デジタル時代における製造業のサービス化の欧州動向

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Acknowledgement of financed projects

- Design projects in Mistra REES – Resource-Efficient and Effective Solutions based on circular economy thinking (2015-23) Mistra (89 MSEK) (DIA. 2014/16)

- Scandere – Scaling up a circular economy business model by new design, leaner remanufacturing, and automated material recycling technologies (2022-25), EU-cofounded ERA MIN (1.3 M€) (101003575 — ERA-MIN3)

- Circ€uit – Circular European Economy Innovative Training Network (2016-20), EU Horizon 2020 (4 M€) (No. 721909)

- RE:think - Rethink and improve product design and service cost for circular economy business models (2022-25), Energy agency (4 MSEK) (No. P2022-00342)

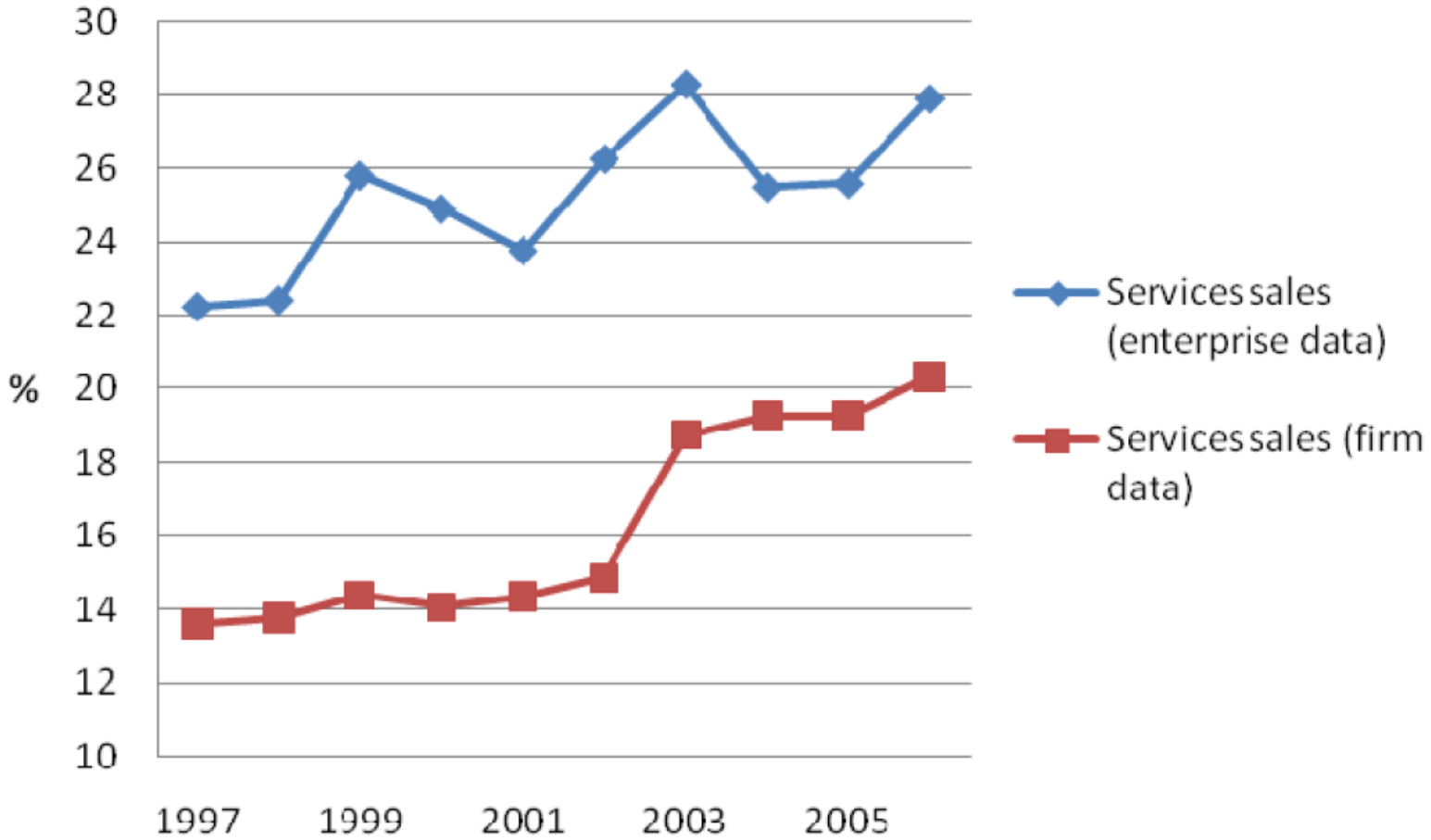
- Adapt2030 - Adaptive lifecycle design by applying digitalization and AI techniques to production (2020-23), VINNOVA (9 MSEK) (No. 2019-05589)

- Vice leader for WASP cluster Manufacturing & Process Control (2022 and onward), WASP (Wallenberg AI, Autonomous Systems and Software Program)

- :

Our industry partners (examples)

Figure 4: Manufacturing's services sales, as shares in total turnover, 1997-2006



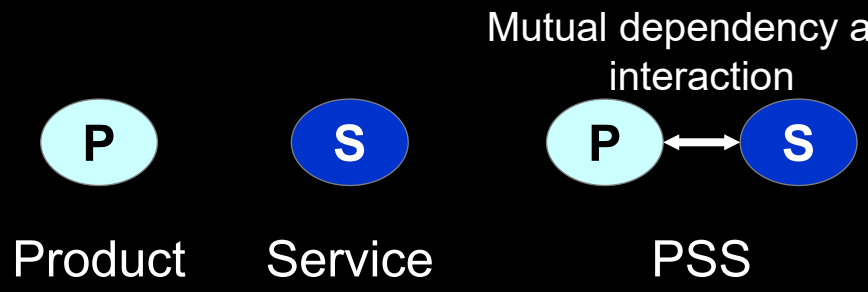
Source: SBS, Statistics Sweden, own aggregation and calculations.

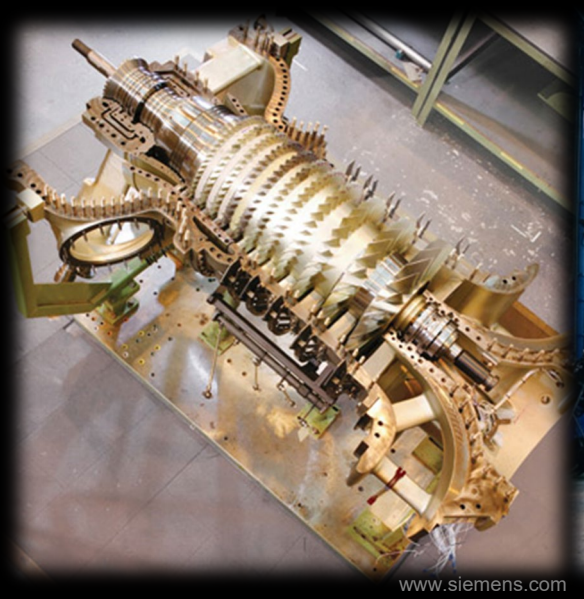
(Lodefalk, Servicification of manufacturing – evidence from Sweden, 2013)

Product/Service System (PSS)

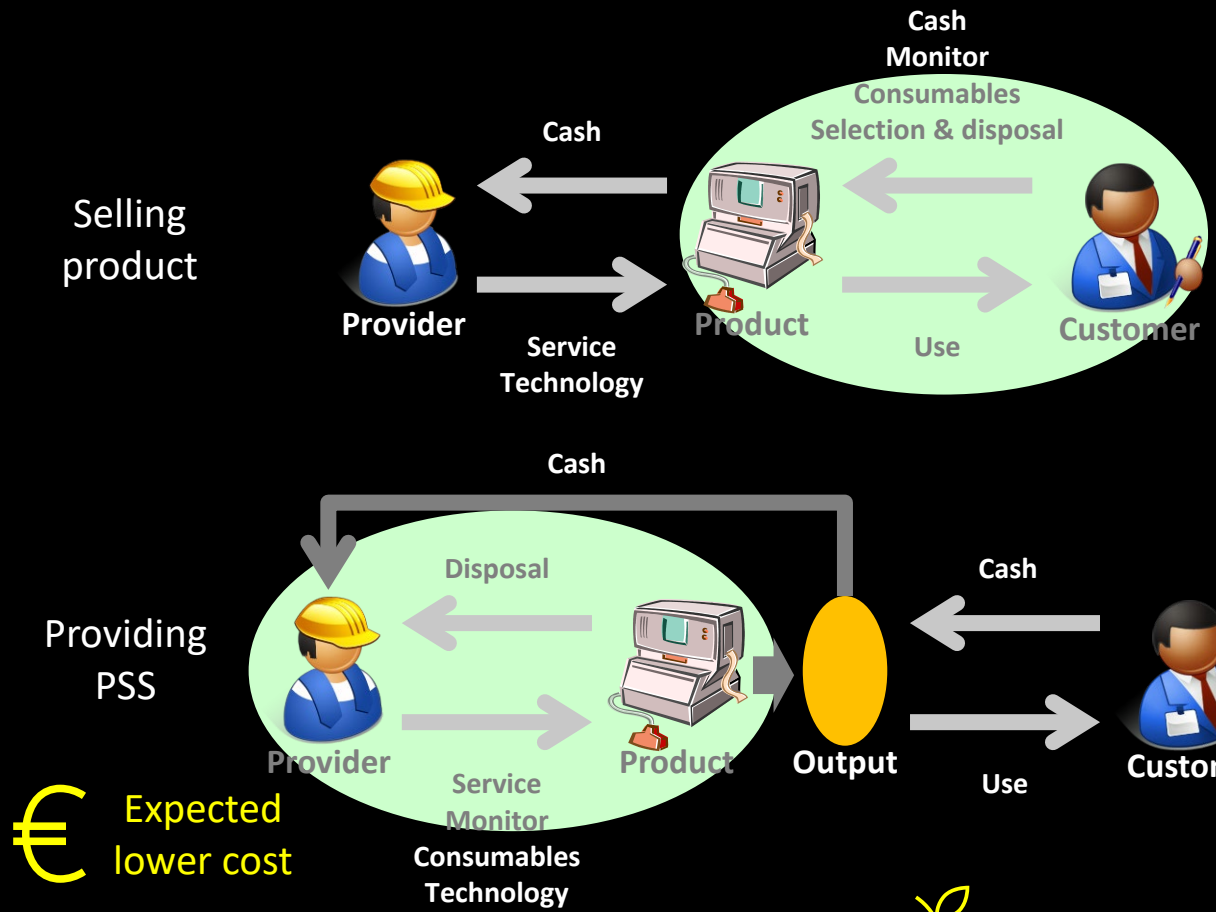
PSS is “tangible products and intangible services designed and combined so that they jointly are capable of fulfilling specific customer needs”.

(Tischner et al., 2002)





Providing Product-as-a-Service vs selling product



Value co-creation system: Enhancing commitment and value captured

See more information in Sakao 2022 (IEEE EMR)
https://ieeexplore.ieee.org/document/9712441

Adapted from (Baines et al., Proc. IMechE, 221 Part B, 2007)

U policies for circular economy

EC JRC, 2022. Towards a green and digital future - Key requirements for successful twin transitions in the European Union.

European Commission, 2020.

CE Action Plan 2020

- improving product **durability, reusability, upgradability and reparability,** addressing the presence of **hazardous chemicals** in products, and increasing their **energy and resource efficiency;**
- increasing **recycled content in products,** while ensuring their performance and safety;
- enabling **remanufacturing and high-quality recycling;**
- reducing **carbon and environmental footprints;**
- restricting **single-use** and countering **premature obsolescence;**
- introducing a **ban on the destruction of unsold durable goods;**
- incentivising **product-as-a-service** or other models where **producers keep the ownership of the product** or the responsibility for its performance throughout its lifecycle;
- mobilising the potential of **digitalisation** of product information, including solutions such as **digital passports, tagging and watermarks;**
- rewarding products based on their **different sustainability performance,** including by linking high performance levels to incentives.

Scandere's topic

Scandere's overarching topic

Product-as-a-Service examples

BlueMovement
Powered by BOSCH

Entdecke alle unsere Produkte

Unverzichtbare Haushaltsgeräte und Produkte, die auch im Alltag Spaß machen. Bei uns findest du eine Auswahl an hochwertigen Bosch und Siemens Geräten.

- **Kühlschränke** — Ab 14,99 € pro Monat
- **Waschmaschinen** — Ab 11,99 € pro Monat
- **Trockner** — Ab 11,99 € pro Monat
- **Gefrierschränke** — Ab 8,99 € pro Monat
- **Waschtrockner** — Ab 14,99 € pro Monat
- **Geschirrspüler** — Ab 12,99 € pro Monat
- **Staubsauger** — Ab 10,99 € pro Monat
- **Kaffeemaschinen** — Ab 22,99 € pro Monat
- **Freistehende Her…** — Ab 19,…

https://www.bluemovement.com/de-de

Subscription from Ca 400 €/month

https://www.volvocars.com/se/care-by-volvo/

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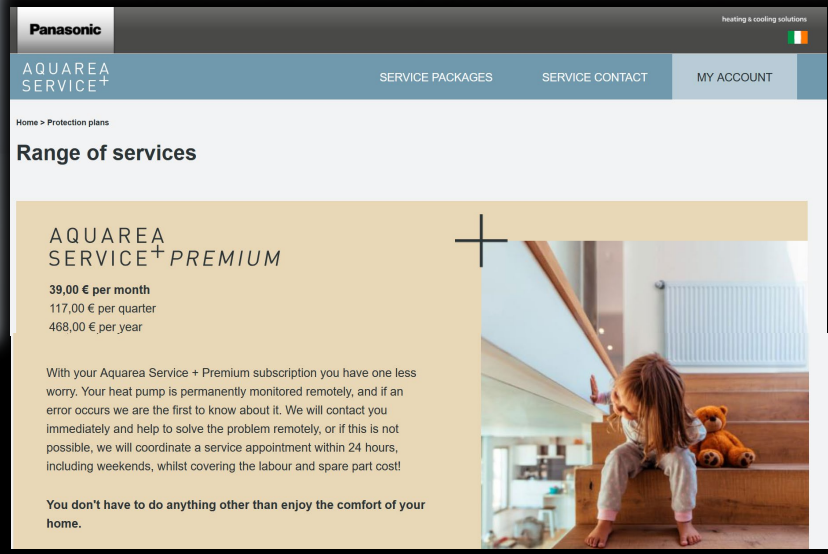
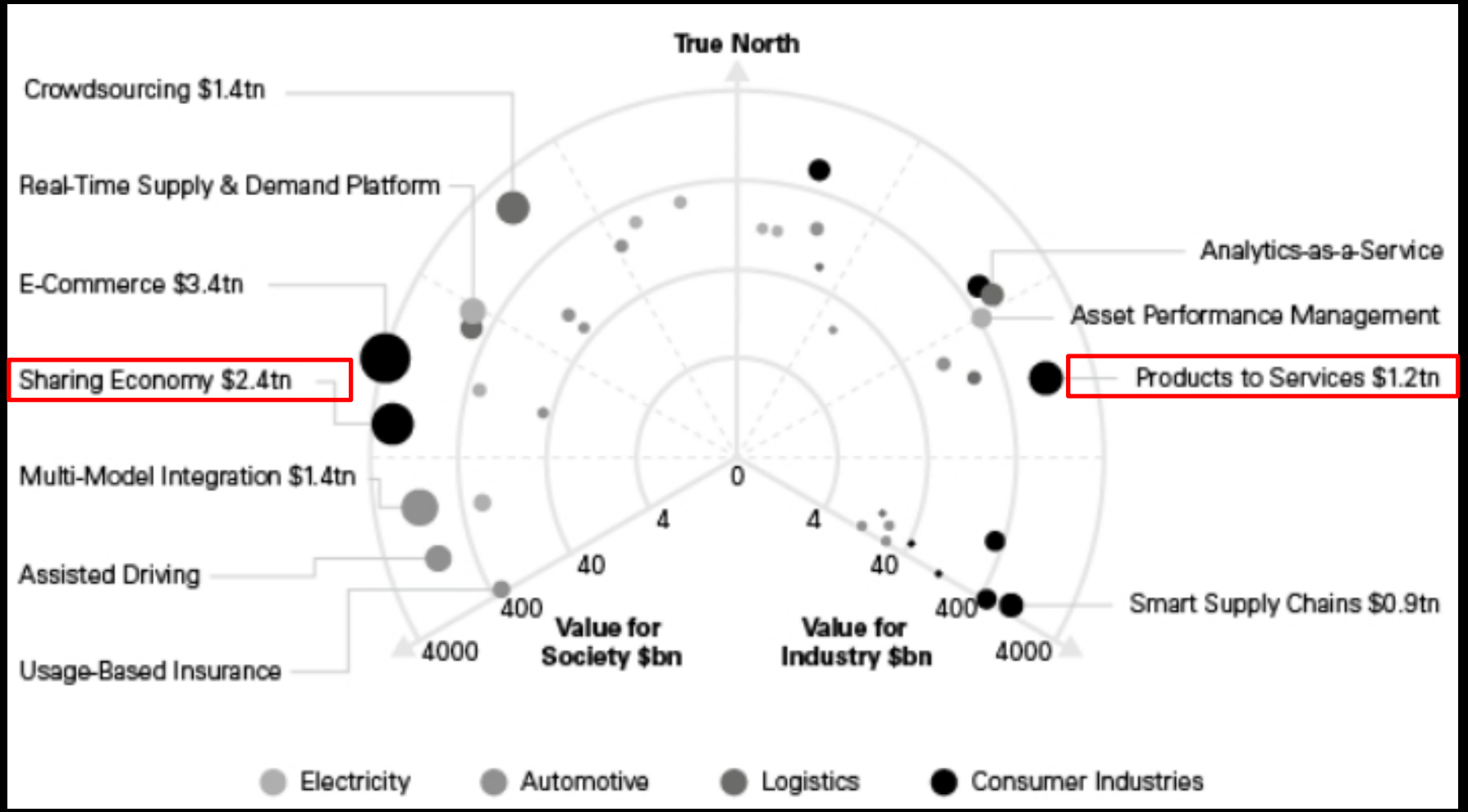


https://shop.aircon.panasonic.eu/en_IE/home/service_package

Magnitudes of *trapped value* of …



Trapped value over the next decade (E. Schaeffer, Industry X.0, 2017)

Contents lists available at ScienceDirect

CIRP Annals
Manufacturing Technology
Journal homepage: www.elsevier.com/locate/cirp

Industrial Product-Service Systems - IPS²

2010

H. Meier[1](2), R. Roy[2](2), G. Seliger[3](1)

[1]Chair of Production Systems, Ruhr-University Boch
[2]Decision Engineering Centre, Cranfield University,
[3]Assembly Technology and Factory Management, TU

In 10 years the following statements will be relevant:

Result oriented business models evolve as an industry standard. Complex development processes are simplified by automatically configuration by Plug&Play of product and service modules. Service will be provided globally by service supply chains based on modularized service processes. The service delivery will be supported by technologies like standard shared-vision systems or new developed industrial service robots. Service robots can be used in industrial applications for automated delivery of service processes. Machine tools are able to communicate over the internet to exchange data, information or knowledge.

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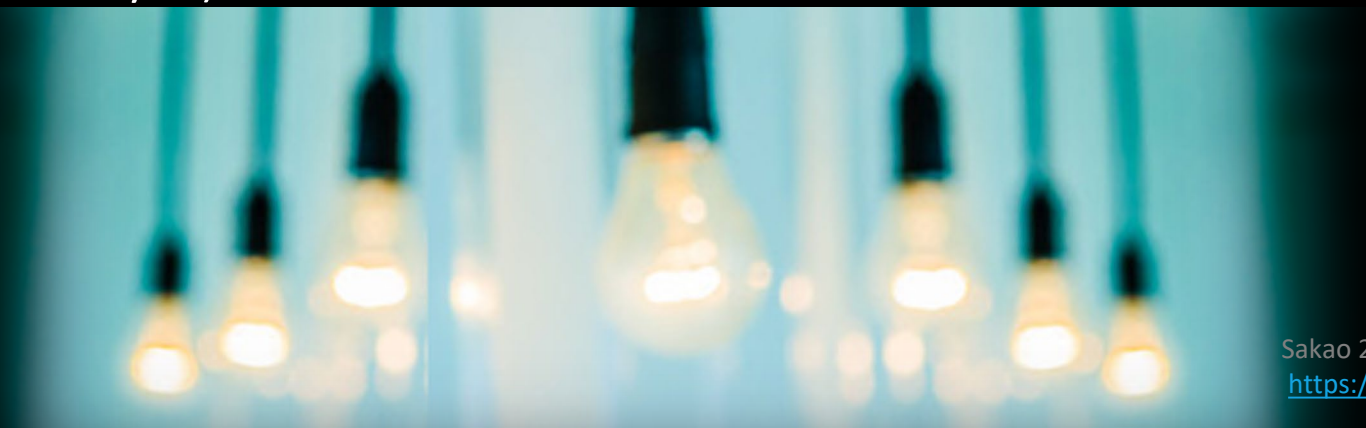
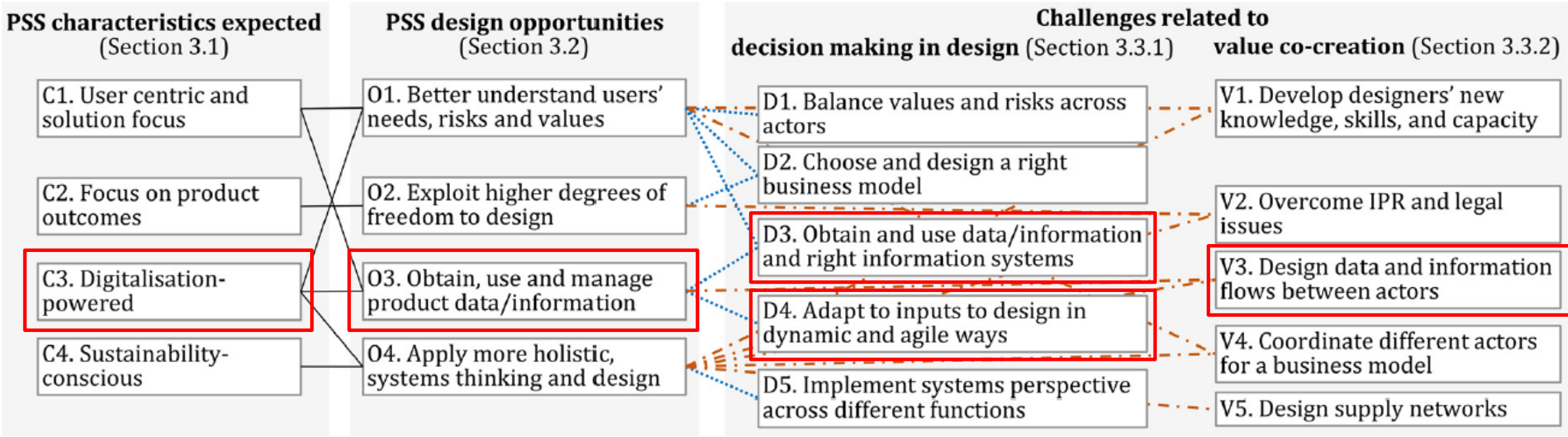
Principles of PSS design – Seven I's

- **I**ntegrative – integration between products and services. Using interplay, interdependence and interference between products and services.
- **I**nformation driven – taking advantage of availability of data/information of different phases of the product lifecycle (esp. use phase).
- **I**ntelligent – designing builds upon business intelligence (not only AI).
- **I**nteractive – referring to not only interaction between products and services but also that between PSSs and users.
- **I**nclusive – including other (new) actors involved in the system.
- **I**ndefinite – reflecting the uncertainty, an inherent characteristic of PSS. Evolving design.
- **I**nnovative – this is what we often want.



Sakao 2022 (IEEE EMR)
https://ieeexplore.ieee.org/document/9712441



Designing value-driven solutions: The evolution of industrial product-service systems

2022

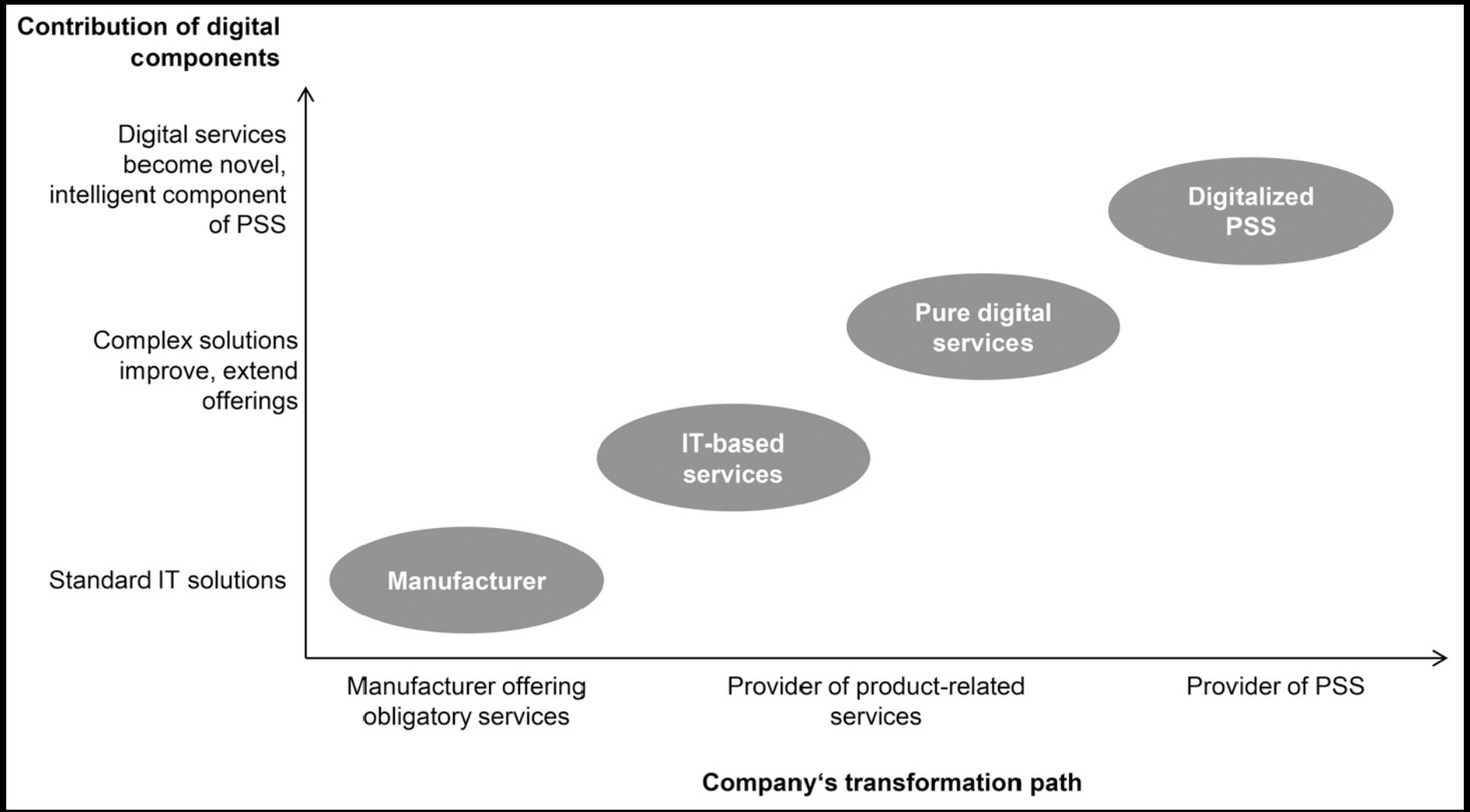
Daniel Brissaud (1)[a,*], Tomohiko Sakao (2)[b], Andreas Riel (2)[a], John Ahmet Erkoyuncu (2)[c]

[a] *Grenoble Alpes University, G-SCOP Laboratory, Grenoble, France*
[b] *Department of Management and Engineering, Linköping University, Linköping, Sweden*
[c] *School of Aerospace, Transport and Manufacturing, Cranfield University, Cranfield,*

areas such as knowledge to design, to use machines. As of 2022, we are still far from real-life implementation of these concepts. Even

knowledge". Obviously, IPS^2 is not an industry standard yet.

Servitization-digitalization transformation framework



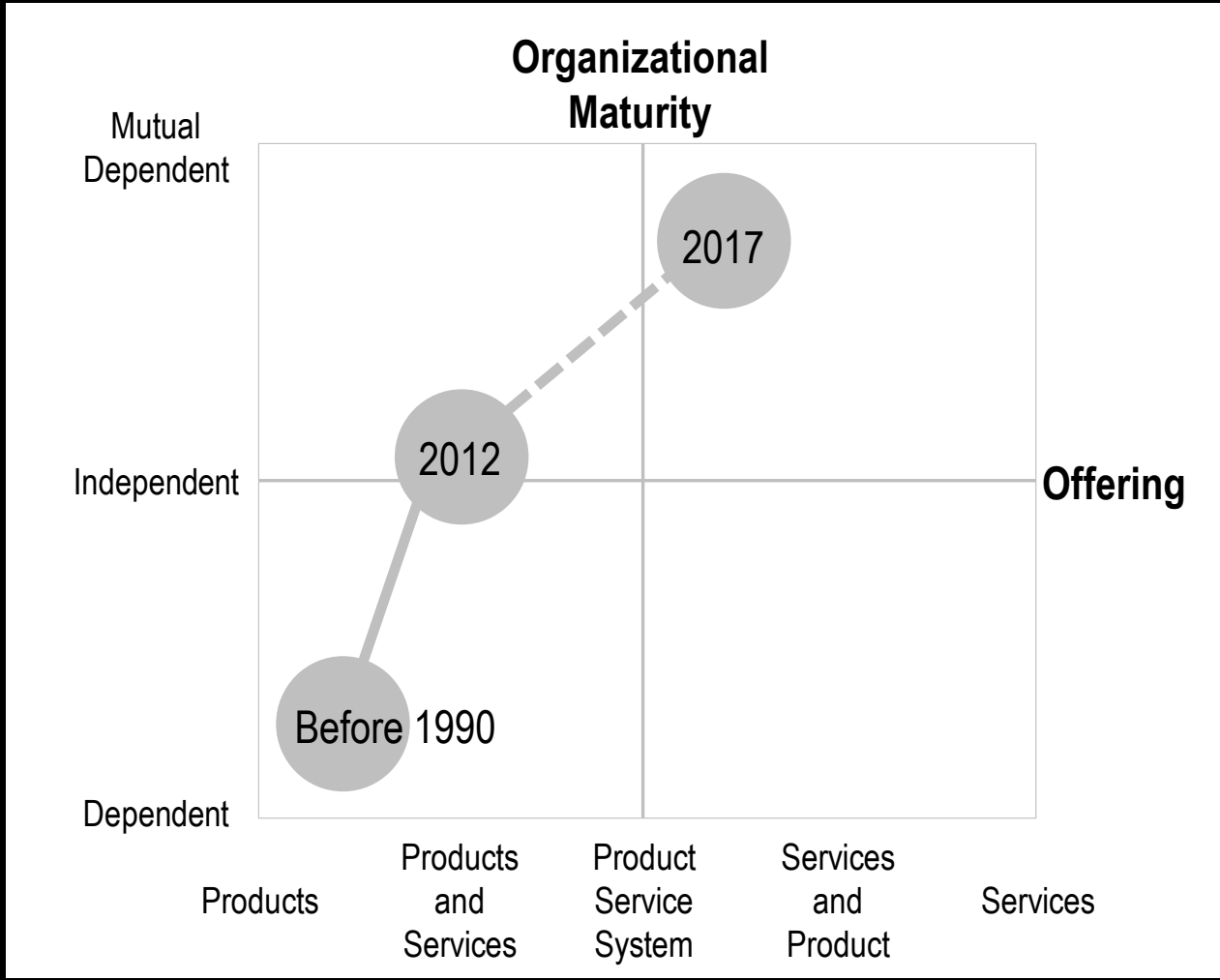
(Lerch et al., 2015)

An example PSS development with gas turbines

- Traditional aftermarket services, e.g., spare part provision, training, upgrades, diagnostics & repair.
- 1980s: Initiated service-based solutions for higher customer value, e.g., uptime, improved output, and hassle-free operation.
  - More critical in operation (used more extensively), more requirements for maintenance.
  - Calendar-based maintenance.
- Around 2010: Introduced condition-based maintenance (CBM)
  - Steep learning on risks (safety as a major driver). Needs on cost savings.
  - Revenue: equal from turbines and services.

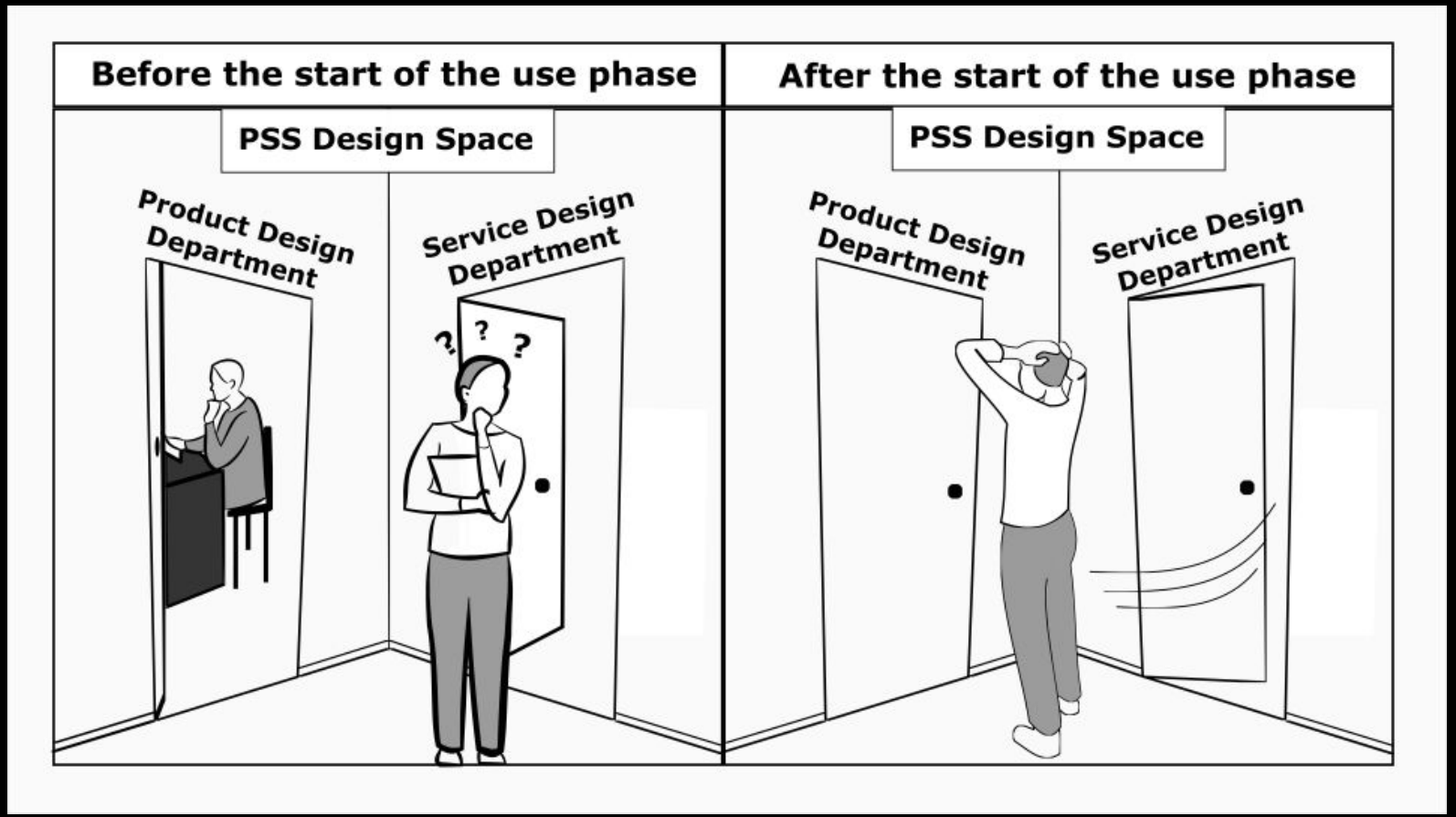
A case of Siemens Energy from (Brissaud et al., 2022)

An example PSS development with telecom systems



A case of Ericsson adjusted from (Elfving et al., 2013)

Service design trap

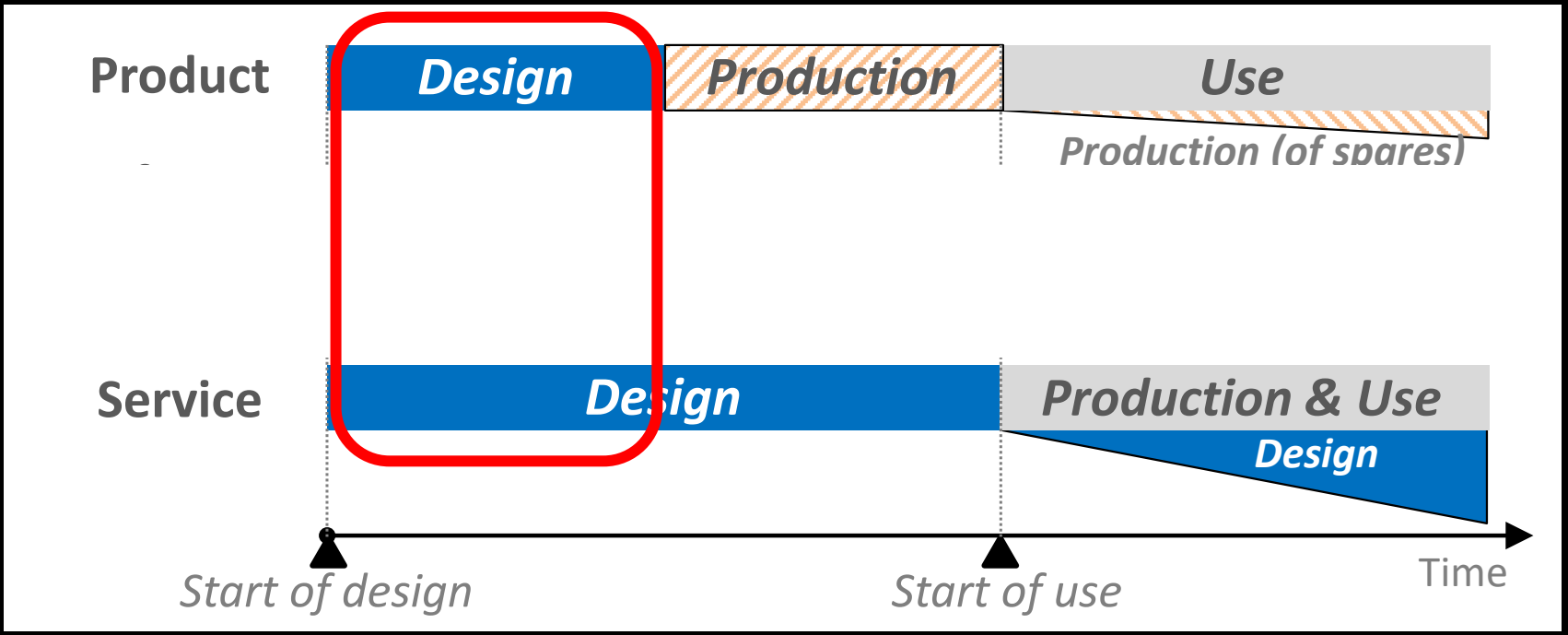


A phenomenon where the ability of service designers over an extended timespan is restricted due to the constraints set by the frozen product design during the use phase.

(Sakao, Neramballi, Matschewsky. Avoid service design trap by guiding product/service system design with product-service dependency knowledge base, 17th Intl. Design Conf. 2022)

Why *service design trap* occurrs?

Possible time windows to design product, software and service



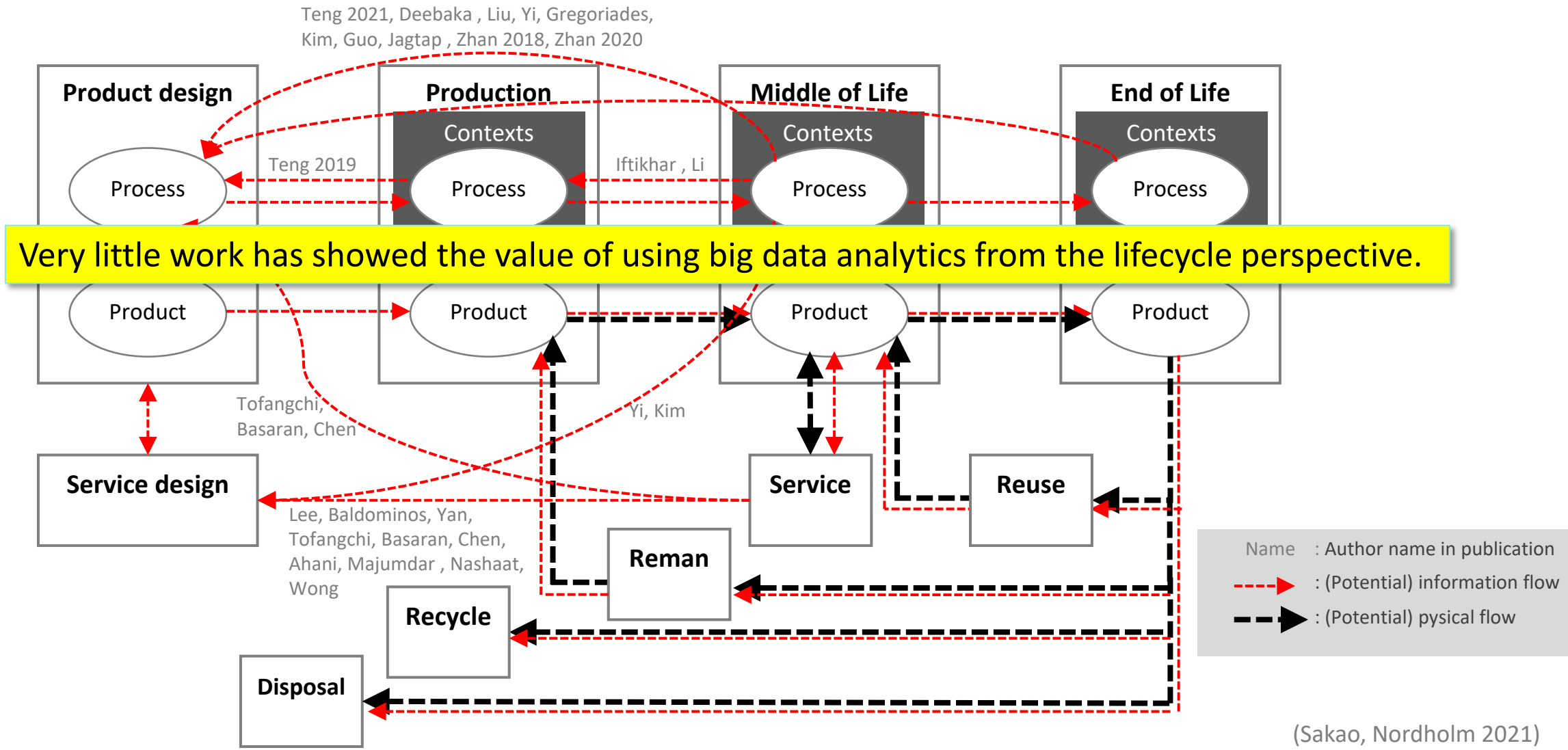
The higher flexibility on the temporal dimension on service design is often not optimally used in practice.
In practice, too many or too few decisions are made for the service design at the end of product design.

Note: This figure is simplified, as concurrent design and production of products is not an issue here.

(Sakao, Neramballi, Matschewsky. Avoid service design trap by guiding product/service system design with product-service dependency knowledge base, 17th Intl. Design Conf. 2022)

Technical feasibility of Adaptive-Intelligent Lifecycle Engineering

Case of big data analytics

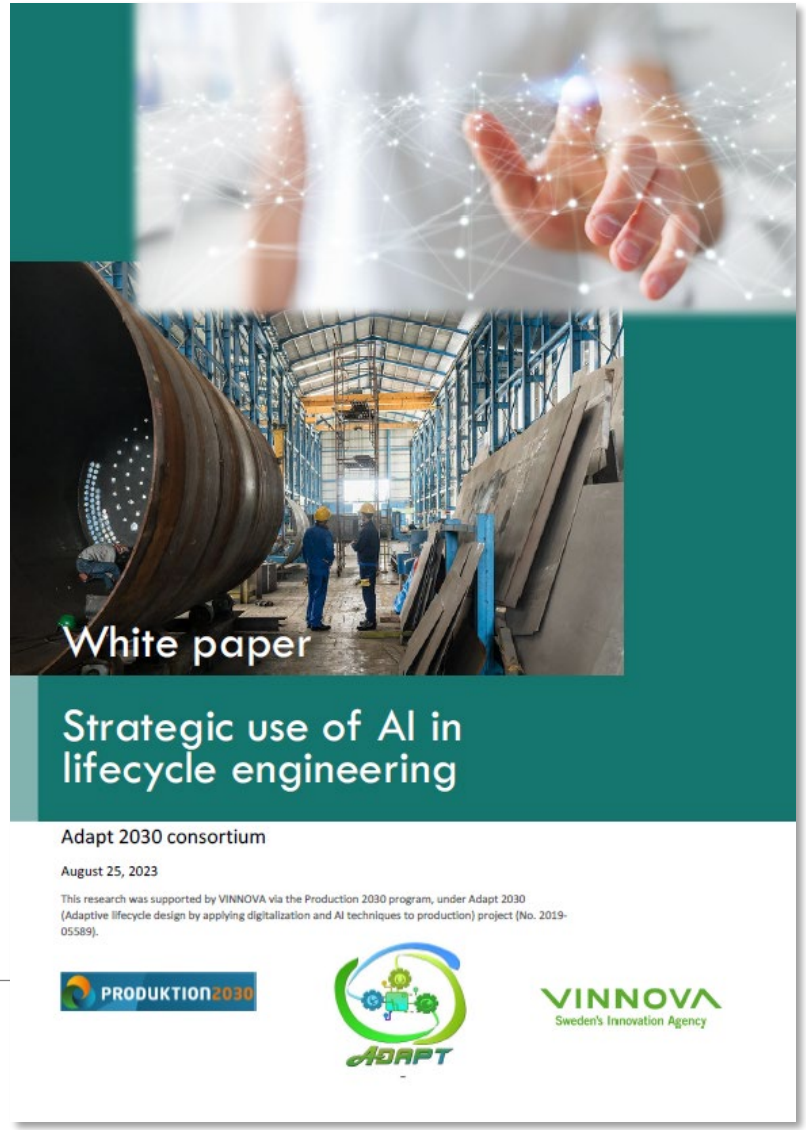


(Sakao, Nordholm 2021)

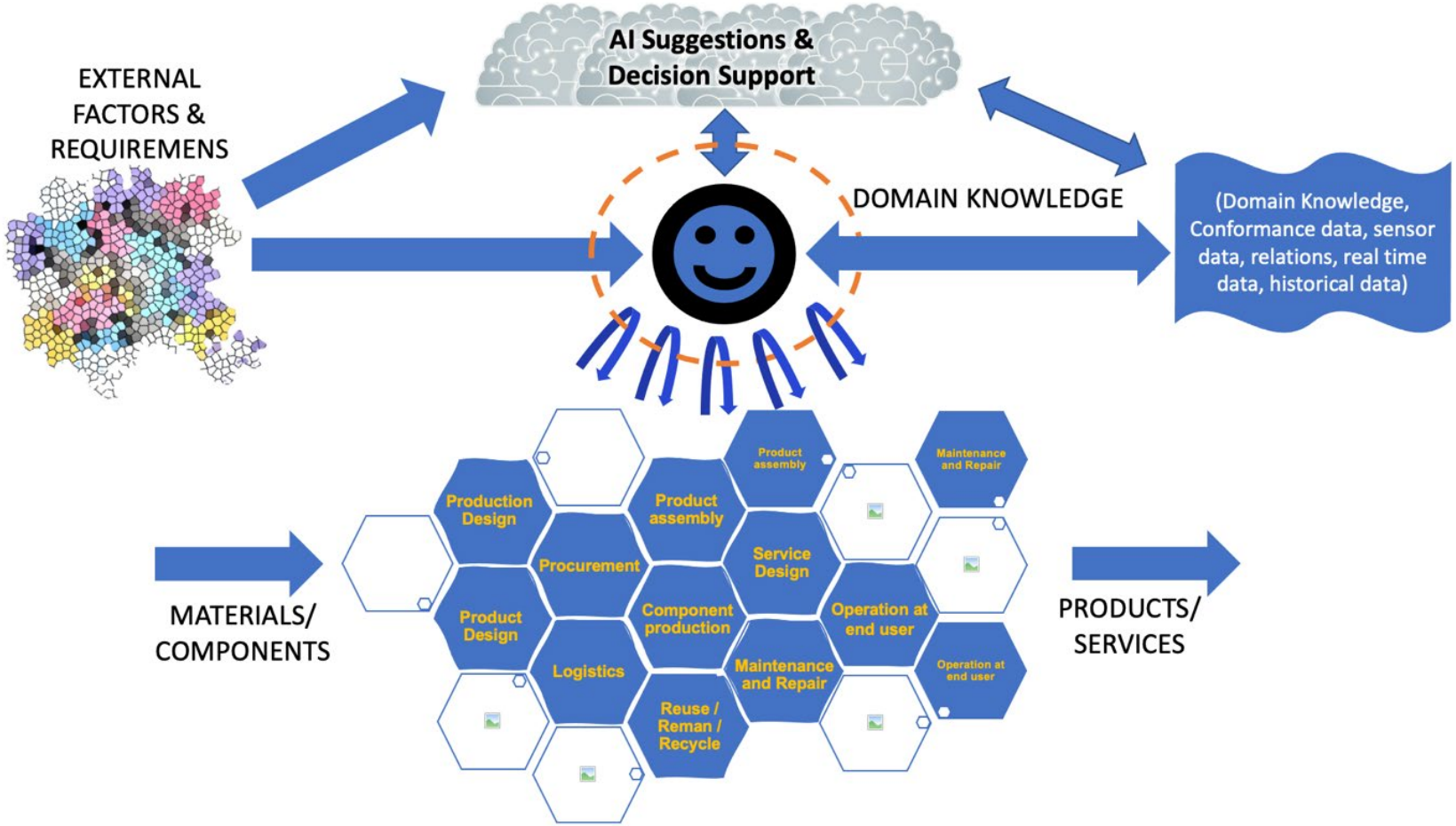
Vision for AI-LCE (Adaptive and intelligent lifecycle engineering)

Motivation

- AI offers unique opportunities to help manufacturers increase holistic improvement. No method or strategy is established for how to do so.



Vision for AI-LCE (Adaptive and intelligent lifecycle engineering)



Source: Adapt 2030 consortium, 2023. White paper - Strategic use of AI in lifecycle engineering.

An example AI method applied to maintenance

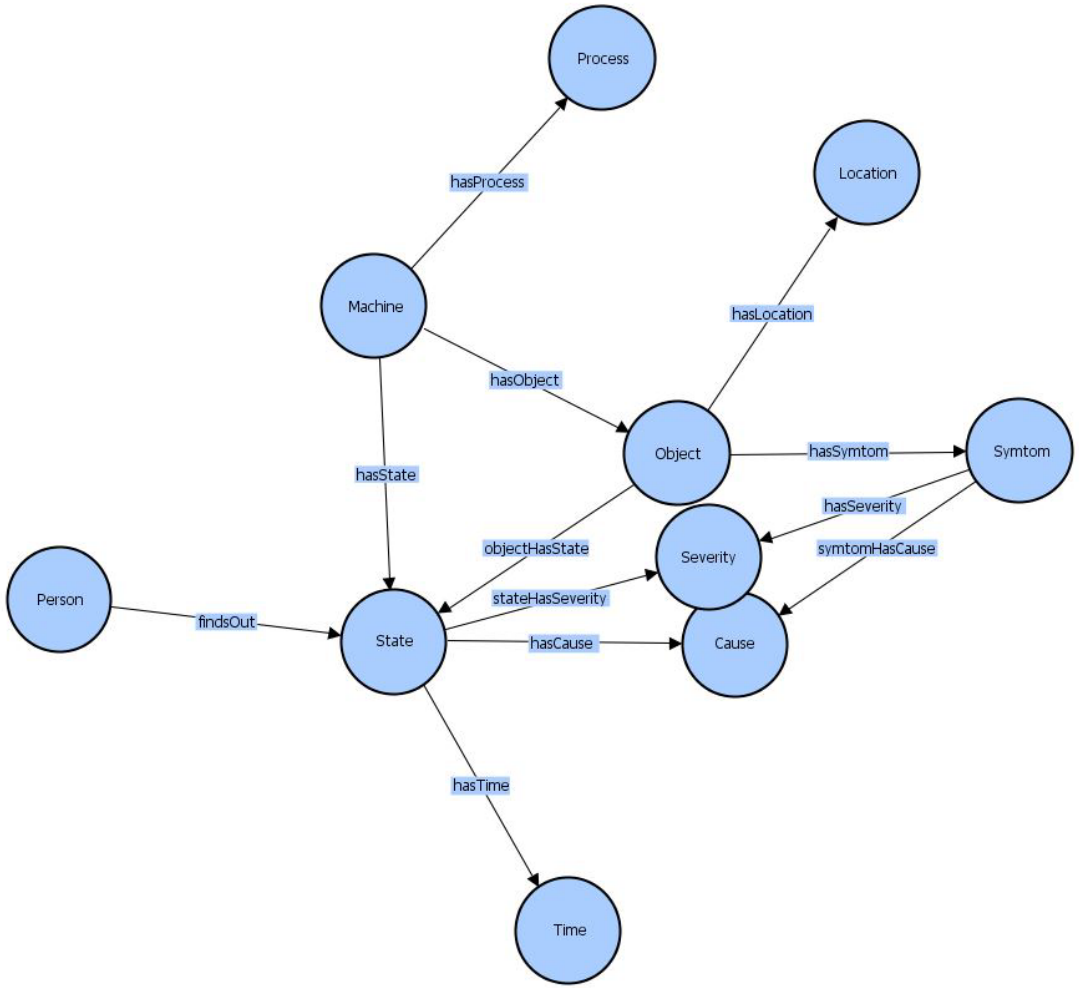
- NLP (natural language processing) + Ontology
- Automatic generation of knowledge graphs from free texts from maintenance error reports.

Table 1. Categories of Extracted data

Category	Extracted data column
Human related	repairman, requester
Machine related	machine number, type of machine,
Work order related	work order(WO) number, worktype, WO requested, WO created WO close, headline, ***description***, fail source, fail cause
Solutions related	closed, cost center, action taken, suggested for long term action, comments after closing

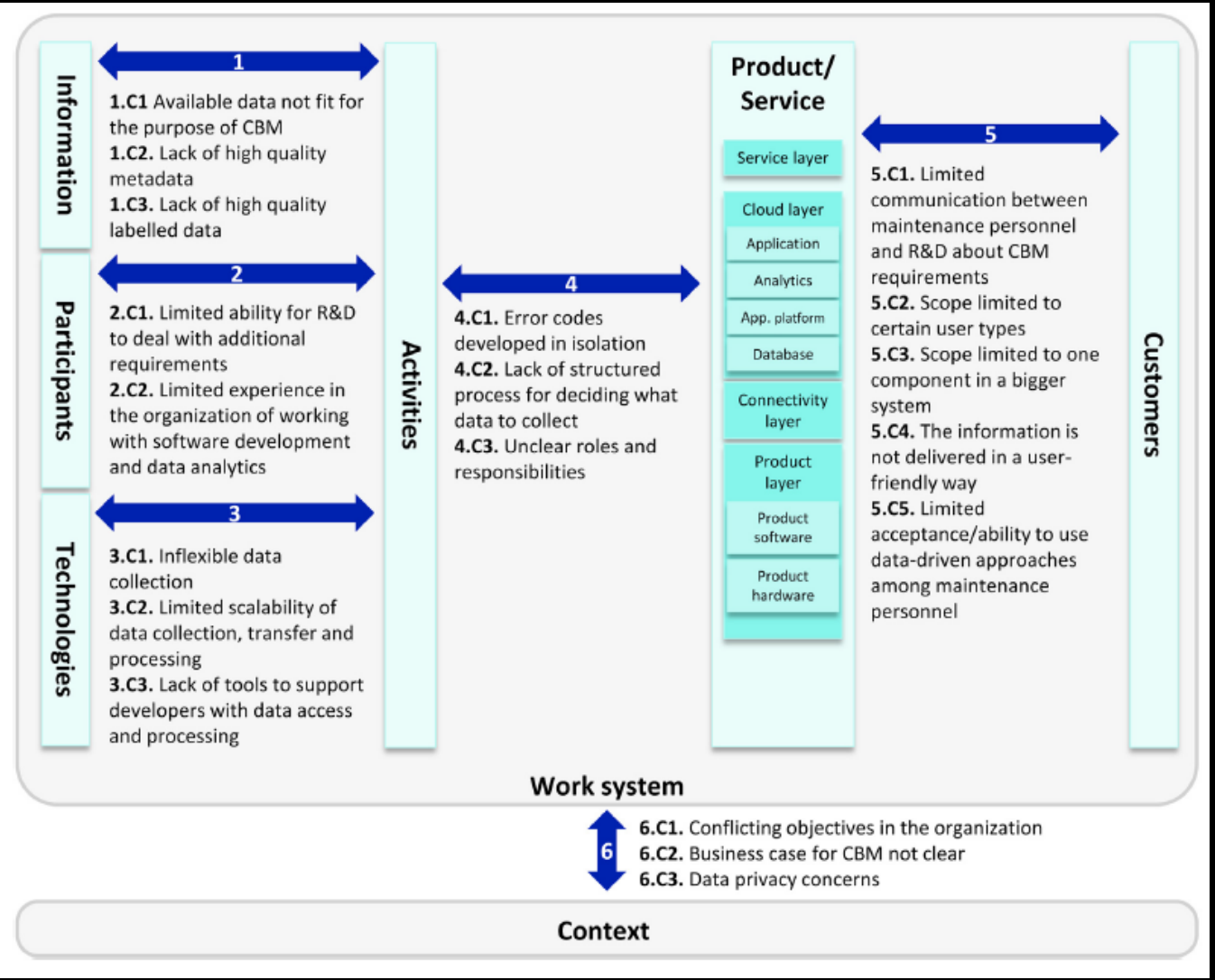
Table 2. Some examples of unstructured text

Cases	Examples of free text
case1	överfull med kylvvatten i kylanläggningen, kommer massa kylvatten i plåten
case2	Samma som förut, kylmedlet slutar bara att genomflöda
case3	Y- stilleståndsövervakning
case4	Maskinen nödstoppas



Source: R. S. D'Cruze, M. U. Ahmed, M. Bengtsson, A. U. Rehman, P. Funk, R. Sohlberg. A Case Study on Ontology Development for AI Based Decision Systems in Industry. 7th International Congress and Workshop on Industrial AI and eMaintenance, 2023

Challenges to implementing CBM



(Ingemarsdotter et al., 2021)

Avoid *efficiency trap*!

Render yourself more efficient!

Oliver Burkeman (2021, Wall Street Journal)
The value of friction and inefficiency (Kevin Meyer, 2021)

Want to know more?

Contact **Tom Sakao**

Many thanks go to colleagues from Linköping Univ.

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Johannes Matschewsky

Marianna Kambanou

Mattias Lindahl

Raphael Wasserbaur

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Published papers of relevance

Reviewed Journal Papers

1. A. Schroeder, T. Baines, T. Sakao: Increasing Value Capture by Enhancing Manufacturer Commitment – Managing the servitization process. IEEE Engineering Management Review, DOI: 10.1109/EMR.2022.3197075, 2022.
2. D. Brissaud, T. Sakao, A. Riel, and J.A. Erkoyuncu: Designing Value-Driven Solutions: The Evolution of Industrial Product-Service Systems, CIRP Annals - Manufacturing Technology, Elsevier, Vol. 71, No. 2, pp. 553-575, 2022, DOI 10.1016/j.cirp.2022.05.006
3. T. Sakao, A. Neramballi, J. Matschewsky, A. Carlson, M. Bäck, V. T. Tirumalasetty: Systemic improvement of lifecycle performance by leveraging product and service interdependencies – a case of a product for wind power generation systems, CIRP Annals - Manufacturing Technology, Elsevier, Vol. 71, No. 1, pp. 9-12, 2022, https://doi.org/10.1016/j.cirp.2022.04.052
4. T. Sakao: Increasing Value Capture by Enhancing Manufacturer Commitment – Designing a value cocreation system. IEEE Engineering Management Review, DOI: 10.1109/EMR.2022.3150851, 2022 https://ieeexplore.ieee.org/stamp/stamp.jsp?arnumber=9712441
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6. A. Neramballi, T. Sakao, S. Willskytt, A.-M. Tillman: A design navigator to guide the transition towards environmentally benign Product/Service Systems based on LCA results, Journal of Cleaner Production, 2020, http://www.diva-portal.org/smash/get/diva2:1471021/FULLTEXT02.pdf
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11. R. Wasserbaur, T. Sakao, M. Ljunggren Söderman, A. Plepys, C. Dalhammar: What if all become sharers? A quantification of the environmental impact of access-based consumption for household laundry activities, Resources, Conservation and Recycling, 2020, http://www.diva-portal.org/smash/get/diva2:1432012/FULLTEXT02.pdf
12. M. L. Kambanou, T. Sakao: Using life cycle costing (LCC) to select circular measures: a discussion and practical approach, Resources, Conservation and Recycling, 2020, http://www.diva-portal.org/smash/get/diva2:1392626/FULLTEXT01.pdf
13. M. Kaddoura, M. L. Kambanou, A.-M. Tillman, T. Sakao: Is prolonging the lifetime of passive durable products a low-hanging fruit of a circular economy? A multiple case study. Sustainability, 2019, https://www.mdpi.com/2071-1050/11/18/4819/htm
14. T. Sakao, R. Wasserbaur, F. Mathieux: A methodological approach for manufacturers to enhance value-in-use of service-based offerings considering three dimensions of sustainability, CIRP Annals - Manufacturing Technology, 2019, http://www.diva-portal.org/smash/get/diva2:1313952/FULLTEXT02.pdf
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Systems – Challenges, Opportunities and Solutions resulting from Prescriptive Approaches in two Industrial Companies, International Journal of Production Research, 2018, http://www.diva-portal.org/smash/get/diva2:1110611/FULLTEXT02.pdf

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