou et al. (2008)	Efficiency and feasibility of product disassembly: A case-based study	CIRP Annals-Manufacturing Technology, 57(2), pp.583–600
6	Method	Parlikad & McFarlane (2007)	RFID-based product information in end-of-life decision making	Control Engineering Practice, 15(11), pp.1348–1363
7	Strategy	Driessen et al. (2013)	Green new product development: The pivotal role of product greenness	IEEE Transactions on Engineering Management, 60(2), pp.315-326
8	Strategy	Piekarski et al. (2013)	Life cycle assessment as entrepreneurial tool for business management and green innovations	Journal of Technology Management & Innovation, 8(1), pp.44-53
9	Strategy	Ramirez et al. (2013)	Barriers and bridges to the adoption of environmentally-sustainable offerings	Industrial Marketing Management, in press
10	Strategy	Epstein et al. (2012)	Managing social, environmental and financial performance simultaneously	Long Range Planning, in press
11	Strategy	Lee & Lam (2012)	Managing reverse logistics to	Industrial Marketing Management, 41(4), pp.589–598
12	Strategy	Liu et al. (2012)	A hub-and-spoke model for multi-dimensional integration of green marketing and sustainable supply chain management	Industrial Marketing Management, 41(4), pp.581–588
13	Strategy	Masoudi et al. (2012)	Characterization of eco-design checklists.	Journal of the Korean Society for Precision Engineering, 29(9), pp.946-970.
14	Strategy	Umeda et al. (2012)	Toward integrated product and process life cycle planning: An environmental perspective	CIRP Annals-Manufacturing Technology, 61(2), pp.681–702
15	Strategy	Hockerts & Wustenhagen (2010)	Greening Goliaths versus emerging Davids: Theorizing about the role of incumbents and new entrants in sustainable entrepreneurship	Journal of Business Venturing, 25(5), pp.481–492
16	Strategy	Holt & Barnes (2010)	Towards an integrated approach to "Design for X": An agenda for decision-based DFX research	Research in Engineering Design, 21(2), pp.123–136
17	Strategy	Coley & Lemon (2009)	Exploring the design and perceived benefit of sustainable solutions: A review	Journal of Engineering Design, 20(6), pp.543–554
18	Strategy	Pujari (2006)	Eco-innovation and new product development: Understanding the influences on market performance	Technovation, 26(1), pp.76–85
19	Method & Strategy	Kuo (2006)	Enhancing disassembly and recycling planning using life-cycle analysis	Robotics and Computer-Integrated Manufacturing, 22(5-6), pp.420–428
20	Method & Strategy	Kobayashi (2005)	Strategic evolution of eco-products: A product life cycle planning methodology	Research in Engineering Design, 16(1-2), pp.1–16

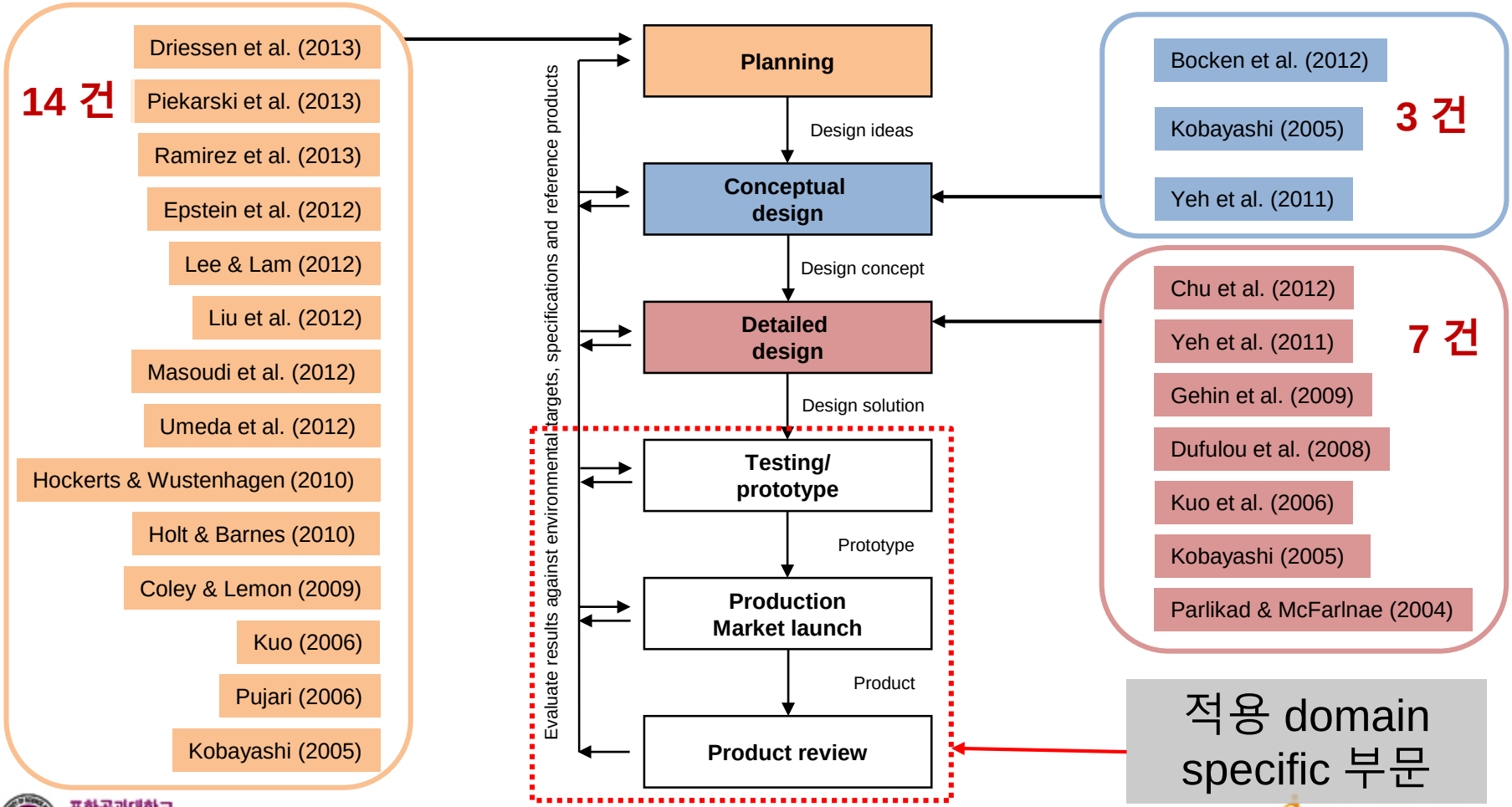
Method (6건)

Strategy (12건)

Method & Strategy (2건)

친환경 제품 개발 프로세스 Mapping

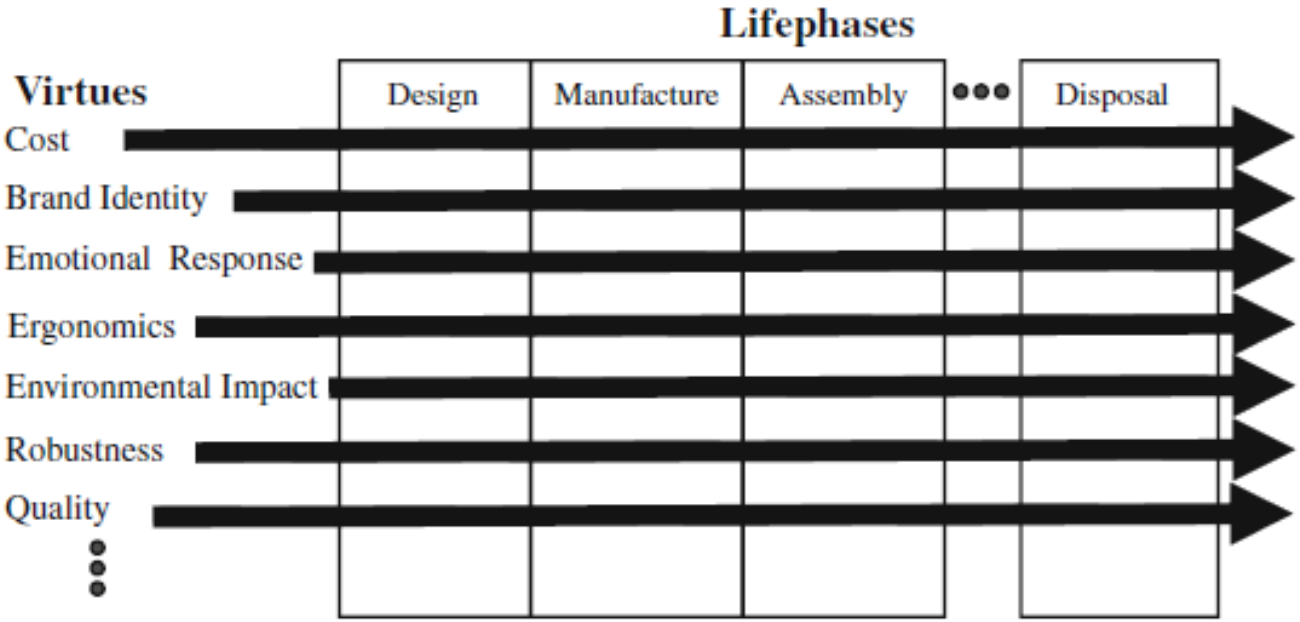
- 선정된 20건의 논문을 ISO TR 14062의 친환경 제품 개발 프로세스의 각 단계에 mapping 하고 통합



Planning: Holt and Barnes (2010)

- Title: Towards an integrated approach to Design for X: An agenda for decision-based DFX research
- 주요내용: 친환경 제품 개발 계획을 수립할 때, virtue와 lifecycle을 동시에 고려한 제품 설계 전략 수립 방법 개발

Virtues must be assessed across all product life phases



Planning: Coley and Lemon (2008)

- Title: Exploring the design and perceived benefit of sustainable solutions: a review
- 주요내용: 체계적이고 지속 가능한 해결책을 제공하는 다양한 design approach 비교 분석

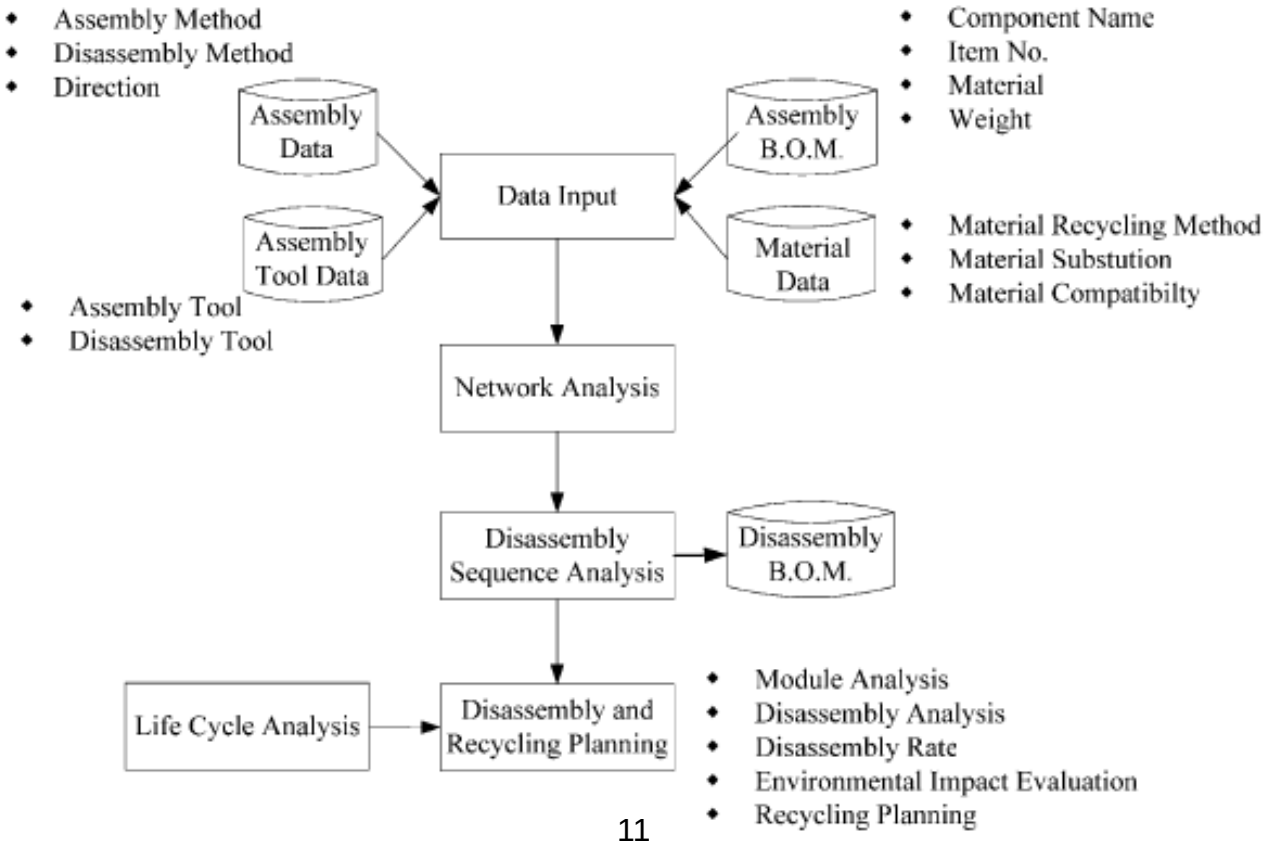
Table. A comparison of design approaches

	PSS	Eco-efficient PSS	SOP	WSD
What is the focus of the approach?	Added value, fulfilment of customer requirements,	Added customer and producer value, sustainable solutions for wider contexts	Highly customised solutions, highly focused on both the solution and the design	Identification of relationships between components of a system
What guidelines are stakeholders given?	Change in focus, inclusion of multiple perspectives	Pushing the boundaries, extending the actor network	Stakeholder involvement, emphasis on collaboration, network of partners	Change/shift in design mentality, systemic thinking, the use of charrettes
Does the approach result in more sustainable solutions?	Unclear	Unclear	Unclear, positive use of local produce and business	Unclear, positive use of systemic thinking
What is the intended outcome of the approach?	Products and/or services	Products and/or services	Products and/or services, partnership between local business and globalisation	Products and/or services

Planning: Kuo (2006) (1/2)

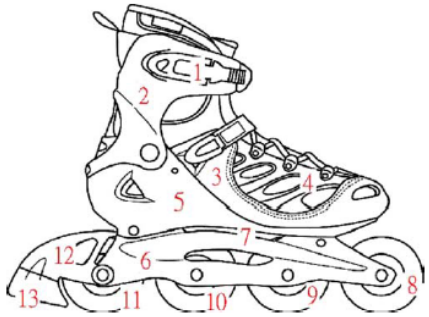
- Title: Enhancing disassembly and recycling planning using life-cycle analysis
- 주요내용: LCA를 활용하여 제품 분해 및 재활용을 강화시킬 수 있는 계획 수립

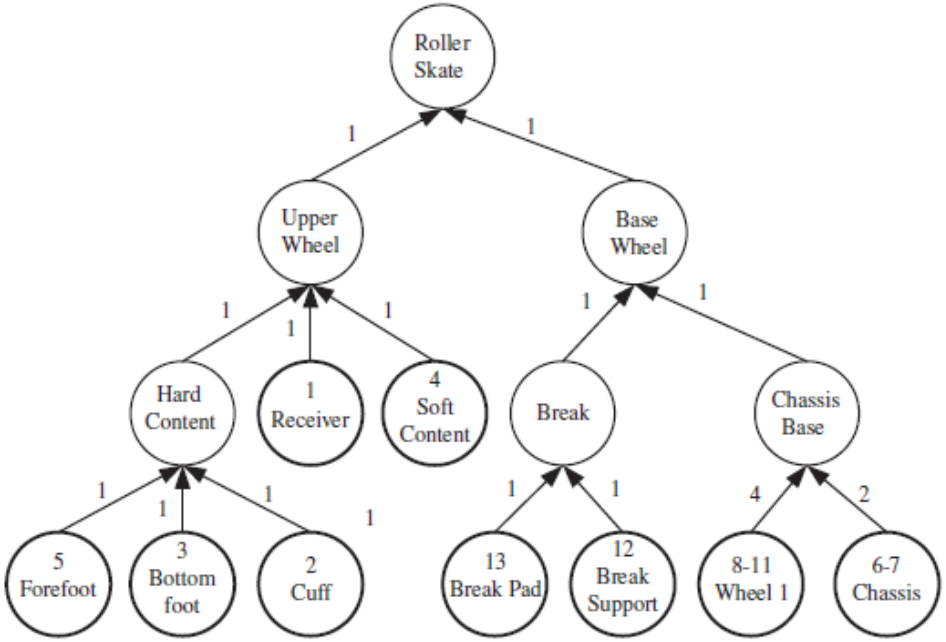
LCA based disassembly and recycling planning



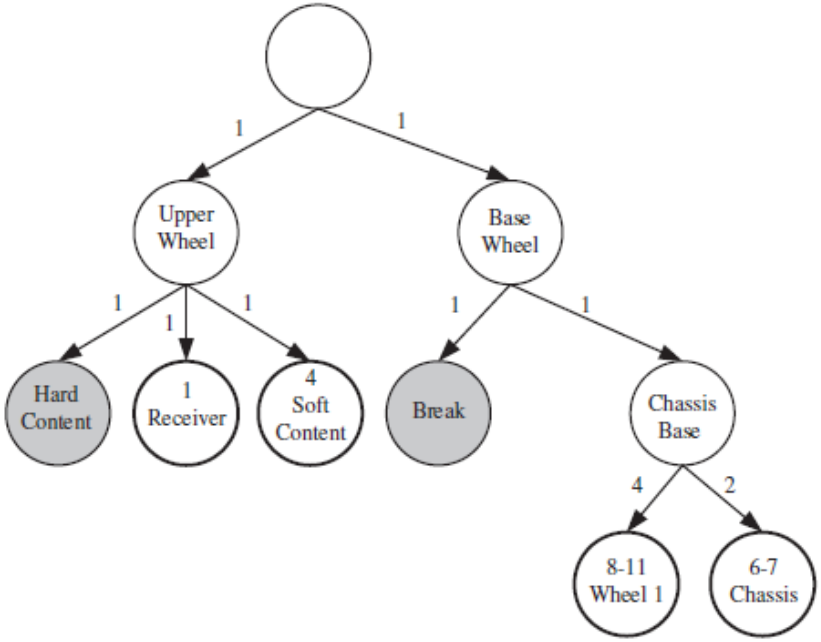
Planning: Kuo (2006) (2/2)

Assembly and disassembly BOM of roller skate





(a) Production BOM

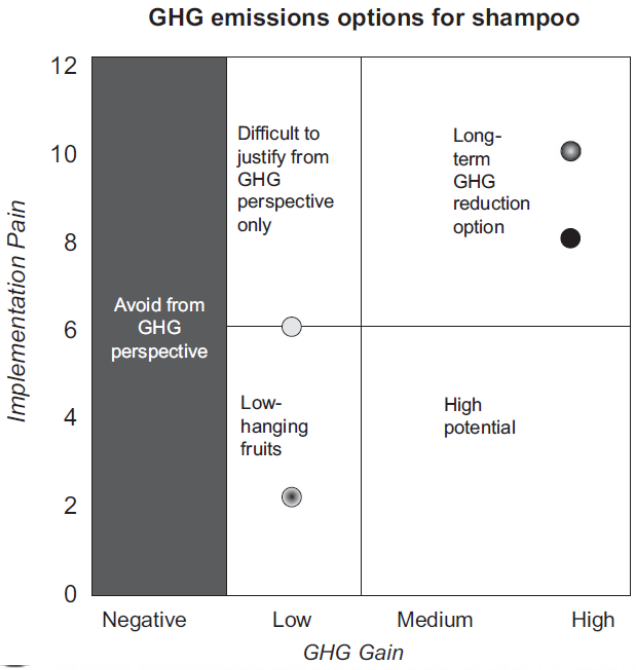


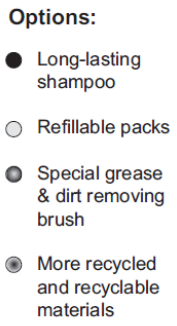
(b) Disassembly BOM

방법 Conceptual Design: Bocken et al. (2012) (1/3)

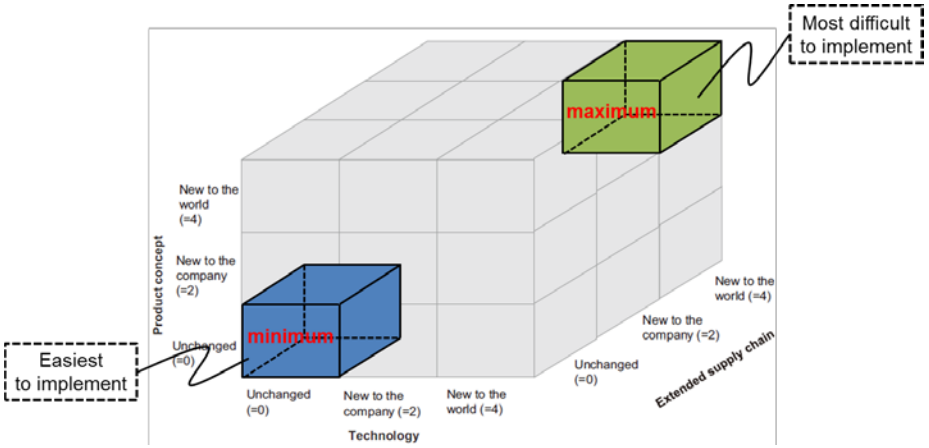
- Title: Development of a tool for rapidly assessing the implementation difficulty and emissions benefits of innovations
- 주요내용: 제품 concept 결정 단계에서 CO_2 방출 감소도 및 시행 난이도를 평가하여 의사결정을 지원하는 도구 개발 및 case study

Pain/gain assessment for shampoo





Pain measurement model



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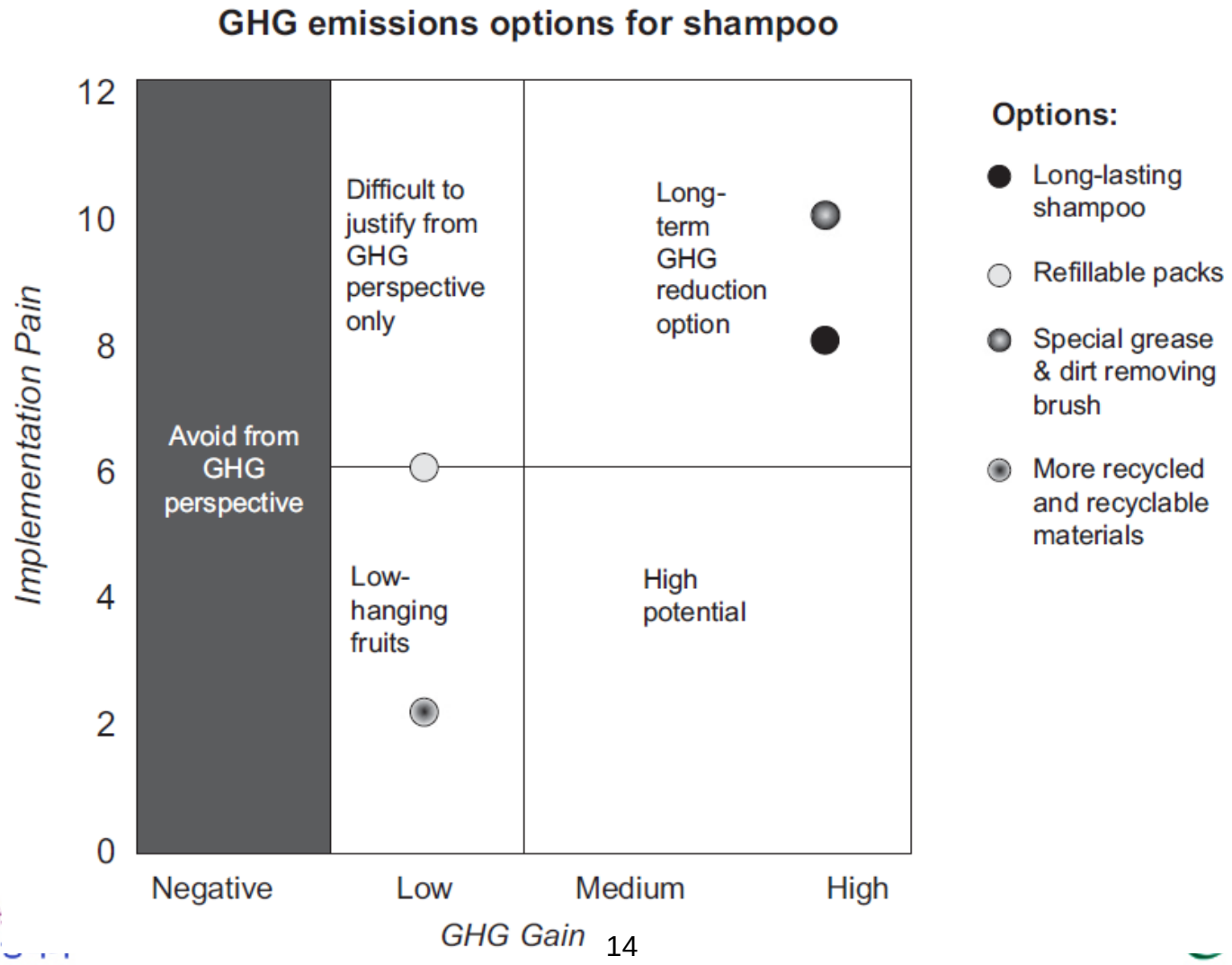
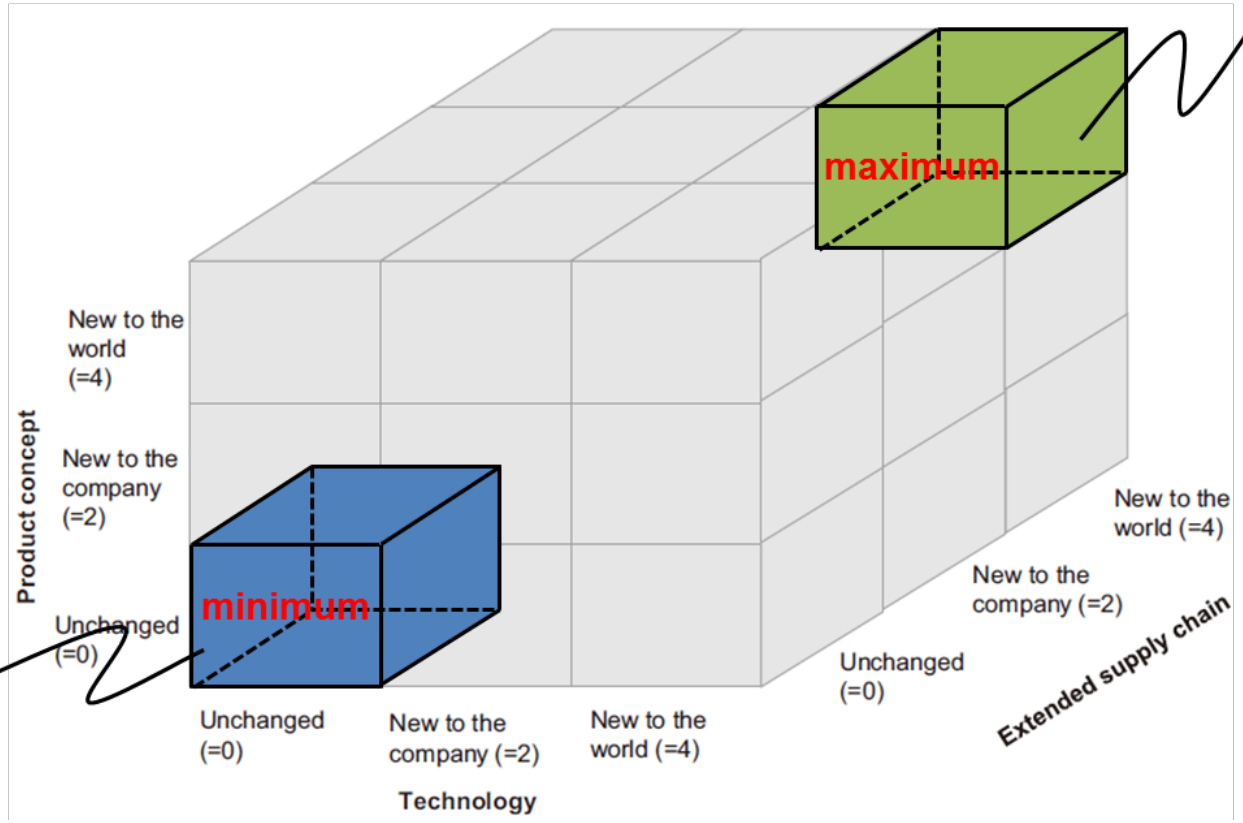
방법 Conceptual Design: Bocken et al. (2012) (2/3)

Pain/gain assessment for shampoo



Conceptual Design: Bocken et al. (2012) (3/3)

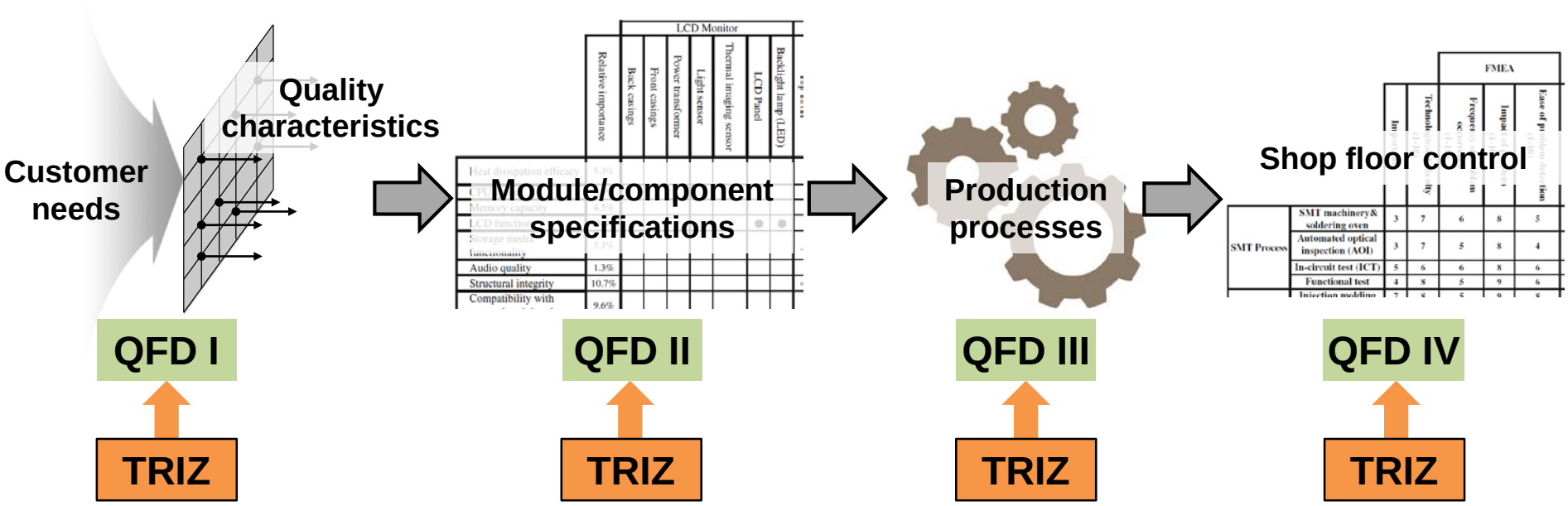
Pain measurement model



방법

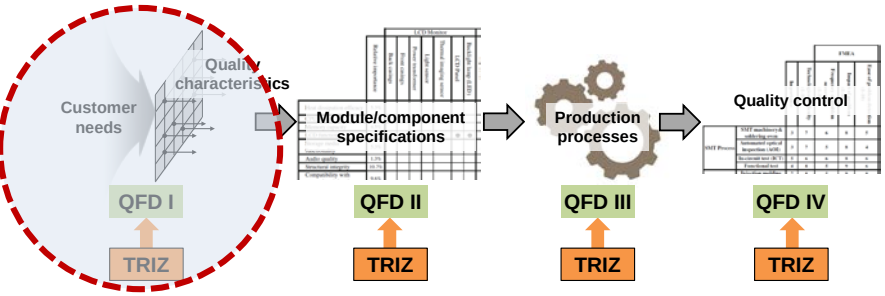
Conceptual Design: Yeh et al. (2011) (1/5)

- Title: Integration of four-phase QFD and TRIZ in product R&D: a notebook case study
- 주요내용: QFD와 TRIZ를 통합하여 고객 needs 파악, 제품 특성 결정, 그리고 부품 제작 방식 및 방법까지 solution을 도출



방법

Conceptual Design: Yeh et al. (2011) (2/5)



Quality characteristics

Customer needs

Customer needs	Quality characteristics	Heat dissipation efficacy	CPU speed	Memory capacity	LCD functions	Multimedia functionality	Audio quality	Structural integrity	Compatibility with external peripherals	Weight	Power management efficiency
High Performance	CPU speed		●	●							
	Display speed		△	○	●						
	Battery life			△	●	○					●
	Video playback clarity				○						
	Monitor resolution				●						
High Reliability	Reboot	●	○	○		○					
	Low failure rate for components					●			●		
	Battery service life									●	●
	Product durability							●	●		
	Endurable to impact							●			
Function completeness	Multimedia functionalities					○	●				○
	Feasible for externally docked peripherals								●	△	
	Not excessively heavy or									●	

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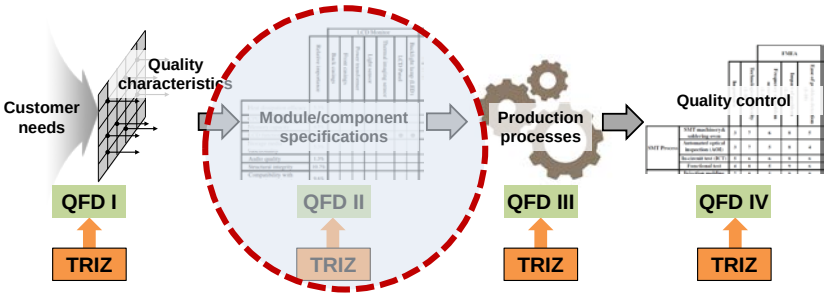
방법

Conceptual Design: Yeh et al. (2011) (3/5)



Module/component specifications

Quality characteristics

		LCD Monitor							Base Assembly Components							
	Relative importance	Back casings	Front casings	Power transformer	Light sensor	Image sensing sensor	LCD Panel	Backlight lamp (LED)	Top cover	Base cover	PCB assembly	I/O board	Speakers and audio module	CPU module	Heat dissipation module	
Heat dissipation efficacy	5.3%									○		△		○	●	
CPU speed	3.3%													●		
Memory capacity	4.5%									○						
[illegible]	13.8%	○	○	△	○	○	●	●								
Storage media	5.3%								△	○						
Audio quality	1.3%												●			
Structural integrity	10.7%								●	●	○					
Compatibility with external peripherals	9.6%										○					
[illegible]		●	●					●	●	●	●		●			

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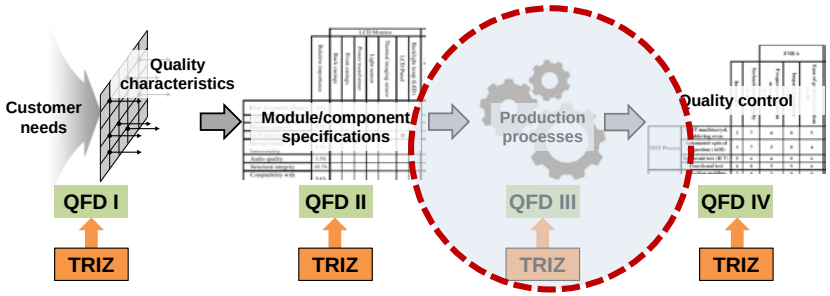
Conceptual Design: Yeh et al. (2011) (4/5)



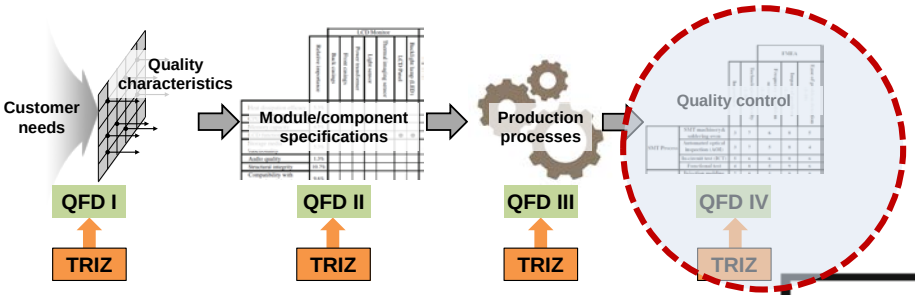
Production processes

Module/component specifications

		Importance	SMT machinery & soldering oven	Automated optical inspection (AOI)	In-circuit test (ICT)	Functional test	Injection molding	Printing	Spray painting	Electroplating	Assembly fixture
LCD Monitor	Back casings	5					●	△	●		○
	Front casings	4					●	△	△		○
Components	Top cover	6					●	○	●	○	○
	Bottom cover	7					●	△			○
	PCB assembly	6	●	●	●	○					△
	External ports	5	△	△		△					
Design and Optional Components	Power management module	8	○	△	●	●					
	Audio module	2			○	○					
Resulting score			83	67	132	101	198	34	103	18	4

방법

Conceptual Design: Yeh et al. (2011) (5/5)



Shop floor control

Production processes

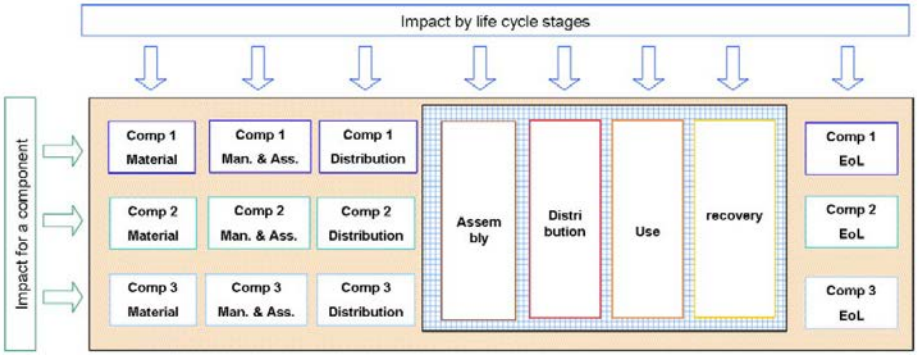
		FMEA				Need for strict controls on the shop floor							
		Importance	Technological difficulty (1-10)	Frequency of problem occurrence (1-10)	Impact of problem (1-10)	Ease of problem detection (1-10)	Total scores	Quality control chart	Preventative maintenance	Fool proof design	Employee training	Equipment / tool precision	Electromagnetic interference testing	Production controls	Final testing
SMT Process	SMT machinery& soldering oven	3	7	6	8	5	5040	ˇ	ˇ		ˇ	ˇ		ˇ	
	Automated optical inspection (AOI)	3	7	5	8	4	3360	ˇ				ˇ		ˇ	
	In-circuit test (ICT)	5	6	6	8	6	8640	ˇ	ˇ	ˇ	ˇ	ˇ		ˇ	
	Functional test	4	8	5	9	6	8640	ˇ	ˇ	ˇ	ˇ	ˇ	ˇ	ˇ	
Plastics Manufacturing Process	Injection molding	7	8	5	9	8	20160	ˇ	ˇ	ˇ	ˇ	ˇ		ˇ	ˇ
	Printing	1	4	1	5	3	60								
	Spray painting	4	6	3	6	3	1296								
	Electroplating	1	9	4	7	6	1512						ˇ		

방법

Detailed Design: Gehin et al. (2009) (1/3)

- Title: Integrated design of product lifecycles - The fridge case study
- 주요내용: 디자인 단계에서 제품의 lifecycle을 고려한 설계를 할 수 있도록 lifecycle brick 개발하고 친환경 냉장고 개발에 적용한 사례

Product lifecycle construction



Environmental impact of the fridge door

DOOR - initial scenario

Weighted value	Usage cycle n° 1			
	C_Mat	C_FabAss	C_Dis	C_EoL
Door	0,960	8,777	0,000	-0,884
Env Impact for 1 usage cycle	8,852			

Ponderated EI (pt, EcoIndicator99)

Design modification

LC modification : « Remanufacture »

$$\left(\frac{90}{100}\times IE_{man}\times 0{,}4+\frac{10}{100}\times IE_{rec}\right)$$

DOOR - 3 Usage Cycle (UC)

Weighted value	Usage cycle n° 1				Usage cycle n° 2				Usage cycle n° 3			
	C_Mat	C_FabAss	C_Dis	C_EoL	C_Mat	C_FabAss	C_Dis	C_EoL	C_Mat	C_FabAss	C_Dis	C_EoL
Door_body	0,142	0,302	0,000	-0,127	0,142	0,302	0,000	-0,127	0,142	0,302	0,000	-0,127
Door_Steel_Handle	0,014	0,004	0,000	0,001	0,001	0,000	0,000	0,001	0,001	0,000	0,000	-0,009
Door_Ubcap	0,013	0,004	0,000	-0,008	0,013	0,004	0,000	-0,008	0,013	0,004	0,000	-0,008
Door	0,169	0,309	0,000	-0,134	0,157	0,306	0,000	-0,134	0,157	0,306	0,000	-0,144
Env Impact for each CDU	0,344				0,328				0,319			
Env Impact for 1 usage cycle	0,332											

Ponderated EI (pt, EcoIndicator99)

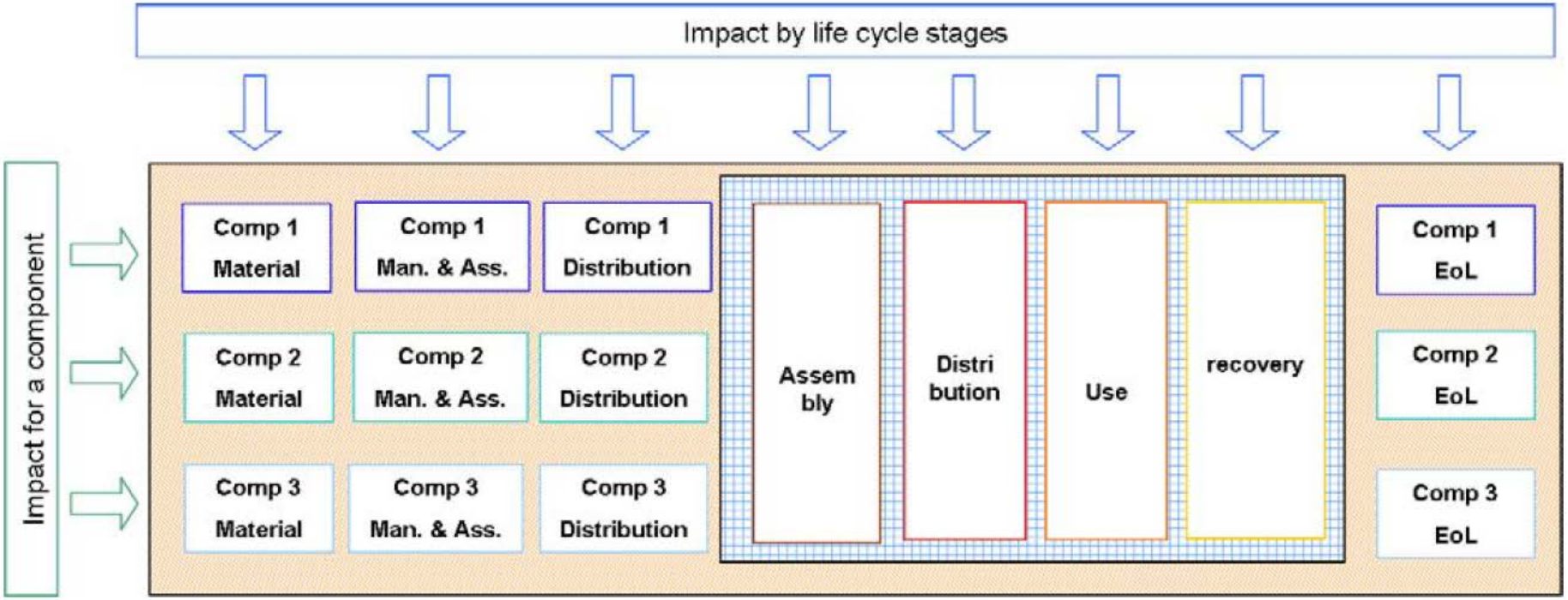
$$\left(\frac{10}{100}\times IE_{man}\right)$$

$$\left(\frac{10}{100}\times IE_{mat}\right)$$

방법

Detailed Design: Gehin et al. (2009) (2/3)

Product lifecycle construction



Detailed Design: Gehin et al. (2009) (3/3)

Environmental impact of the fridge door

DOOR - initial scenario				
Weighted value	Usage cycle n° 1			
	C_Mat	C_FabAss	C_Dis	C_EoL
Door	0,960	8,777	0,000	-0,884
Env Impact for 1 usage cycle	8,852			

Ponderated EI (pt, EcoIndicator99)

Design modification

LC modification : « Remanufacture »

$$\left(\frac{90}{100}\times IE_{man}\times 0{,}4+\frac{10}{100}\times IE_{rec}\right)$$

DOOR - 3 Usage Cycle (UC)												
Weighted value	Usage cycle n° 1				Usage cycle n° 2				Usage cycle n° 3			
	C_Mat	C_FabAss	C_Dis	C_EoL	C_Mat	C_FabAss	C_Dis	C_EoL	C_Mat	C_FabAss	C_Dis	C_EoL
Door_body	0,142	0,302	0,000	-0,127	0,142	0,302	0,000	-0,127	0,142	0,302	0,000	-0,127
Door_Steel_Handle	0,014	0,004	0,000	0,001	0,001	0,000	0,000	0,001	0,001	0,000	0,000	-0,009
Door_Ubcap	0,013	0,004	0,000	-0,008	0,013	0,004	0,000	-0,008	0,013	0,004	0,000	-0,008
Door	0,169	0,309	0,000	-0,134	0,157	0,306	0,000	-0,134	0,157	0,306	0,000	-0,144
Env Impact for each CDU	0,344				0,323				0,319			
Env Impact for 1 usage cycle	0,332											

Ponderated EI (pt, EcoIndicator99)

$$\left(\frac{10}{100}\times IE_{man}\right)$$

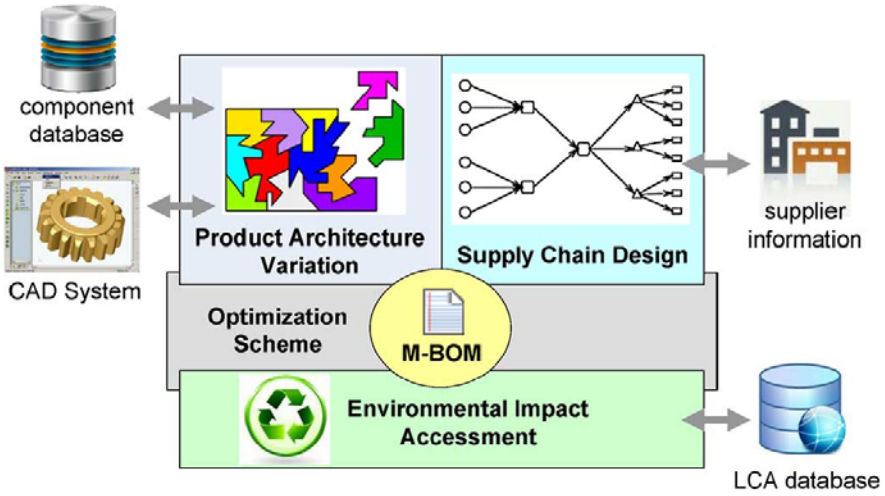
$$\left(\frac{10}{100}\times IE_{mat}\right)$$

방법

Detailed Design: Chu et al. (2012) (1/3)

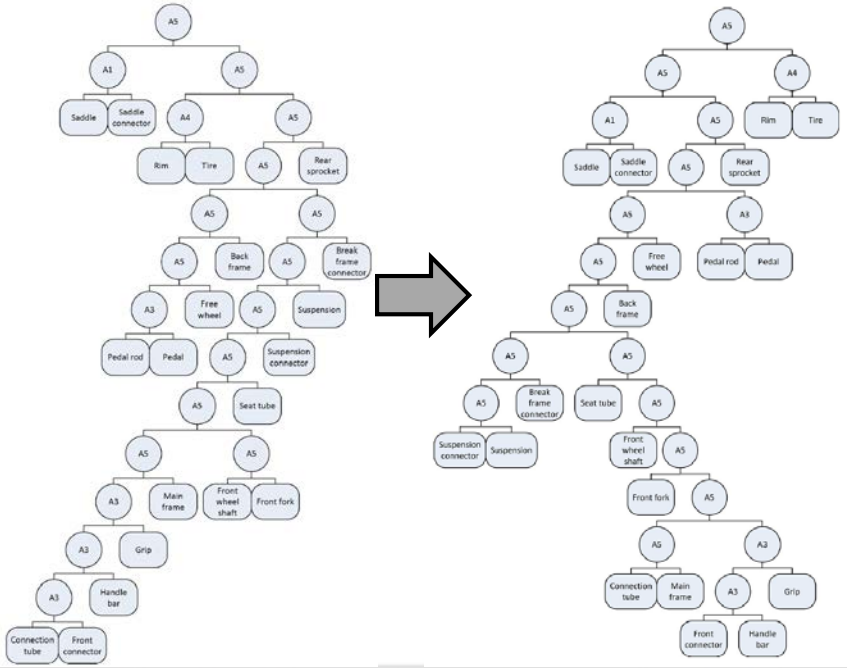
- Title: A concurrent approach to reducing environmental impact of product development at the system design stage
- 주요내용: 제품 개발 시 환경영향을 줄이기 위해 product design, manufacturing, 그리고 supply chain을 동시에 고려할 수 있는 computational framework 개발

Framework of product architecture design based on environmental impact assessment



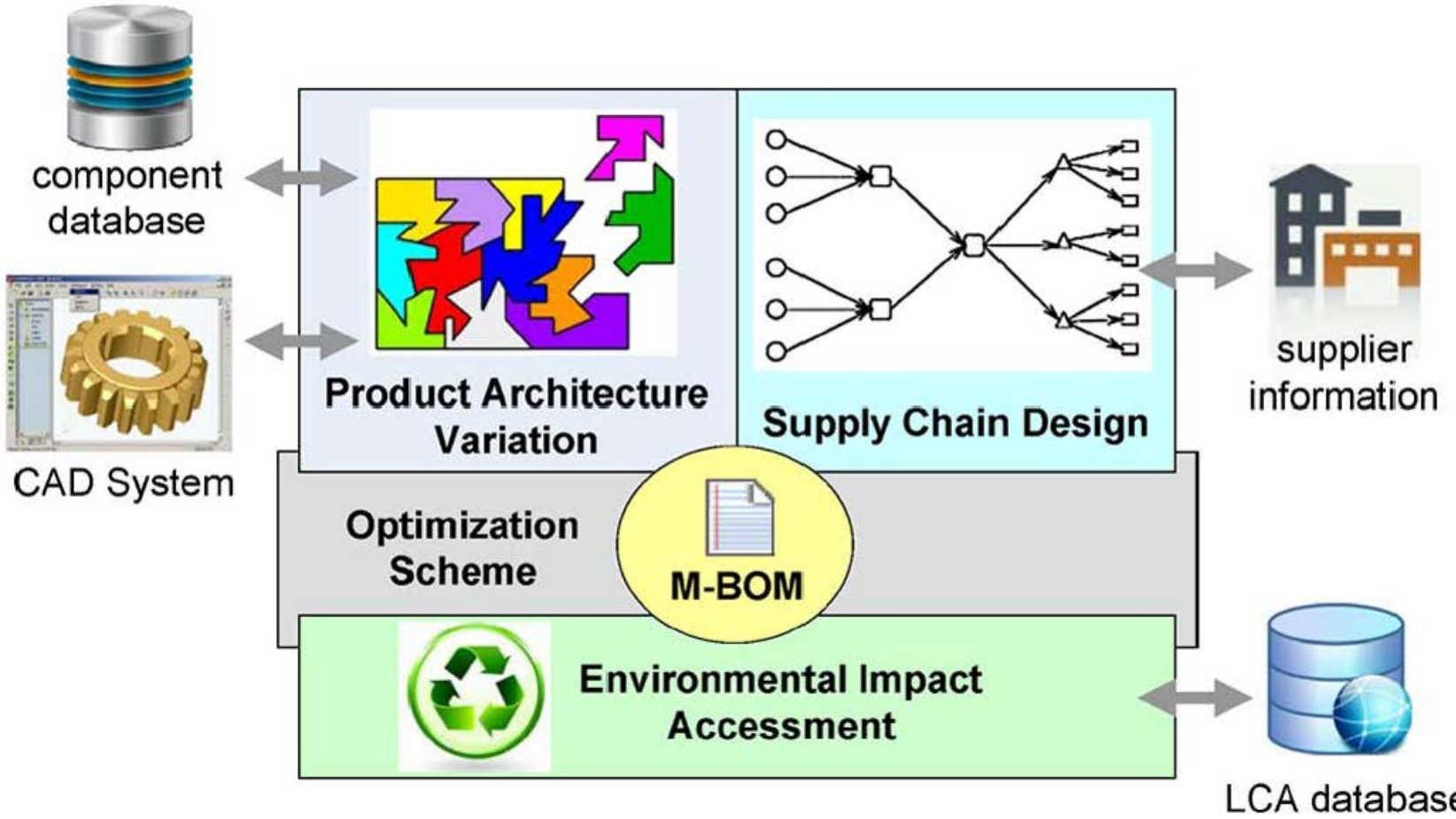
Optimal assembly sequence with reduced CO_2 emission

Optimal assembly sequence with preferred design attributes



Detailed Design: Chu et al. (2012) (2/3)

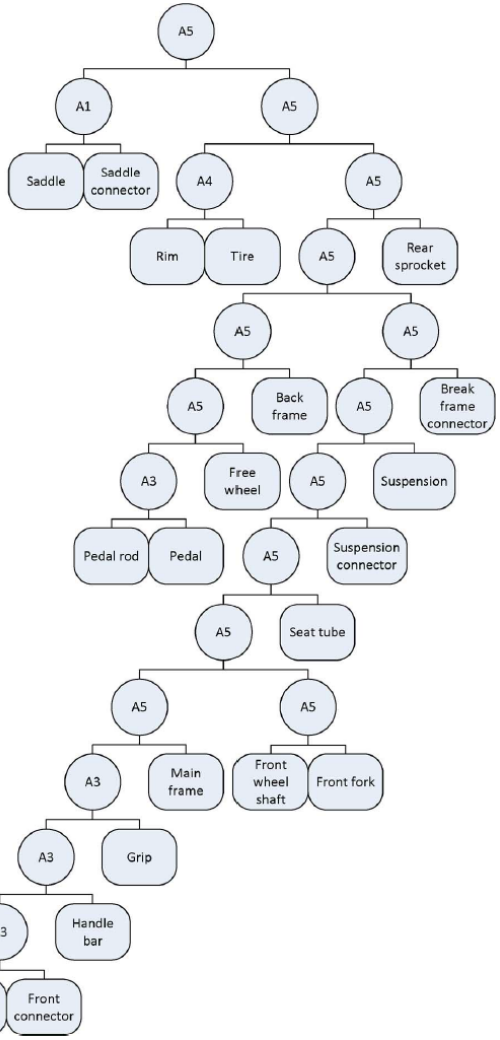
Framework of product architecture design
based on environmental impact assessment



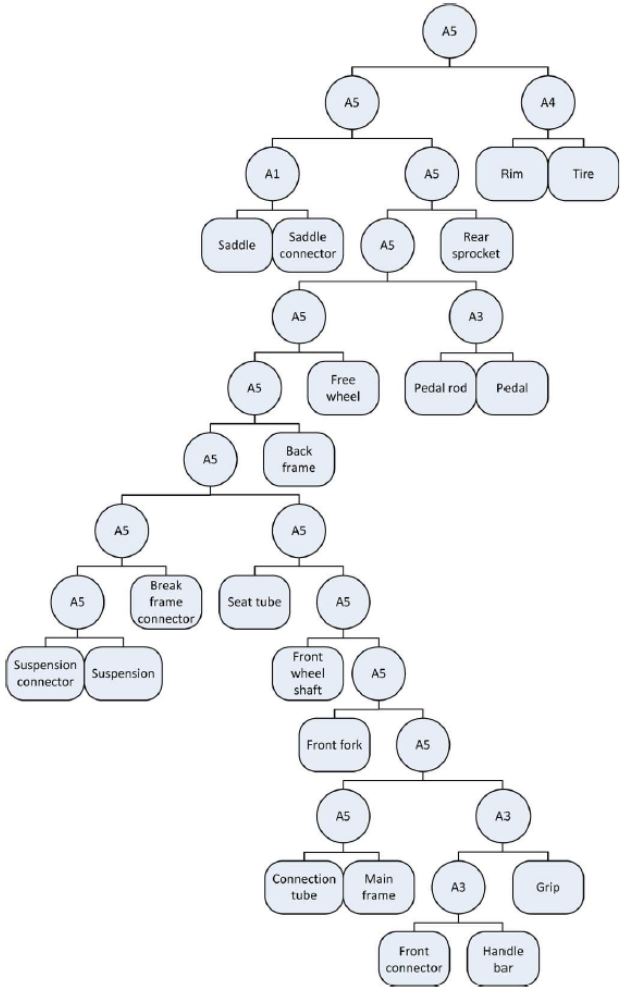
방법

Detailed Design: Chu et al. (2012) (3/3)

Optimal assembly sequence with reduced CO_2 emission



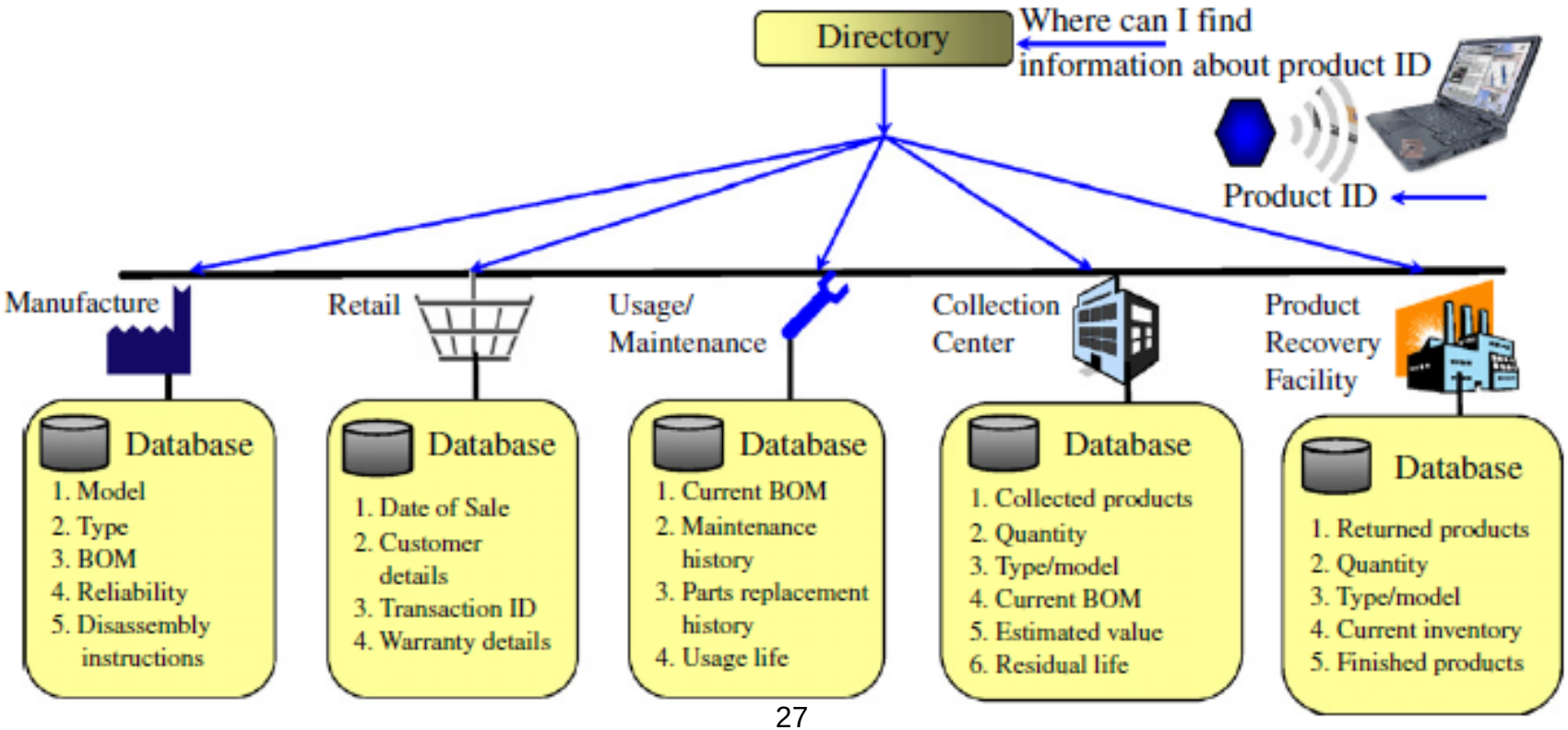
Optimal assembly sequence with preferred design attributes



방법 Detailed Design: Parlikad and McFarlnae (2007)

- Title: RFID-based product information in end-of-life decision making
- 주요내용: 제품 폐기단계에 의사결정을 돕기 위해 RFID 방식의 제품 정보 수집 기술 도입

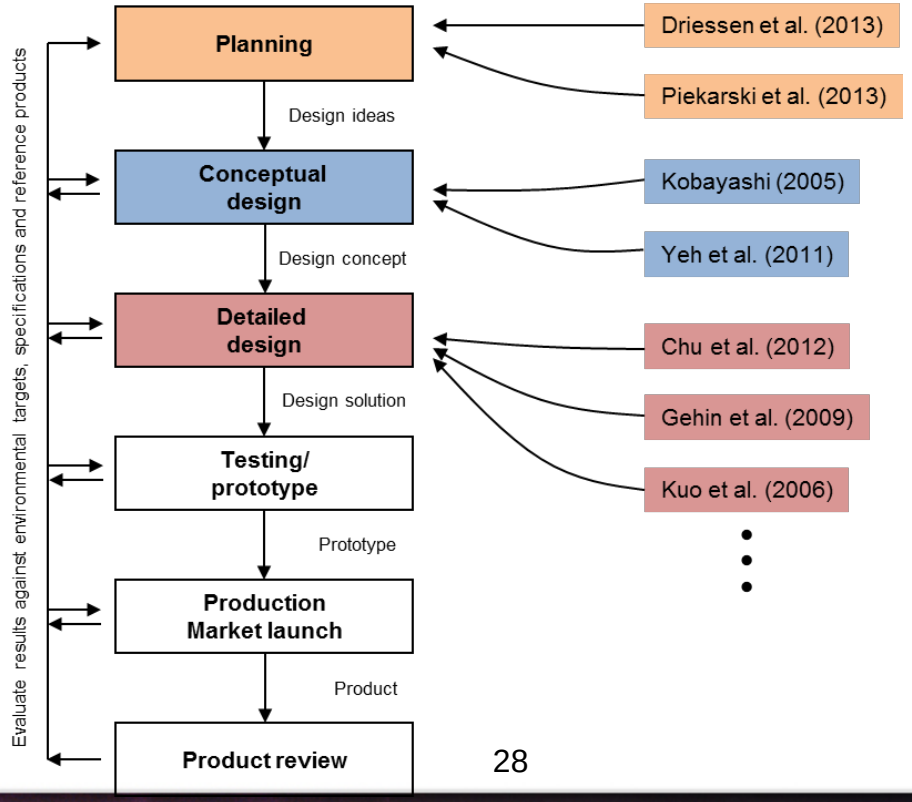
Retrieving product information using “Networked RFID”



Discussion (1/2)

- 본 연구에서는 친환경 제품 개발에 활용될 수 있는 다양한 방법과 전략들을 특성과 용도에 맞게 planning, conceptual design, 그리고 detailed design 단계에 mapping

  ⇒ 기업과 개발자들이 친환경 제품 개발 프로세스의 각 단계별 고려사항을 쉽게 파악하고, 제품의 특성에 따라 선택적으로 활용할 수 있을 것으로 기대됨



Discussion (2/2)

- 기존 친환경 제품들은 환경 요구 사항 충족이 중심이 되었으나 최근에는 고객 요구 사항, 그린 마케팅, 사회적 책임, 지속 가능한 공급망 관리 등이 확장되는 경향을 나타냄

  ⇒ 친환경성뿐만 아니라 경제성, 기능성 등의 다양한 사항들의 종합적 고려 필요

Environmental requirements

Eco Product

고려 사항 확대 필요

Environmental requirements

Customer requirements

Green marketing

Sustainable supply chain management

Q & A

THANK YOU FOR YOUR ATTENTION

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