



Design for Remanufacturing

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Research areas:

**Circular
Economy**

Product Service Systems

Recycling

Remanufacturing

**Design for
remanufacturing**

EcoDesign

Cleaner production

Agenda

- What is Remanufacturing?
- Volvo engine reman in Flen, Sweden
- The generic remanufacturing process
- Industrial examples of remanufacturing
- Drivers for remanufacturing
- Research on remanufacturing
- Design for remanufacturing
- Product design analyses



What is remanufacturing?

“the process of rebuilding a product, during which: the product is cleaned, inspected and disassembled; defective components are replaced; and the product is reassembled, tested and inspected again to ensure it meets or exceeds newly manufactured product standards”

Core

used/broken down products (or components) aimed for remanufacturing



Various terms used in industry and academia

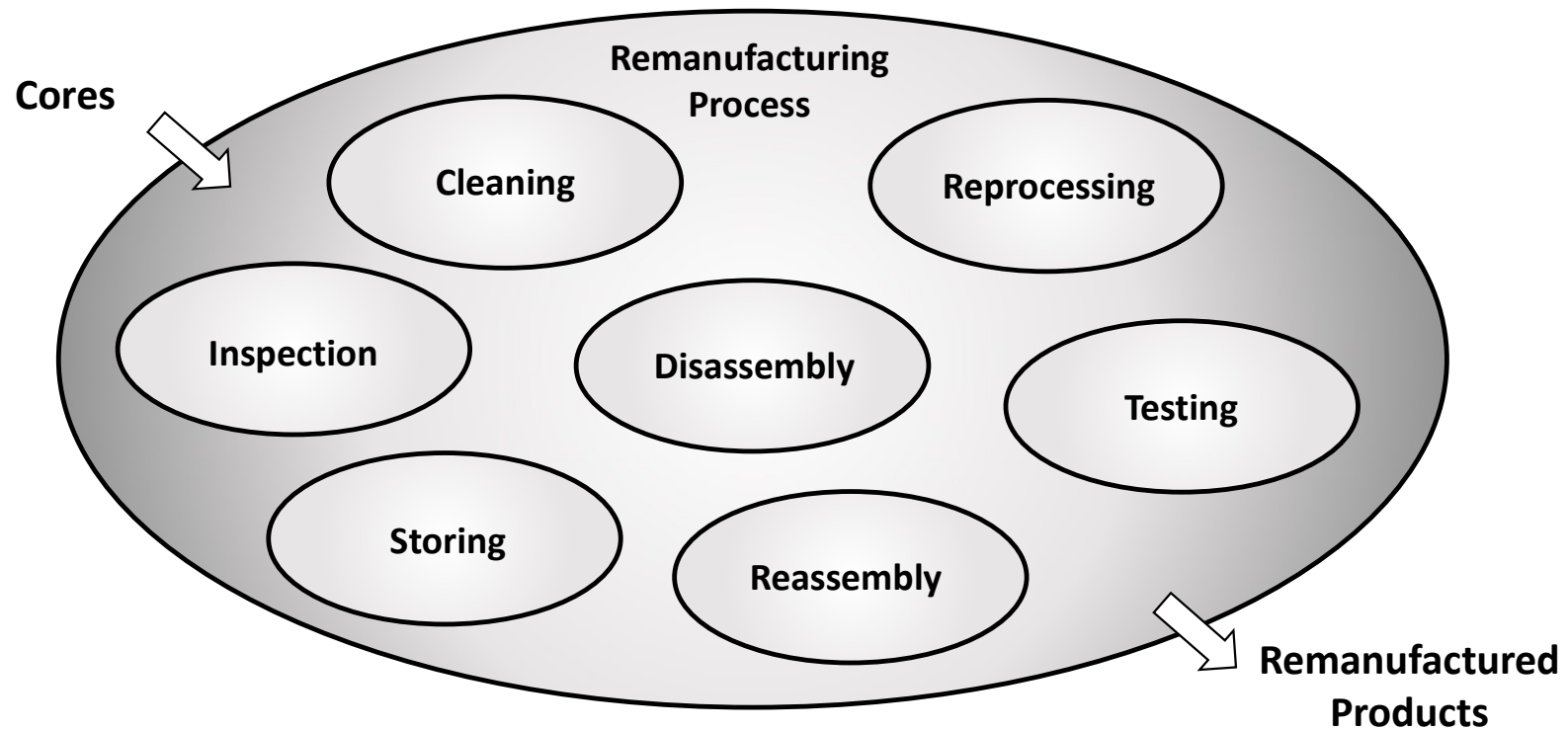
Reman research	Toyota Material Handling	TetraPak
Remanufacturing	Refurbishment	Renovation
Core	Used forklift trucks	2 nd Hand Equipment
Remanufacturing facility	Fleet Management Center	Renovation Center



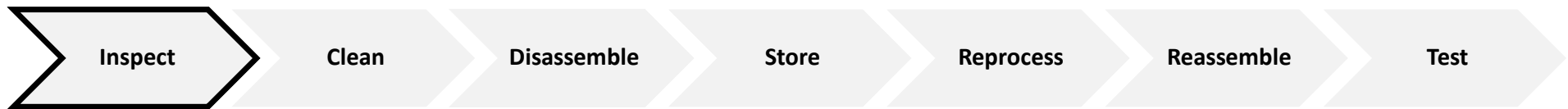
Engine remanufacturing by Volvo Reman in Flen



A generic remanufacturing process



Inspection



- Identify the malfunctions/errors
- Base the inspection from a failure report

Clean



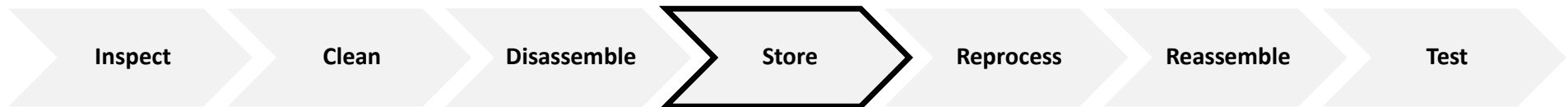
- Choice of cleaning technology
 - which cleaning liquids do the cores withstand?
- Various products have various cleaning difficulties
 - type of product
 - type of behaviour

Disassembly



- Disassembly instructions
- Use of special tools
- Valuable parts are put into storage
- Worn out / broken parts are sent to material recycling / incineration / landfill

Store



- Cores and/or parts are stored until reassembly
- Registration in storage database
- Storage costs

Reprocess



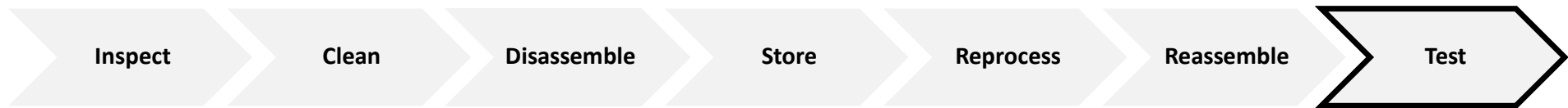
- Cutting and grinding of metal (on e.g. engines)
- Refilling with new material e.g. metal/toner

Reassembly



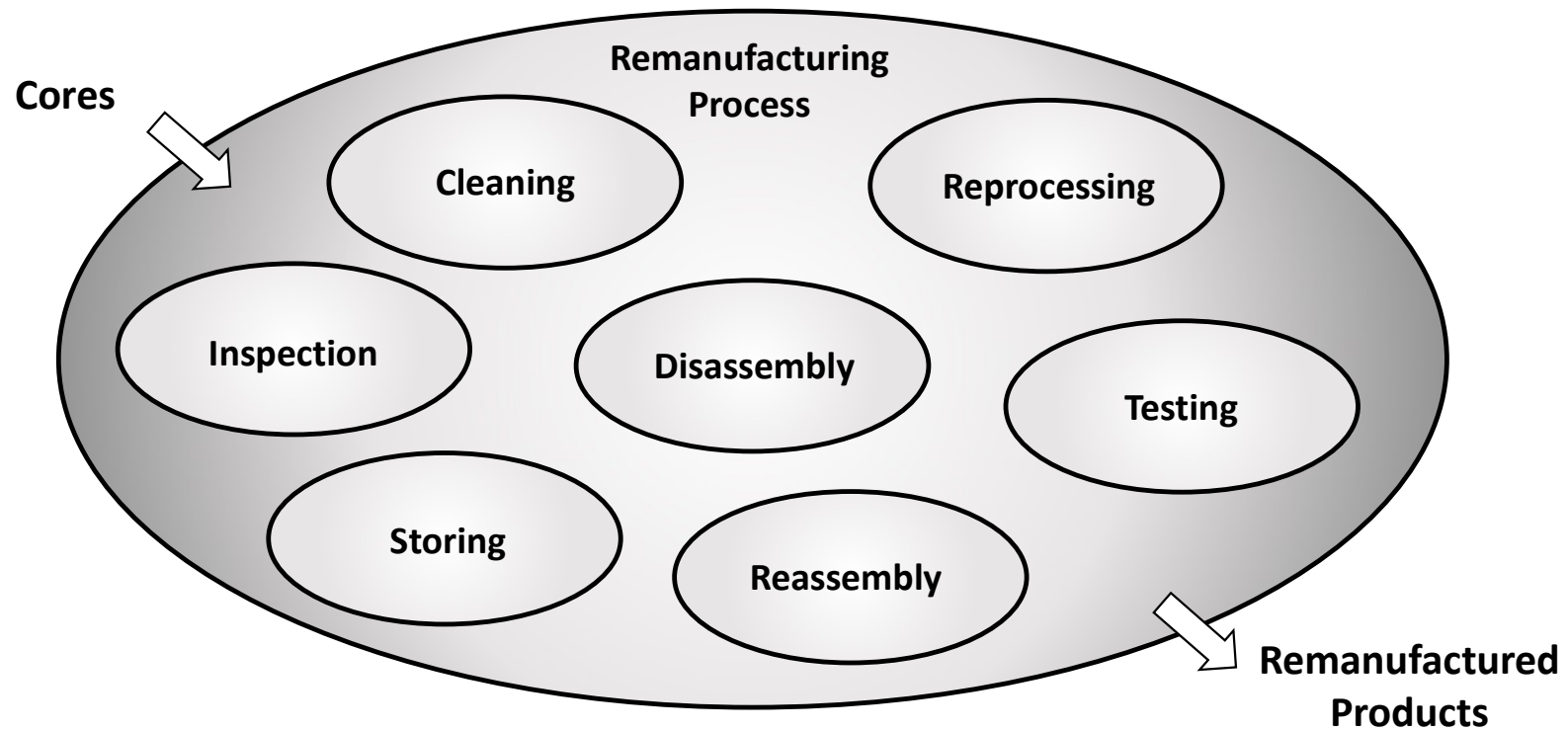
- Choice of fasteners
- Condition of parts
- Upgrading of parts
- Upgrading of software

Testing

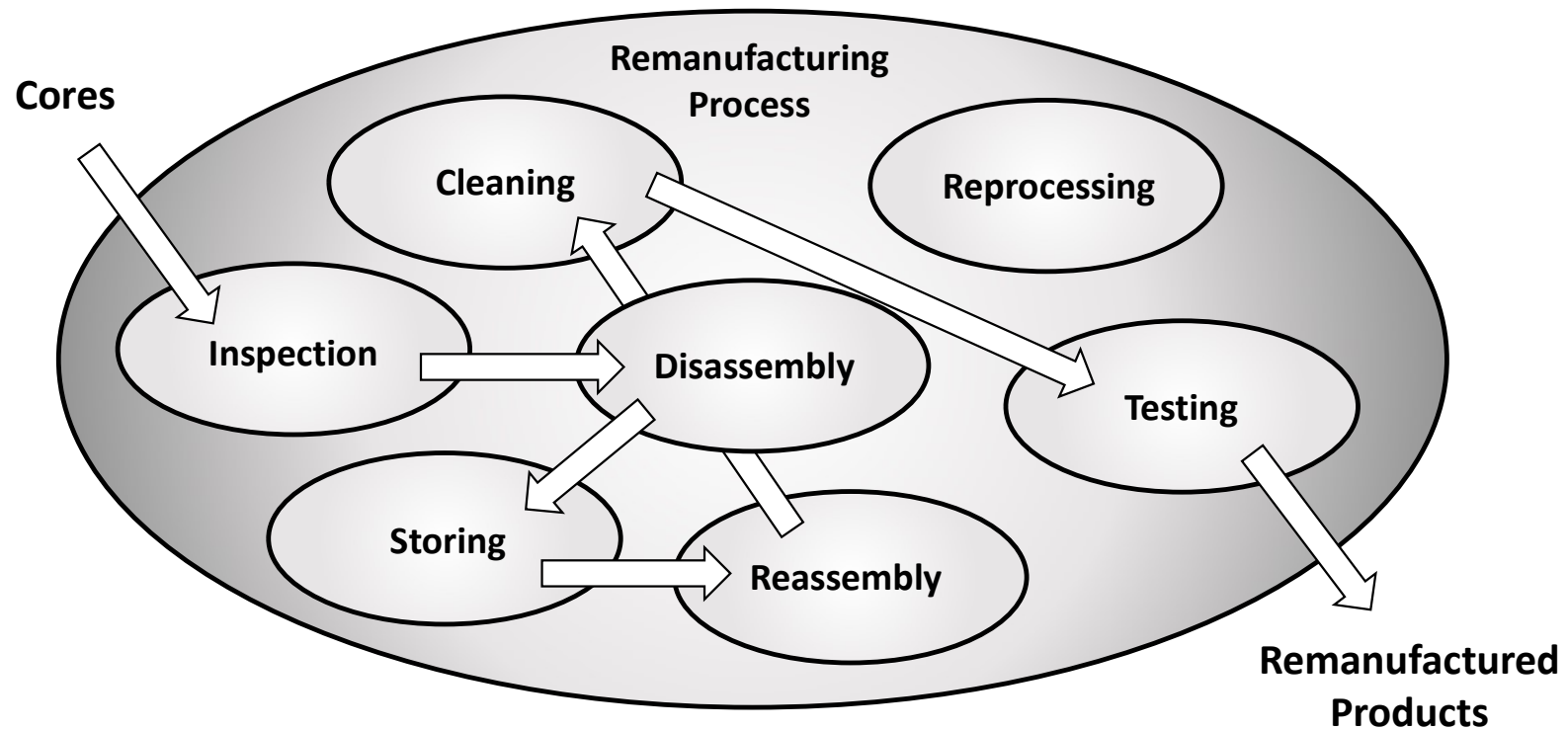


- Final tests made to ensure:
 - Function
 - Safety
 - Quality

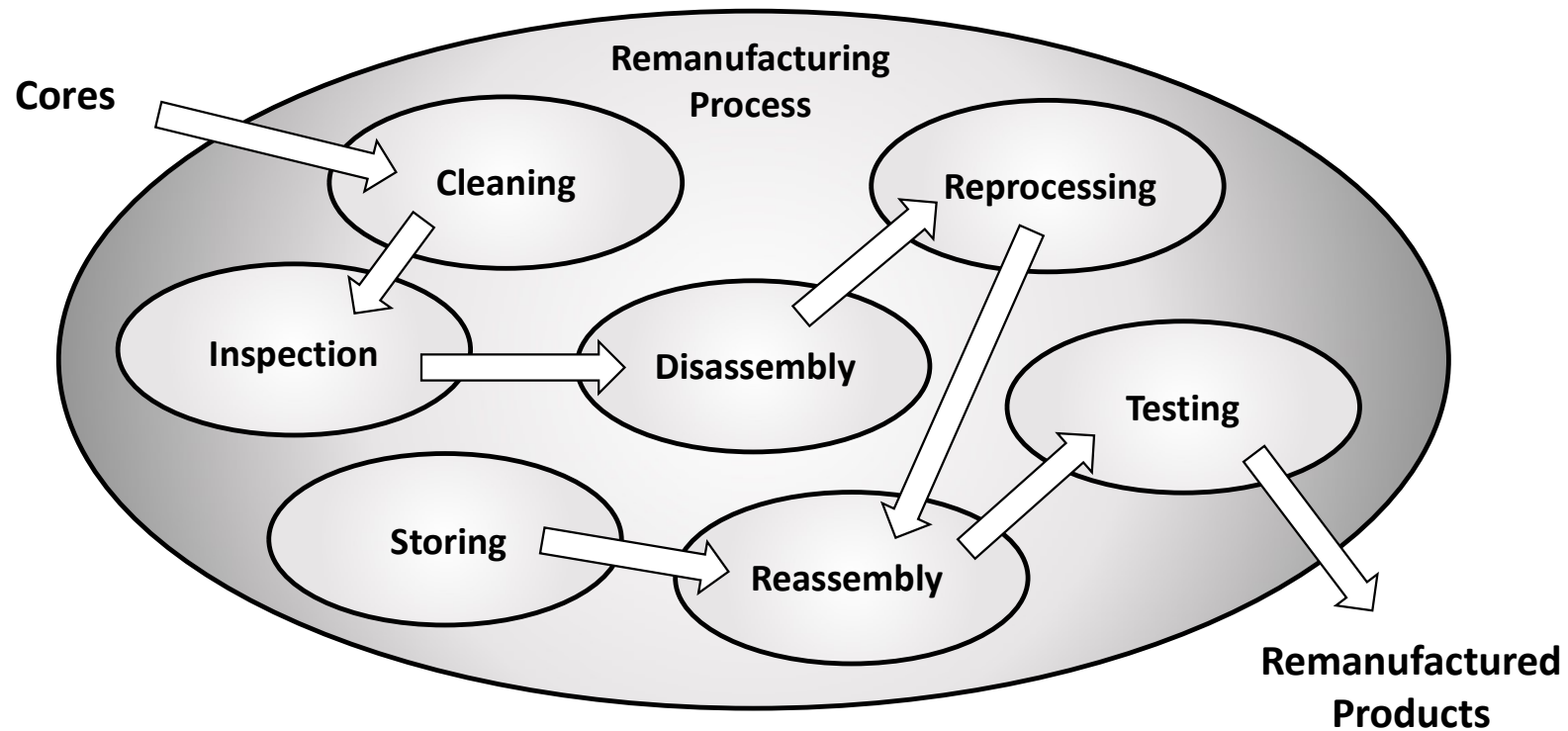
A generic remanufacturing process



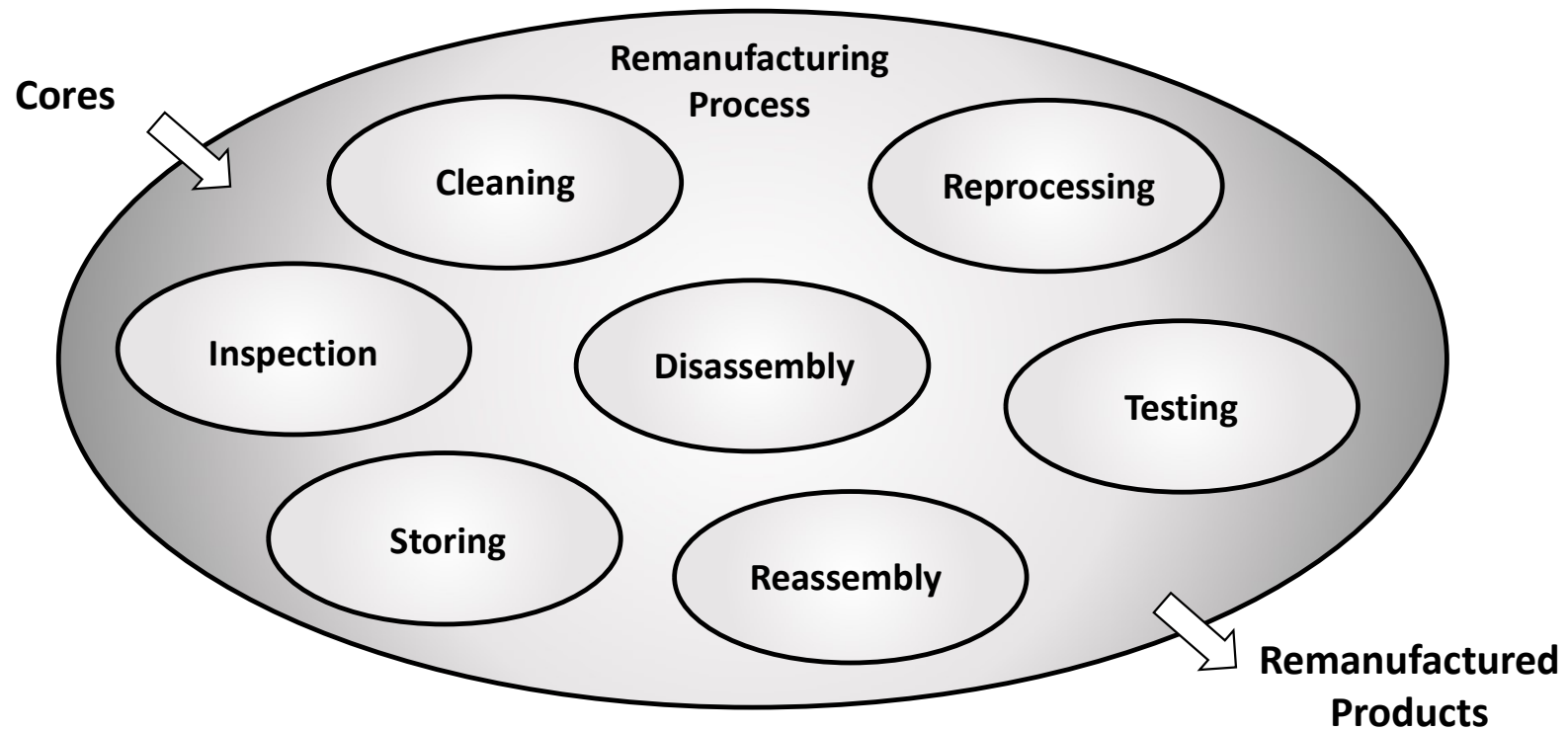
Remanufacturing of household appliances



Remanufacturing of diesel engines



A generic remanufacturing process



UBD Cleantech AB



Remanufactures e.g.:

- Diesel particle filters
- Brake calipers
- Servo pumps
- EGR valves

Web: www.ubd.eu



Facts:

- Remanufacture automotive parts
- Located in Höör (Sweden) and plants in Stettin and Wroclaw (Poland)
- 130 employees (around 50 in Höör)
- Order winning quality but low productivity (manual)
- Few competitors
- Customers
 - Car manufacturers (service workshops)
 - Retailers of car components, Mekonomen etc.

Inrego AB



Remanufactures e.g.:

- Laptops
- Desktops
- Smart phones
- Tablets
- Screens

Web: www.inrego.se



Facts:

- Remanufacture IT equipment
- Located in Täby (Sweden) and expanding to Helsinki (Finland)
- 160 employees
- 25 000 products each month
- Customers include companies, organizations, private consumers e.g. Skanska, Telia, Lund University, Cloetta, RISE

Source: Sundin E., Sakao T., Lindahl M., Kao C.C., Joungerious B. and Ijomah W. (2016) Map of Remanufacturing Business Model Landscape, ERN - European Remanufacturing Network. The ERN Business Model Report is available at: www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf + company website www.inrego.se



re-form
commercial
office furniture



re-form
commercial
office furniture







Enterprise Services

For more than 30 years, Re-form has been adding depth to furniture reuse programs all across the country. Whether your organization is large, small or somewhere in between....

Re-form Office Furniture Remanufacturing



DAVIES
OFFICE

DAVIES
OFFICE

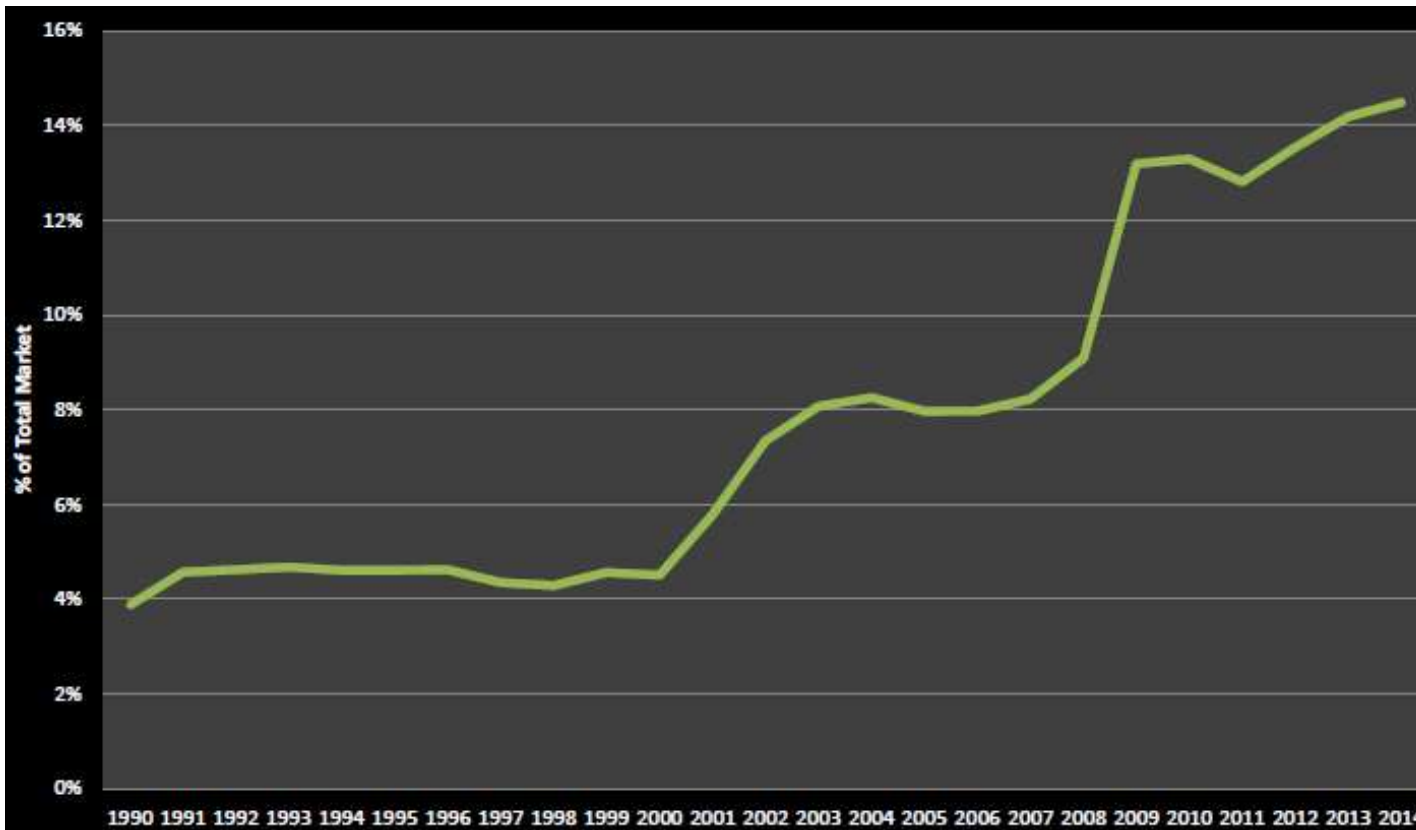


DAVIES
OFFICE

A photograph of a modern office workspace. In the foreground, a white desk is partially visible. A red office chair is positioned to the left. On the desk, there is a black laptop that is open. A black desk lamp with a flexible arm is also on the desk. In the background, there are glass partitions and another desk area. The overall lighting is bright and even.

***THIS IS
REMANUFACTURED***

US market of remanufactured/refurbished furniture



37 times better!



Source: William E Davies, Presentation vid World Remanufacturing Summit (2015) Amsterdam, Holland. www.daviesoffice.com

Company incentives for remanufacturing

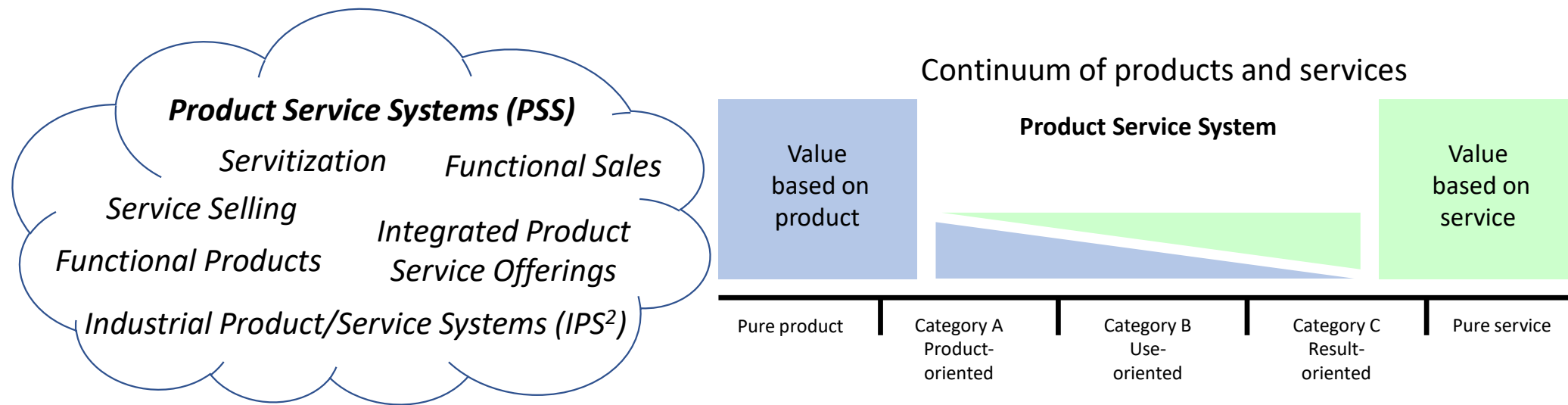
Profit

- Cost reductions
- Customer needs
- Providing spare parts
- Targeting new market segment with reman products
- New business models (i.e. way of selling things e.g. Product as a Service)

Product as a Service (PaaS)

Selling the function of a product rather than the product itself

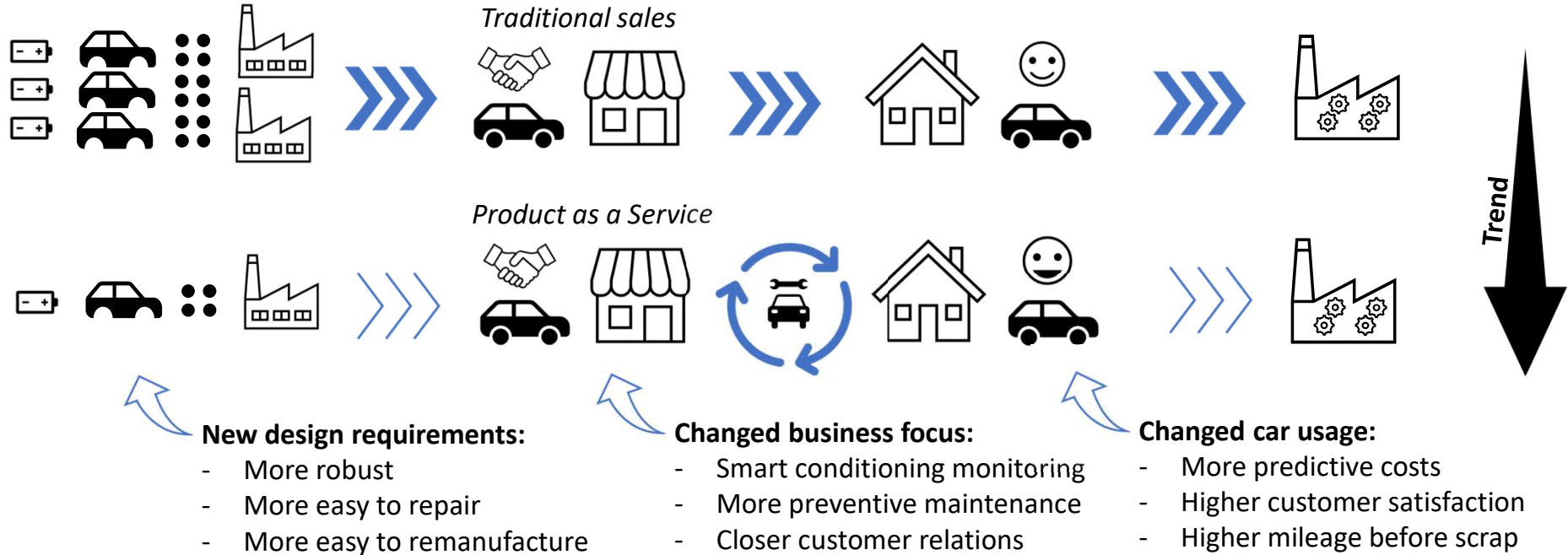
- number of copies instead of a photocopier
- number of flight hours instead of an aircraft engine



Tischner och Verkuijl (2002)

Product as a Service (PaaS) / Servitization

Changes in product and component flows



Product as a Service (PaaS)

Supplier(s)	Physical equipment	PaaS type
Toyota Material Handling	Forklift trucks	Rental plans
Swepac / Ramirent	Soil compactors	Rental contracts
Electrolux	Robot vacuum cleaners	Rental contracts



Hyr en
robotdammsugare



Pure i9.2 Robotdammsugare

Toyota Material Handling Sweden

Don't buy trucks

**It makes sense to use a
fleet of trucks to facilitate
efficient
materials handling**

**- but you don't have to own it to
use it**



Facts about TMHS:

- Remanufacture forklift trucks
- Situated in Mjölby, Sweden
- 30 employees
- >75% are sold through rental (PaaS)



Company incentives for remanufacturing

Profit

- Cost reductions
- Customer needs
- Providing spare parts
- Targeting new market segment with reman products
- New business models (i.e. way of selling things e.g. Product as a Service)

Environment

- Directives / Legislation
- Moral and ethical reason

Company incentives for remanufacturing

Profit

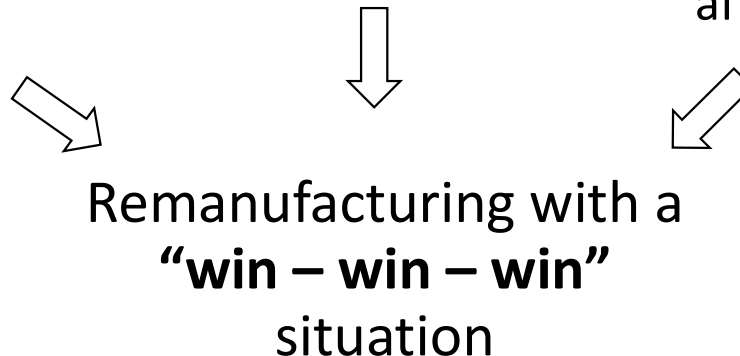
- Cost reductions
- Customer needs
- Providing spare parts
- Targeting new market segment with reman products
- New business models (i.e. way of selling things e.g. Product as a Service)

Environment

- Directives / Legislation
- Moral and ethical reason

Policy

- Protecting aftermarket
- Protecting brand
- Providing additional aftermarket solutions



European Remanufacturing Network (ERN) (2015-2017)

Ambitions:

- Encourage new businesses to take up remanufacturing
- Help existing remanufacturers improve their operations
- Improve competitiveness of remanufacturers domestically and internationally
- Create greater awareness of remanufacturing to increase demand and address barriers

Deliverables:

- Market Study on Remanufacturers in Europe: 200-300 remanufacturing companies.
- Best practises of Business Models / Product Design / Remanufacturing Processes
- Workshops and recommendations for policy makers, researchers and industry



European Remanufacturing Council

Website: www.remanufacturing.eu



Linköping University



European remanufacturing industry sectors

Sectors	Turnover (€bn)	Firms	Employment	Cores ('000)	Intensity*
Aerospace	12.4	1,000	71,000	5,160	11,5%
Automotive	7.4	2,363	43,000	27,286	1,1%
EEE	3.1	2,502	28,000	87,925	1,1%
Furniture	0.3	147	4,000	2,173	0,4%
HDOR	4.1	581	31,000	7,390	2,9%
Machinery	1.0	513	6,000	1,010	0,7%
Marine	0.1	7	1,000	83	0,3%
Medical equipment	1.0	60	7,000	1,005	2.8%
Rail	0.3	30	3,000	374	1.1%
Total	29.8	7,204	192,000	132,405	1,9%

*Intensity = ratio of remanufacturing to new manufacturing; EEE = Electronic and Electrical Equipment; HDOR = Heavy Duty and Off-Road equipment

Source: Parker, D., Riley, K., Robinson, S., Symington, H., Tewson, J., Jansson, K., Ramkumar, S., and Peck, D. (2015).
 ERN - European Remanufacturing Network, Remanufacturing Market Study. Delft, The Netherlands: European Remanufacturing Council,
 The ERN Market Report is available at: www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf

Business Model Survey



Business Model Descriptions

Company / Location

Type of Remanufacturer

Experience in remanufacturing

Sector / Product

Contact / Website

Core sourcing

Business model

Value chain

Remanufacturing process

Customer value

Economic benefits

Economic challenges

Key resources

Environmental benefits

Social benefits



ACES	Inrego	Schmitz+Krieger
ARP Suppliers	IT-Lyftet	SCM Turbo
ATP Industries	Leapp	Siemens ITAB
Autoelectro	Linde	Stone Computers
Borg Automotive	Oerlikon LV	Storebro Industrier
Büroservice Hübner	Polyplank	Ståthöga MA Teknik
Carwood	PSS	Toyota MHS
Desko	RDC	UBD Cleantech
ES Power	RobotIF	UBD Cleantech
Hitachi CME	Scandi-Toner	Vector Aerospace

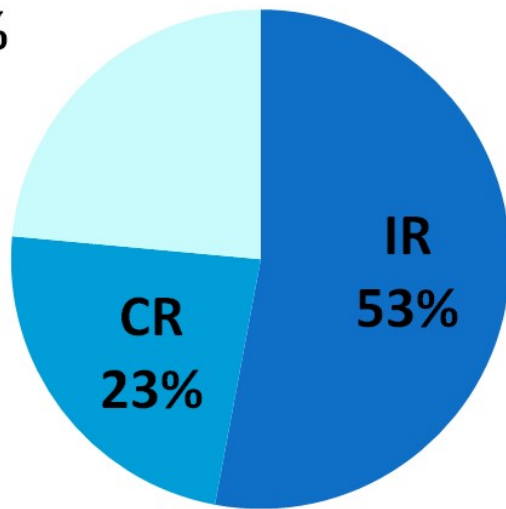
Source: Sundin E., Sakao T., Lindahl M., Kao C.C., Joungerious B. and Ijomah W. (2016) Map of Remanufacturing Business Model Landscape, ERN - European Remanufacturing Network. The ERN Business Model Report is available at: www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf



Business Model Survey

Type of remanufacturer

OEM/OER
24%



OEM/OER = Original Equipment Manufacturer/Remanufacturer

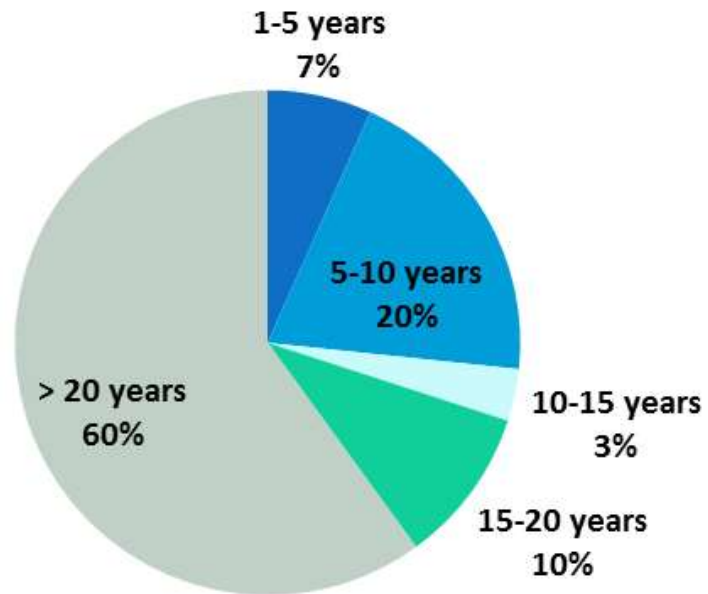
CR = Contracted Remanufacturer

IR = Independent Remanufacturer

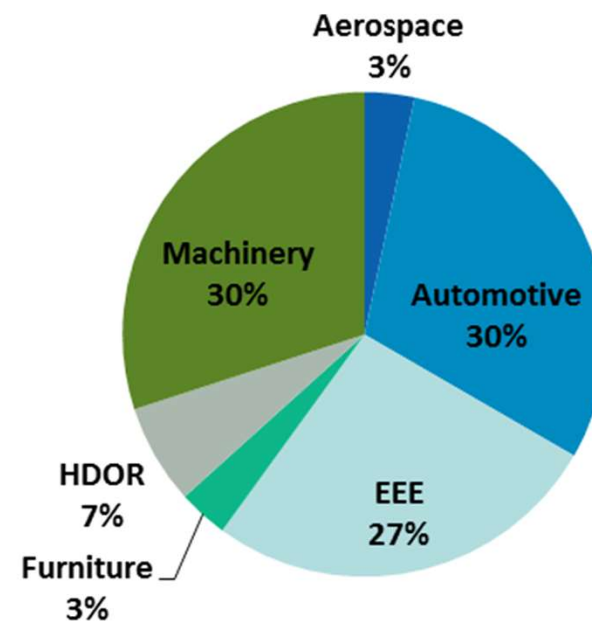


Business Model Survey

Experience of remanufacturing



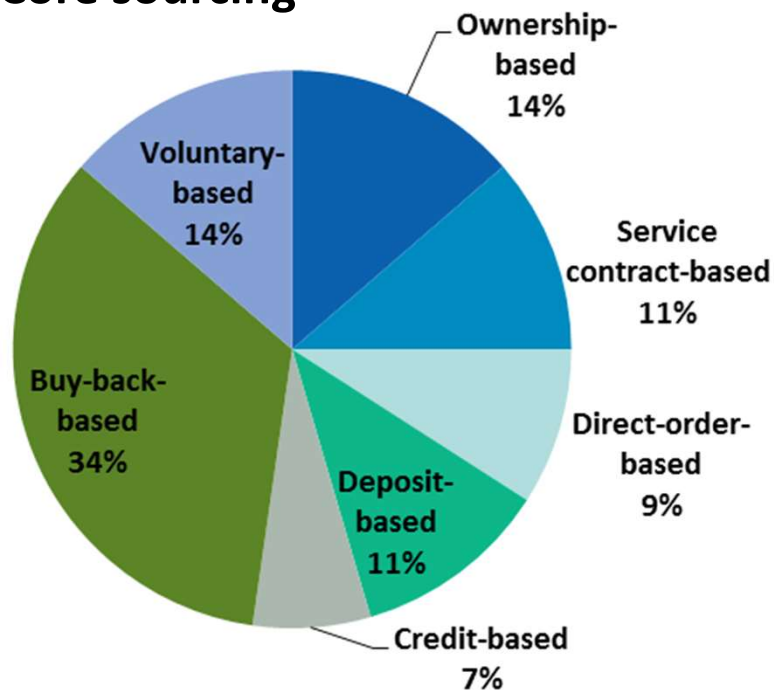
Industrial sectors



Source: Sundin E., Sakao T., Lindahl M., Kao C.C., Joungerious B. and Ijomah W. (2016) Map of Remanufacturing Business Model Landscape, ERN - European Remanufacturing Network. The ERN Business Model Report is available at: www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf

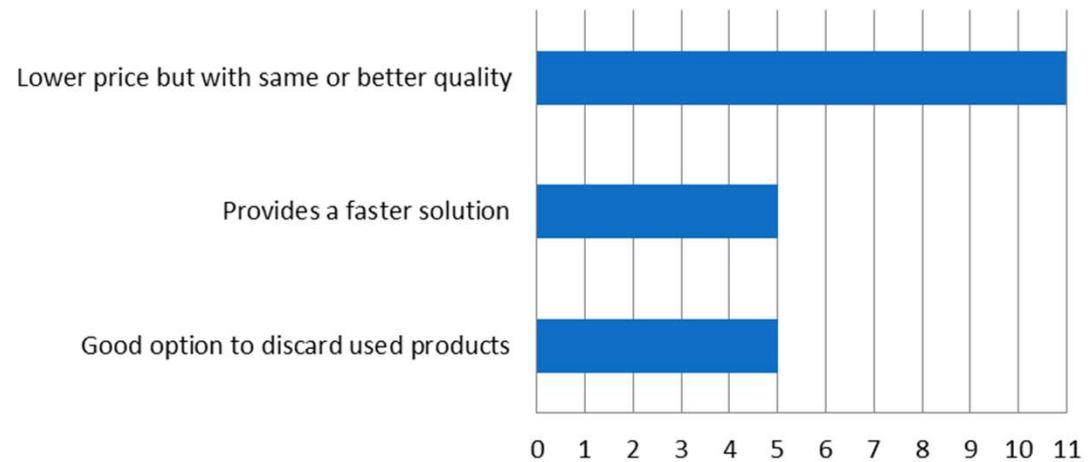
Business Model Survey

Core sourcing



Customer values

Most companies say it is a **price-worthy option** in comparison to new products.



Source: Sundin E., Sakao T., Lindahl M., Kao C.C., Joungerious B. and Ijomah W. (2016) Map of Remanufacturing Business Model Landscape, ERN - European Remanufacturing Network. The ERN Business Model Report is available at: www.remanufacturing.eu/assets/pdfs/remanufacturing-market-study.pdf

Funded by the Horizon 2020
Framework Programme of
the European Union



Business Model Survey

Price reductions

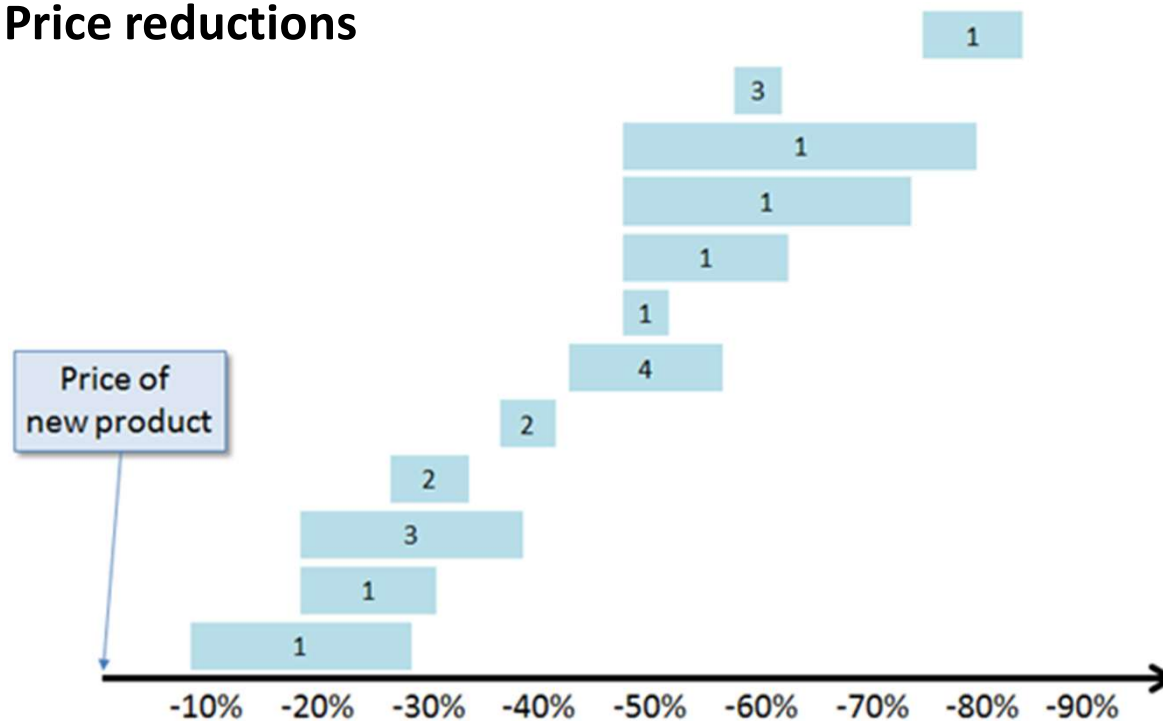
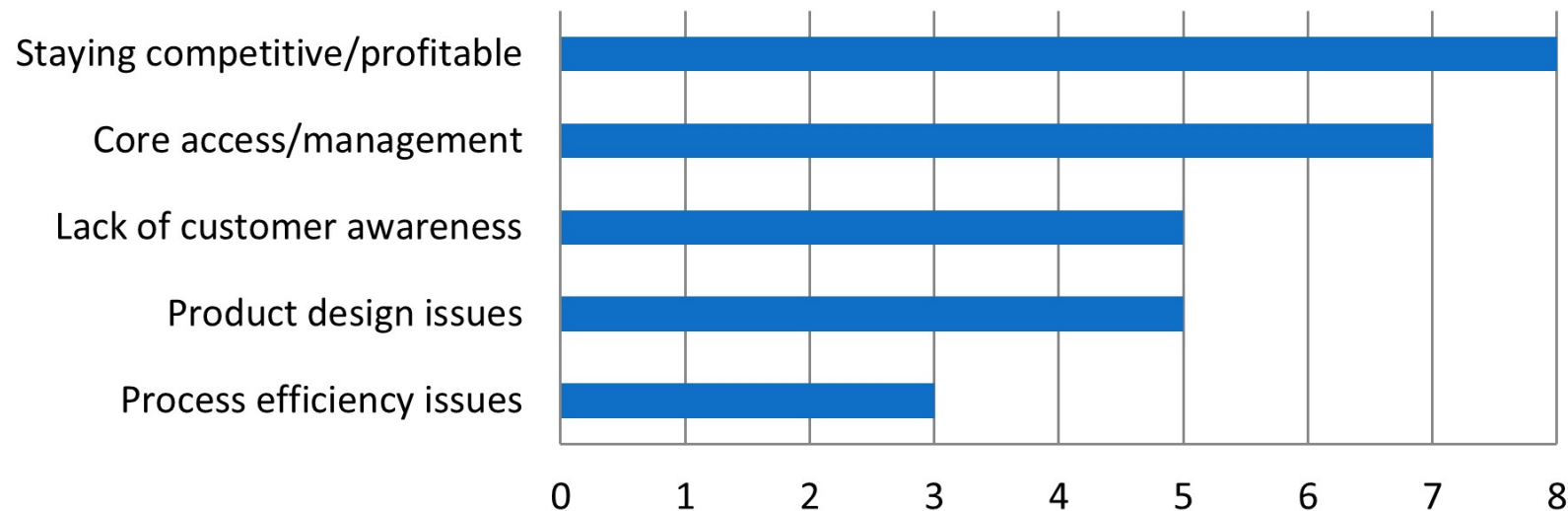


Fig 12. Reductions in prices. The length of the bars illustrate the price reduction range while the number in brackets responds to the number of cases.

Business Model Survey

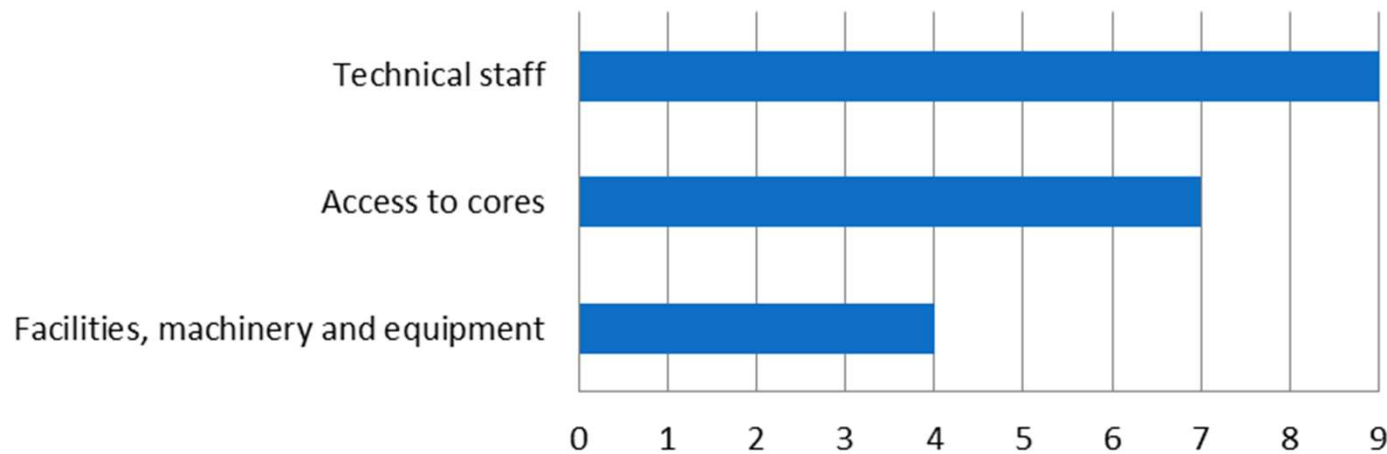
Economic challenges



Business Model Survey

Key resources

Many companies mentioned their **staff**, **access to cores**, **remanufacturing know-how**, and **equipment and facilities** as their key resources for their remanufacturing business.



“Core is king!” -
Malcolm Morris
OEM Sales Manager
ATP Industries Group



Academic remanufacturing researchers around the world



Prof. Winifred Ijomah
University of Strathclyde,
Glasgow, SCO
Areas: e.g. Automotive

Prof. Erik Sundin
AProf. Jelena Kurilova-Palisaitiene
PhD Stud. Johan Vogt Duberg
Linköping University, SWE **Areas:** e.g.
Automotive, Forklift trucks, Electronics



Dr. Matsushita Matsumoto
Center for Service Research, AIST, JPN
Prof. Yasushi Umeda
Osaka University, Japan
Area: Electronic Industry



Prof. Nabil Nasr
Rochester Institute of
Technology, USA
Areas: Military vehicles,
Printing machines, Toner
cartridges, Automotive



**Prof. Peggy
Zwolinski**
Univ. of Grenoble,
FRA **Areas:** e.g.
Automotive



Prof. Rolf Steinhilper
Bayreuth University, GER
Area: Automotive



Prof. Sheng Zhu
National Key Laboratory,
Beijing, CHI
Area: e.g. Automotive

World perspective

Results from 2520 Answers to Questionnaire and Media

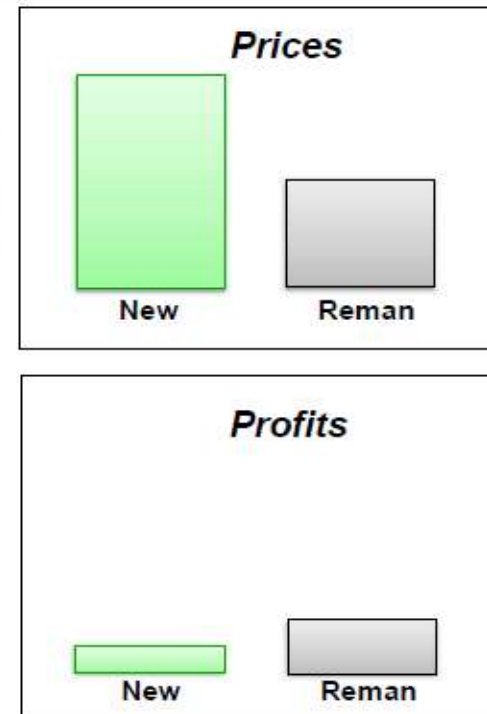
- Garages spend 50% of total repair times for failure diagnosis and faulty part identification.
- Only 25% of the customers request "Original-New-Parts" to repair their car.
- 47% of the garages would – if available – use remanufactured parts instead of new parts.
- Used parts (e. g. ebay) are considered important by 33%.
- 97% of the garages wish to use more types of remanufactured parts instead of expensive new parts if available.



Source: Rolf Steinhilper, Bayreuth University, Germany

World perspective

Prices and Profits (Example)

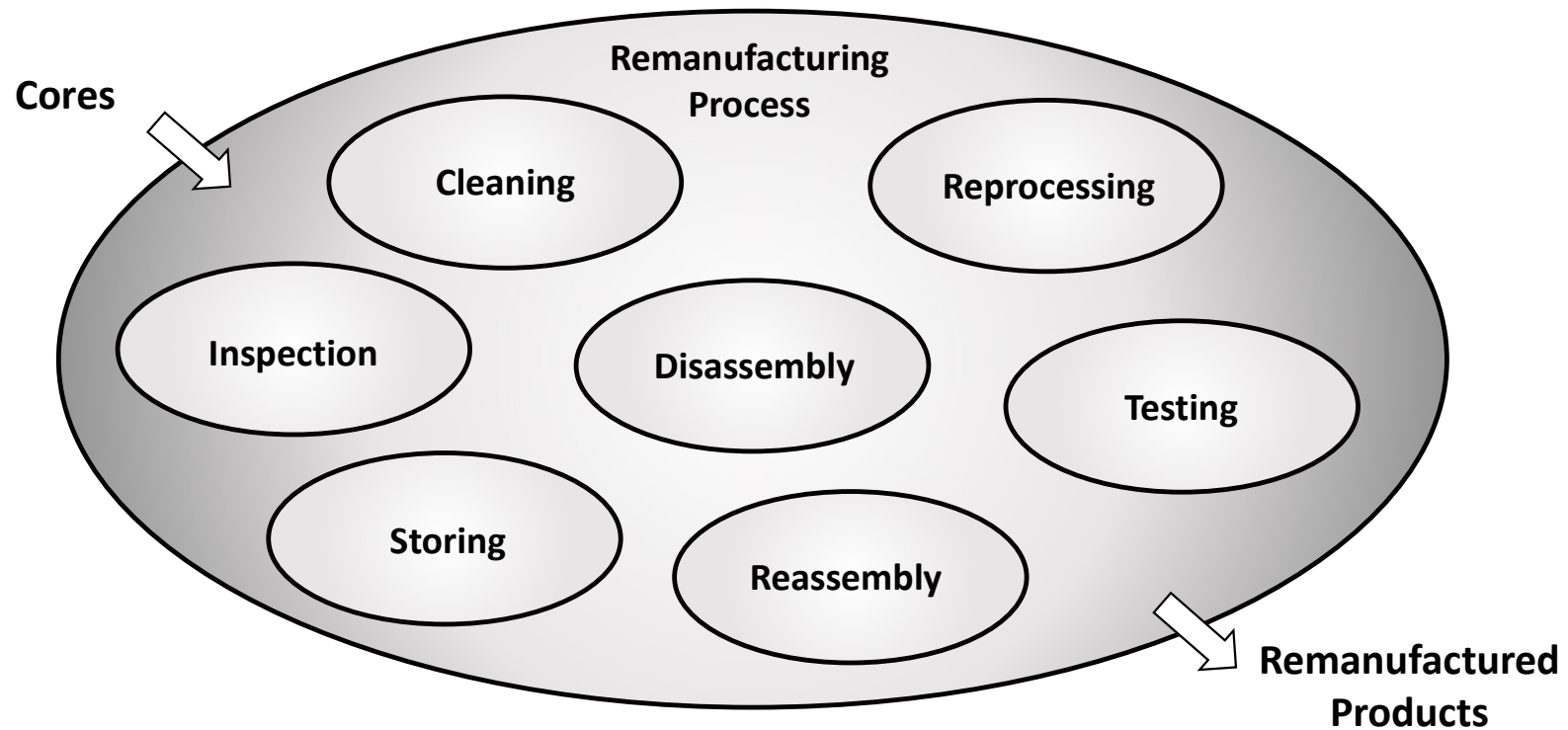


Source: Rolf Steinhilper, Bayreuth University, Germany

Sources and further reading on remanufacturing

- **Remanufacturing in the Circular Economy – Operations, Engineering and Logistics**
Nabil Nasr (ed), Scrivener publishing (2020) ISBN: 9781118414101 (213 pages).
- **Prerequisite factors for original equipment manufacturer remanufacturing**
Vogt Duberg J., Johansson G., Sundin E. & Kurilova-Palisaitiene J. (2020)
Journal of Cleaner Production, Vol 270, 122309.
- **Business Drivers for Remanufacturing**
Östlin J., Sundin E. & Björkman M. (2008) 15th CIRP International Conference on Life Cycle Engineering, Sydney, The University of New South Wales, Australia.
- **Importance of Closed-Loop Supply Chain Relationships for Product Remanufacturing**
Östlin J., Sundin E. & Björkman M. (2008) Int. Journal of Production Economics, 115(2), pp 336-348.
- **Making Functional Sales Environmentally and Economically Beneficial through Product Remanufacturing**, Sundin E. & Bras B. (2005) Journal of Cleaner Production, Vol. 13(9), pp 913-925.

A generic remanufacturing process



Preferable product properties of remanufacturing

RemPro Matrix

Remanufacturing Step Product Property	Inspection	Cleaning	Disassembly	Storage	Reprocess	Reassembly	Testing
Ease of Identification	x		x	x			x
Ease of Verification	x						
Ease of Access	x	x	x		x		x
Ease of Handling			x	x	x	x	
Ease of Separation			x		x		
Ease of Securing						x	
Ease of Alignment						x	
Ease of Stacking				x			
Wear Resistance		x	x		x	x	

FUJI Film – Quick snap



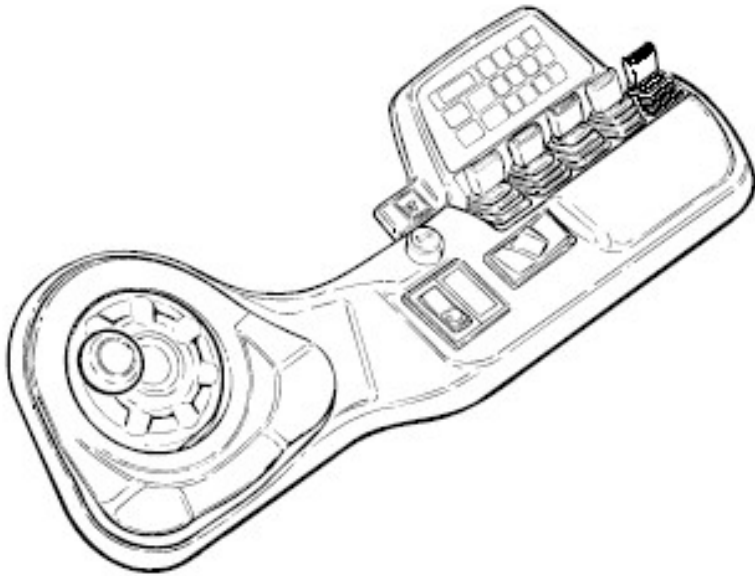
Source: Sundin E. and Lindahl M. (2008) Rethinking Product Design for Remanufacturing to Facilitate Integrated Product Service Offerings, Proceedings of IEEE International Symposium on Electronics and the Environment (IEEE-08), San Francisco, USA.

Toyota Material Handling forklift truck remanufacturing in Mjölby (Sweden)

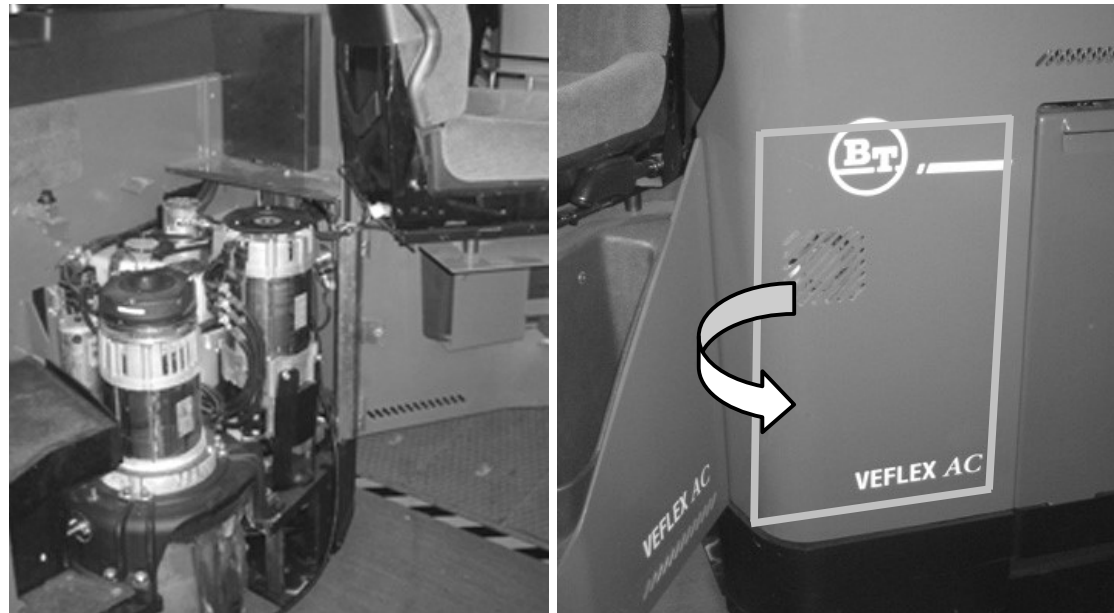


Forklift truck design analysis

Maneuver console and regulating knobs

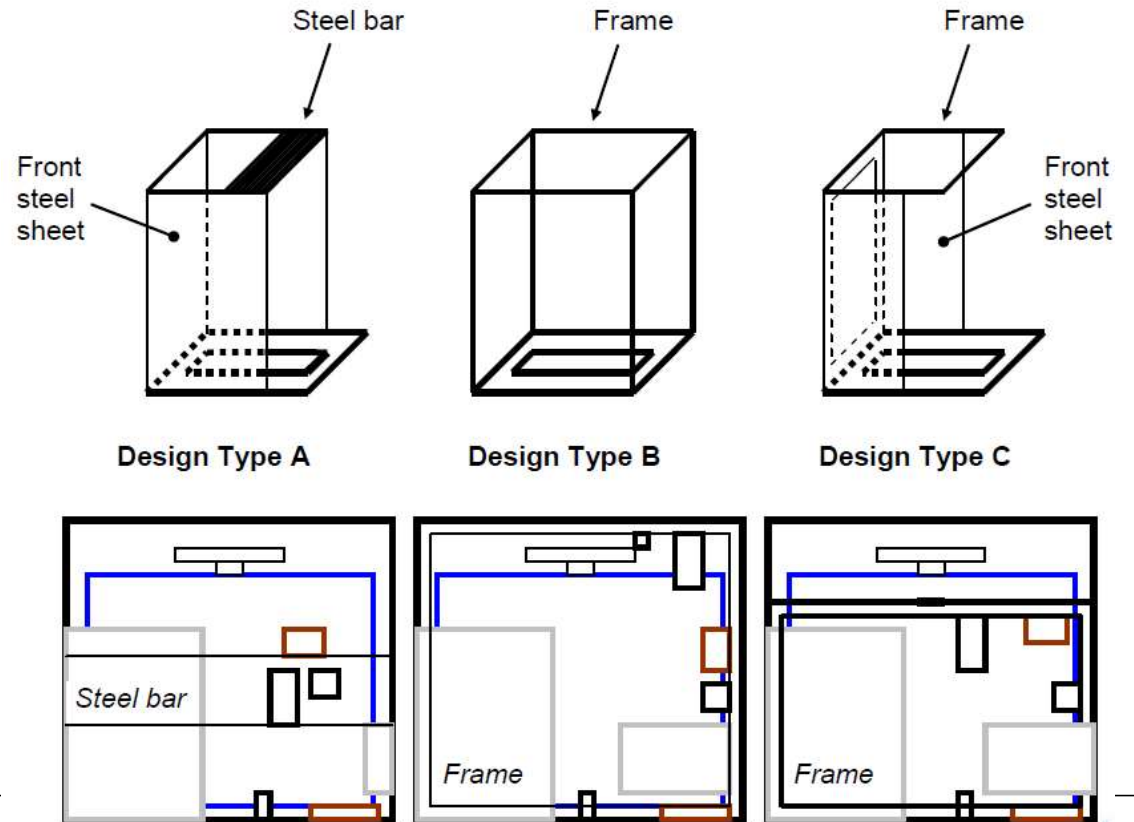
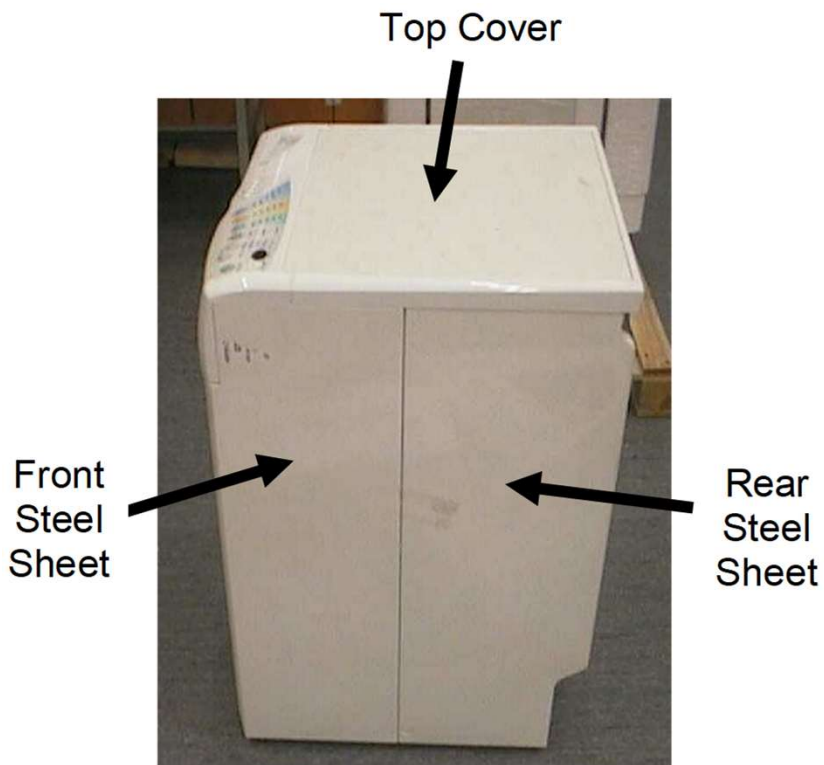


Access to engine by introducing service door



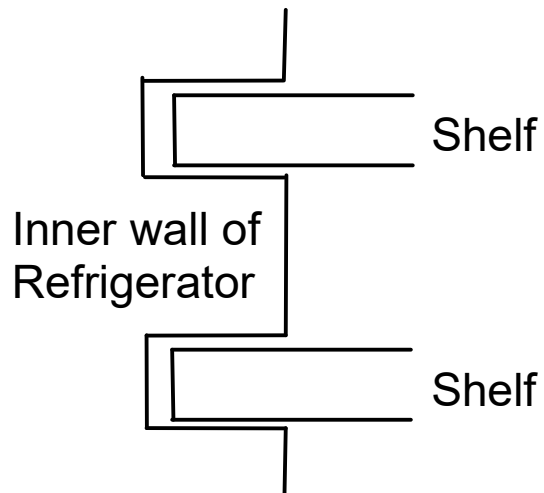
Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Washing machine design analysis

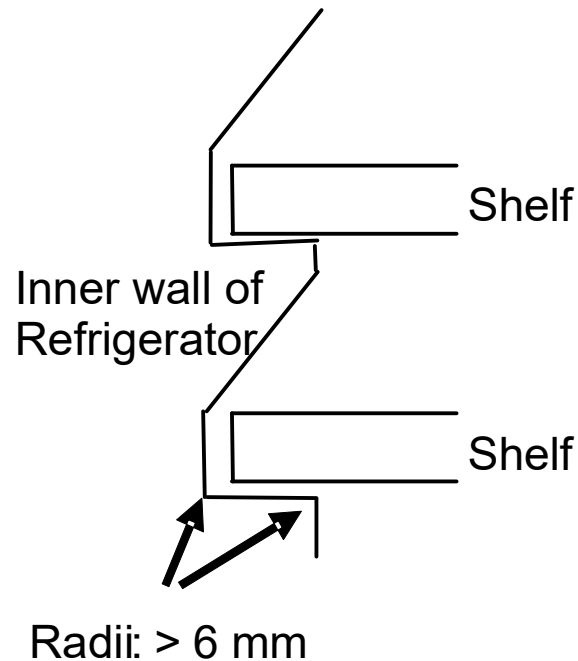


Refrigerator design analysis

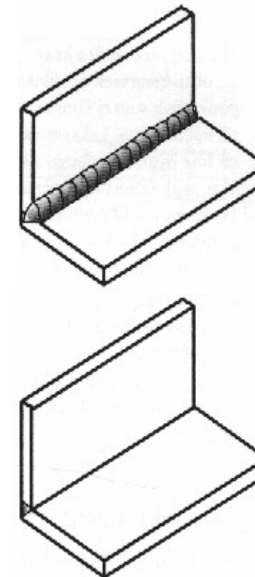
Existing design



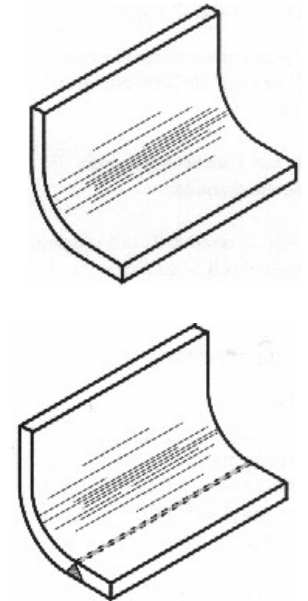
Improved design



Not suitable

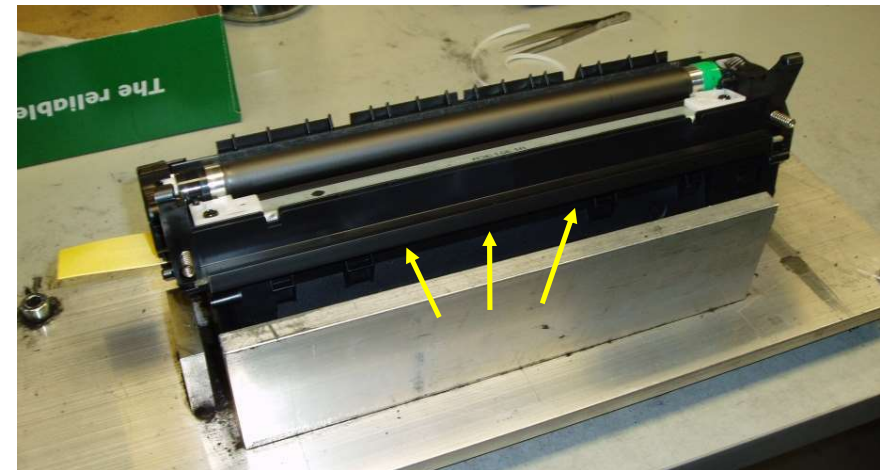
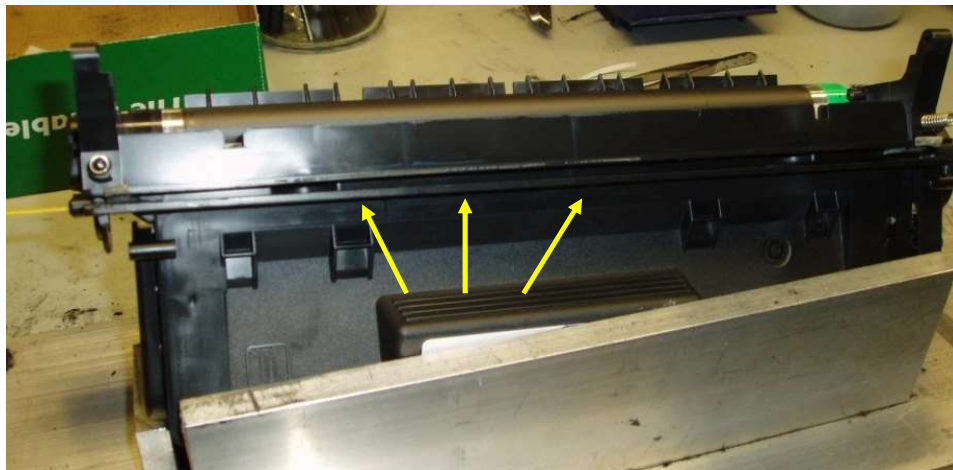


Suitable



Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Toner cartridge design analysis



Source: Sundin E. and Östlin J. (2005) Case Study of Three Toner Cartridge Remanufacturers, Proceedings of EcoDesign-05, Tokyo, Japan, December 12-14.

Soil compactors

Swepac International AB

- Understanding of customer value
- Adapted product
- Adapted service organization

www.swepac.se



Soil compactor design analysis



- Hood material changed
- Additional rubber bellow
- Change of transport device
- Bottom plate of Hardox steel



- Less visible damages
- Less need of re-painting
- Easier change of cover
- Less wear-out at transports
- Safer transports

Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Transporting soil compactors

Move between construction sites



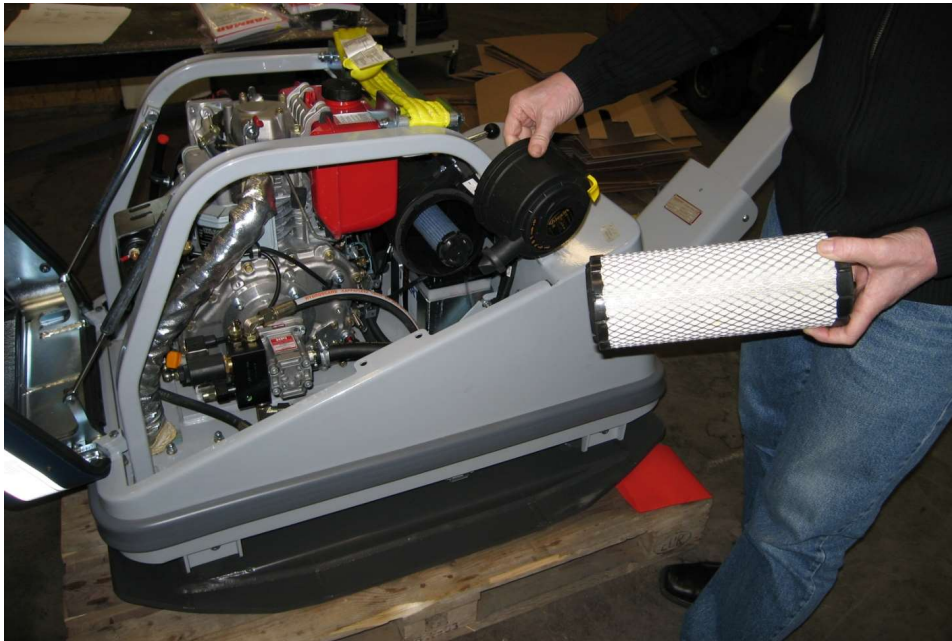
Foldable transport strap



Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Soil compactor design analysis

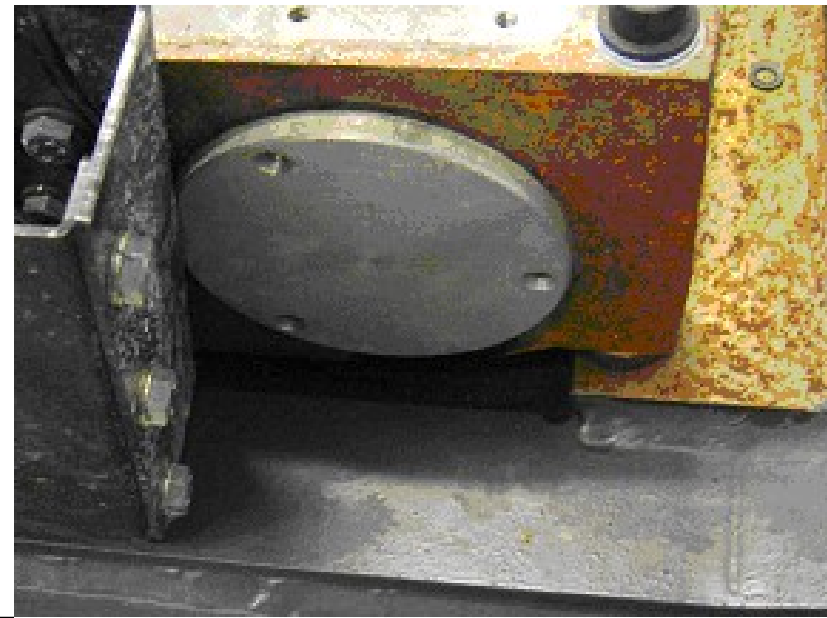
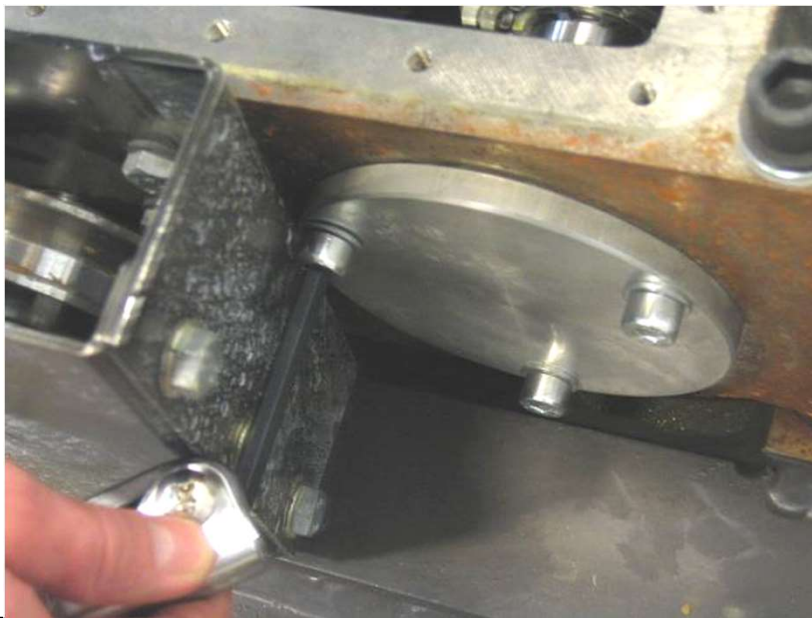
Adapted air filter



Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Soil compactor design analysis

Re-positioning of screws for the lid to the chamber of revolving cylinders



Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

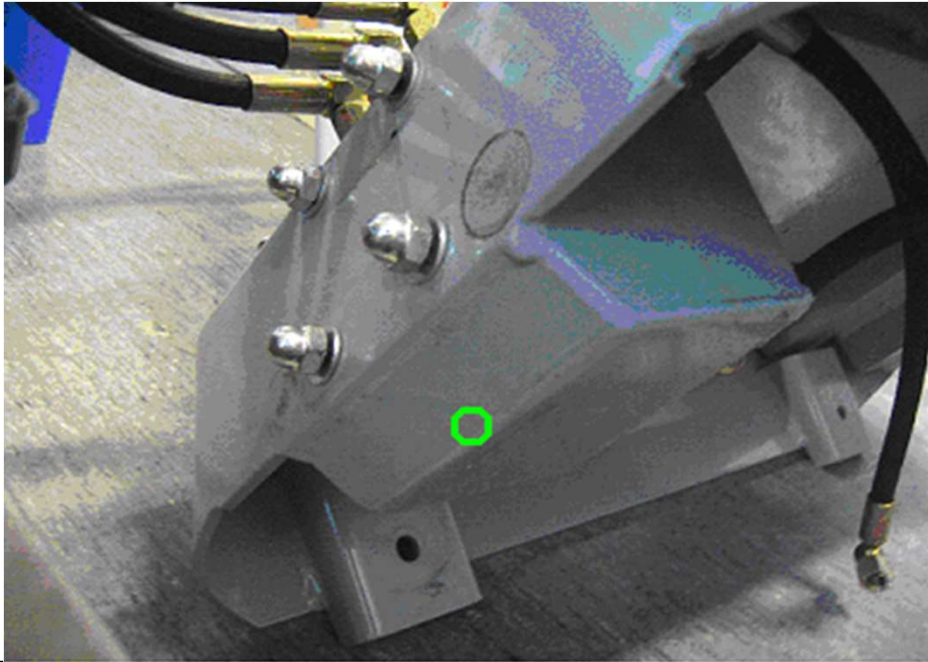
Soil compactor design analysis

Standardizing screw types



Soil compactor design analysis

Add tap hole to ease the drainage of oil



Source: Sundin E., Lindahl M. and Ijomah W. (2009) Product design for product/service systems - design experiences from Swedish industry, Journal of Manufacturing Technology Management, Vol. 20, Issue 5, pp 723-753.

Sources and further reading on design for remanufacturing

Supporting design for remanufacturing - A framework for implementing information feedback from remanufacturing to product design, Lindkvist Haziri L. & Sundin E. (2020) *Journal of Remanufacturing*, 10:57–76.

Circular Economy and design for remanufacturing, Sundin E. (2019) Chapter 18 in *Designing for the Circular Economy* edited by Martin Charter, Routledge, ISBN: 978-1-138-08101-7.

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Questions?

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