

Manufacturing_as_a_service: a service-oriented automation approach



Summary of the course

This course intends to introduce a global approach to manufacturing-as-a-service based on a network of services that can be instantiated by cyber-physical systems (CPSs) or entire collaborative plants worldwide. In either case, the focus is on the design of new production arrangements using knowledge and knowledge management and combining design methods for automated processes and workflow management with ambidextrous innovation. The course will be offered starting in March by the Graduate Program in Mechanical Engineering, Escola Politécnica, USP (<https://ppgem.poli.usp.br>).

Prof. José Reinaldo Silva

2025

Modules of the course

The course is divided into four modules with the following topics:

- Service-oriented manufacturing, agent-based manufacturing, manufacturing-as-a-service;
- Cloud Manufacturing (CMfg) concepts and design;
- Systems Design methods applied to cloud manufacturing service (CMfgS);
- Digital Transformation, Artificial Intelligence, roadmap design for I4.0.

Bibliography

1. Qiu, R. G.; Service Science: The Foundation of Service Engineering and Management, Wiley, 2014.
2. Salvendy, G., Karwowsky, W.; Service Engineering, Wesley, 2010.
3. Schaefer, D. (editor), Cloud-Based Design and Manufacturing (CBDM): A Service-Oriented Product Development Paradigm for the 21st Century, 4a. edição, Springer, 2014.
4. Badr, Y.; Smart Digital Service Ecosystems: A Research Roadmap from Service Computing and Engineering Perspectives, Springer, 2023. .
5. Silva, J.R., Service-Oriented Digital Transformation: An Innovative Approach for Intelligent Manufacturing, draft book, submitted to Springer, 2025.

Other papers and references will be suggested during the course.



Module 1 3 classes

Module 2 3 classes

Module 3 3 classes

Module 4 3 classes

Introduction

Service Science and
Manufacturing
Services

KEY TOPIC 1



KEY TOPIC 2
AGENT-BASED AND
CLOUD MFG



KEY TOPIC 3
MANUFACTURING_AS_
A_SERVICE



KEY TOPIC 4
DIGITAL
TRANSFORMATION /I4.0

Module 1 3 classes

Module 2 3 classes

Module 3 3 classes

Module 4 3 classes

For each module we will have:

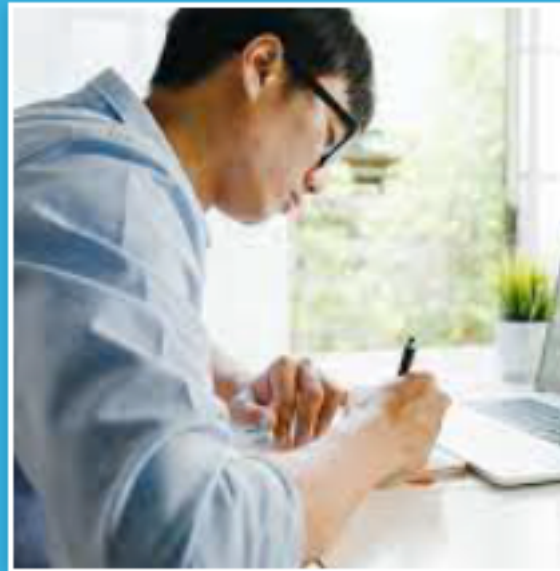
- A lecture;
- A sub-lecture;
- A discussion highlighting specific topics.



Class models



Lectures summarize the key topic and its academic impacts.



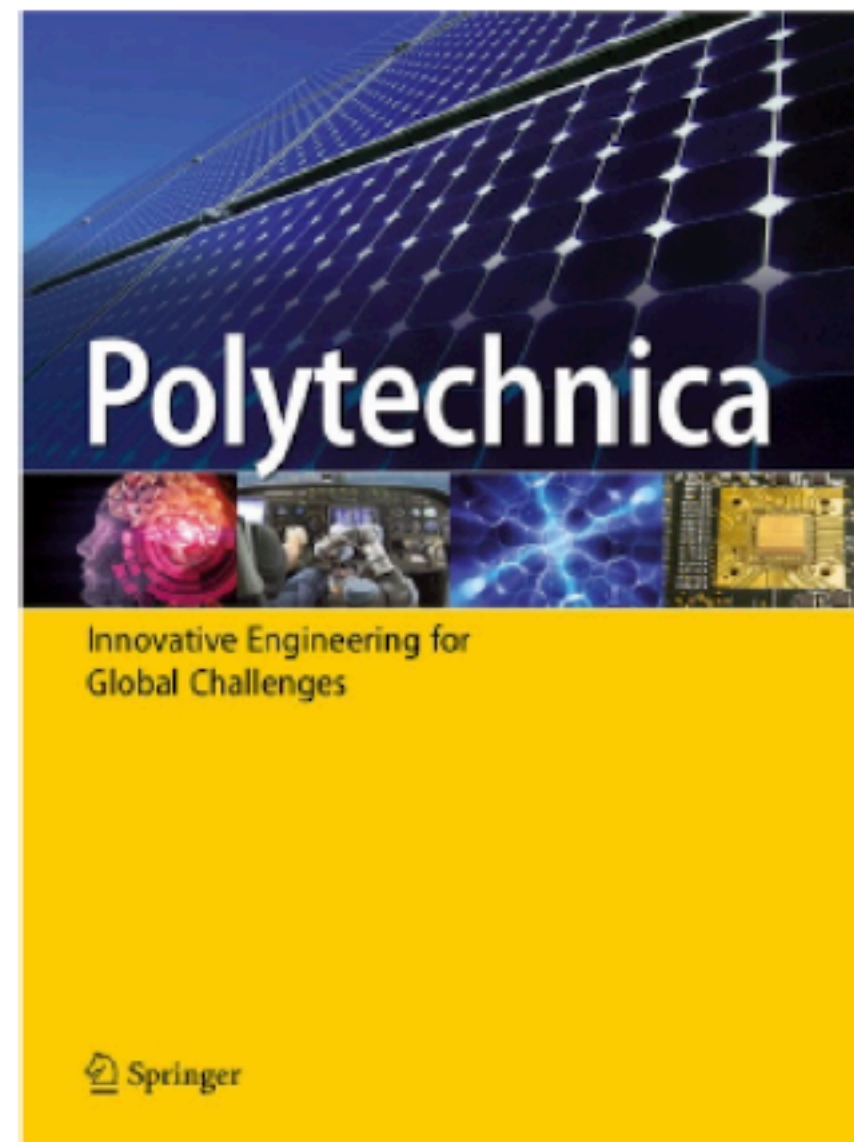
Extended classes will expose practical aspects, state of art and possible implementations.



Interactive classes will discuss topics from selected position papers.

Gradings

Grades will be based on the composition of the position papers (three at the end) and a final four-page article combining all previous positioning or pointing to new perspectives from the student's point of view. The final article will be in the format of an IFAC (Int. Federation of Automatic Control) event, the IFAC Workshop on Intelligent Manufacturing Systems (IMS). It is a biannual event currently being held in Koszalin, Poland, this year and will be repeated in 2026 in a place that will be defined this year. Extended versions could also be submitted to Polytechnica Journal (Springer), whose aims and scope are on <https://link.springer.com/journal/41050/aims-and-scope>.



Moodle e-disciplines

PMR5414 - Manufacturing-as-a-Service: Uma abordagem Orientada a Serviço Para a Manufatura (2025)

2025 > EP
> PMR

Manufacturing_as_a_Service (MaaS) World

Collapse all



MaaS
scope

Manufacturing_as_a_Service (MaaS) is a recent topic of industry evolution strongly related to similar attempts of the past of industrialization. The most prominent evolutionary link is with the Virtual Enterprises launched in the late 1980's. Another important characteristic of MaaS is its strong relation with the academy and the studies toward Industry 4.0 (I4.0) and its practical impact, which is also linked with I4.0 through digital transformation (in the digitalization phase) with the IIoT. The perspective from the academy does not conflict with the market view (<https://www.rtinsights.com/manufacturing-as-a-service-production-without-owning-machines/>), including the possibility of encouraging emerging tech startups (<https://www.startus-insights.com/innovators-guide/5-top-emerging-manufacturing-as-a-service-maas-startups/>). However, there is a discomfort to look at this two (or three) different viewpoints as



March 2025 UK

Calendarpedia
Your source for calendars

Wk	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday	Sunday
9	24	25	26	27	28	1	2
10	3	4	5	6	7	8	9
11	10	11	12	13	14	15	16
12	17	18	19	20	21	22	23
13	24	25	26	27	28	29	30
14	31	1	2	3	4	5	6

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Schedule

1st. Position paper : 04/01 (not a joke)

2nd. Position paper: 04/29

3rd. Position paper: 05/21

Final paper : 06/17

APRIL 2025

SUNDAY	MONDAY	TUESDAY	WEDNESDAY	THURSDAY	FRIDAY	SATURDAY
		1	2	3	4	5
6	7	8	9	10	11	12 Full moon
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30			

SunCatcherStudio.com

May 2025 UK

Calendarpedia
Your source for calendars

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20	12	13	14	15	16	17	18
21	19	20	21	22	23	24	25
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June 2025

Calendarpedia
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Sunday	Monday	Tuesday	Wednesday	Thursday	Friday	Saturday
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29	30	1	2	3	4	5

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Lecture 1



PMR5414

Service-oriented manufacturing, agent-based
manufacturing, manufacturing-as-a-service;

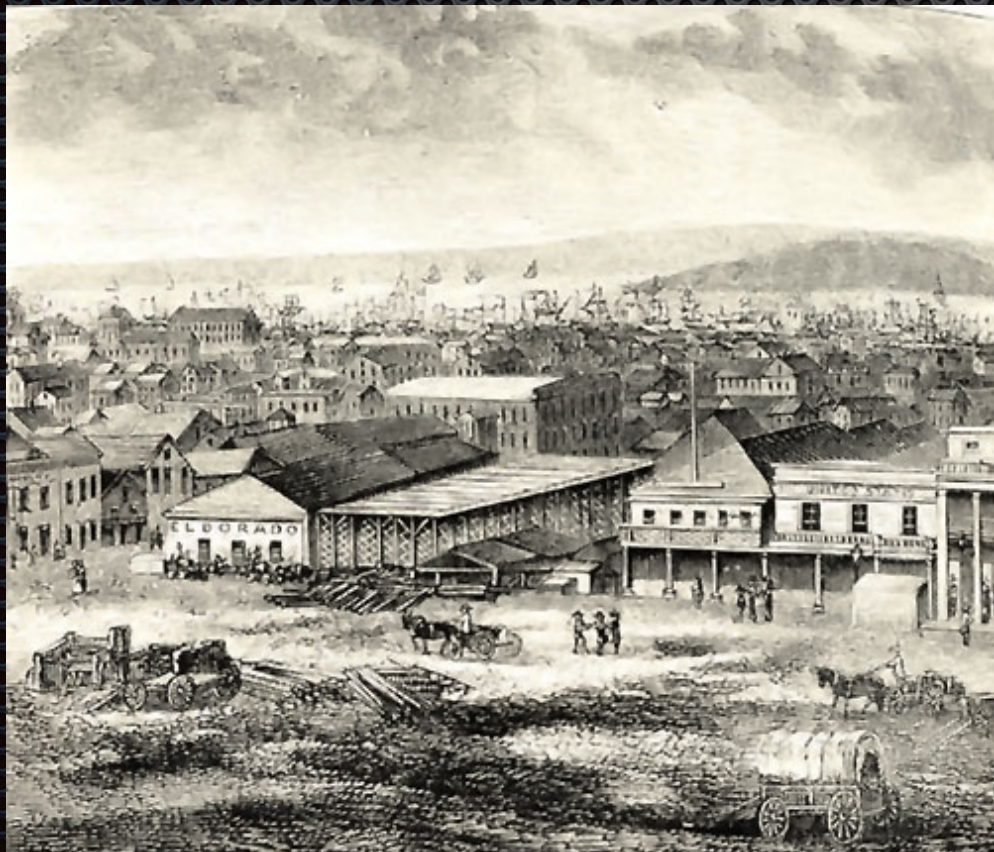
Lecturer :
José Reinaldo SILVA



Service appears in the Agricultural Revolution 12.000 years ago.



Evolution of economy in US: The Managerial Revolution



1850



The Visible
Hand The
Managerial
Revolution
in American
Business
Alfred D.
Chandler, Jr.

The
Pulitzer Prize
and
The Bancroft
Prize

Product dominant

X

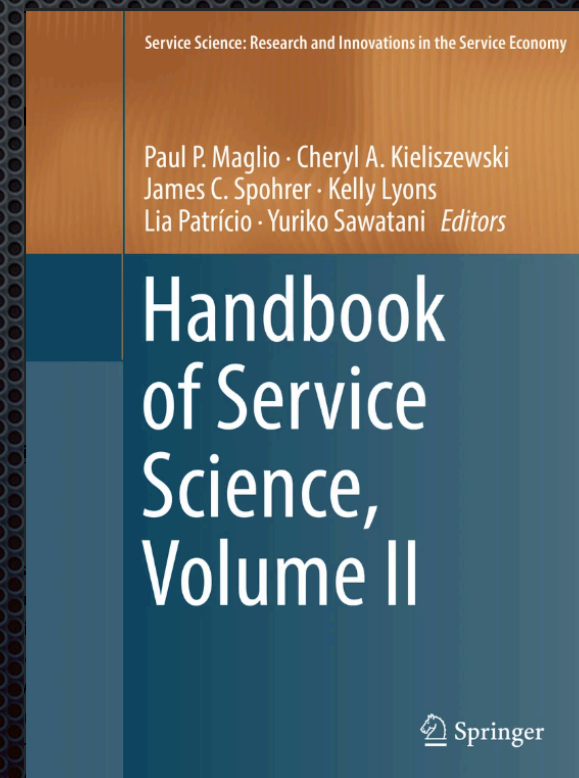
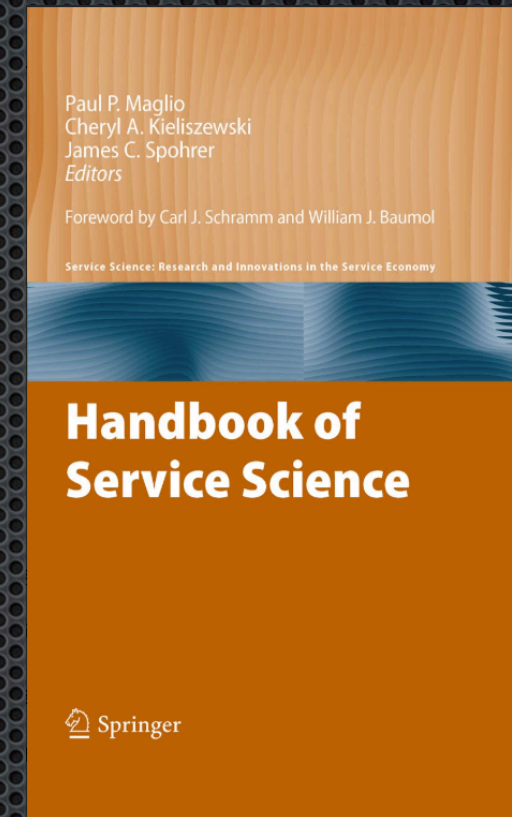
Service Dominant



Jim Spohrer, IBM

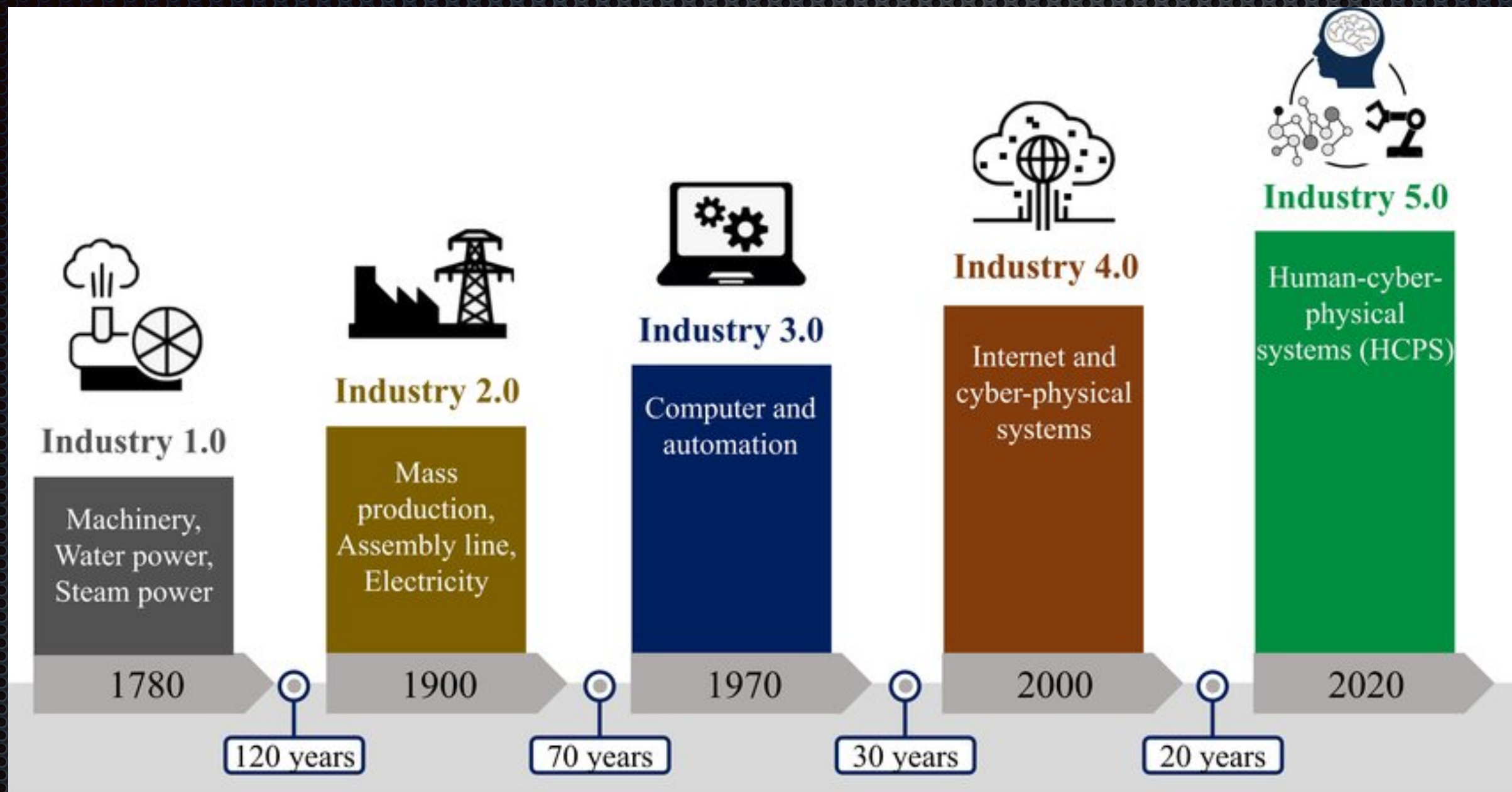


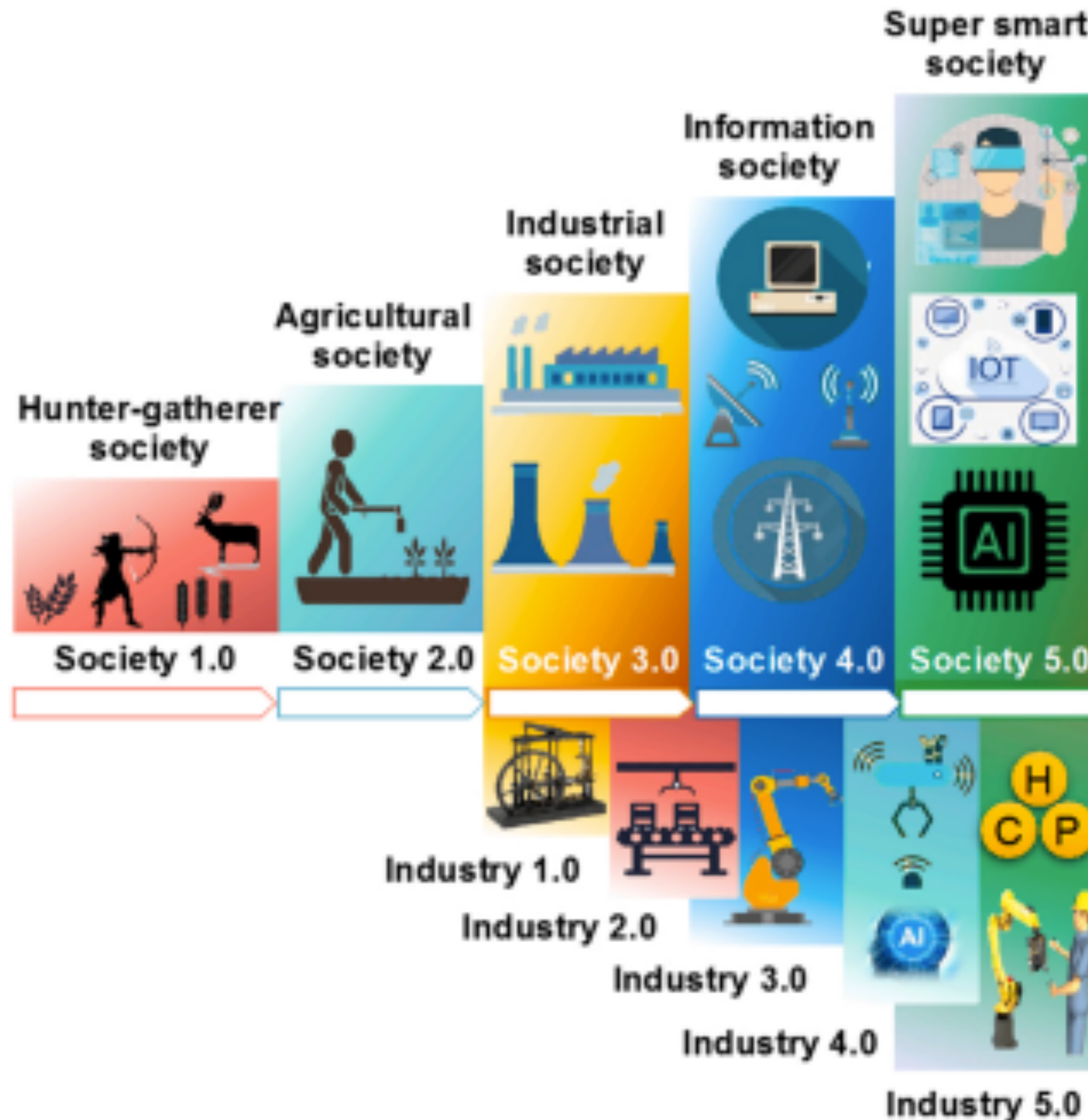
Paul Maglio, UC Merced

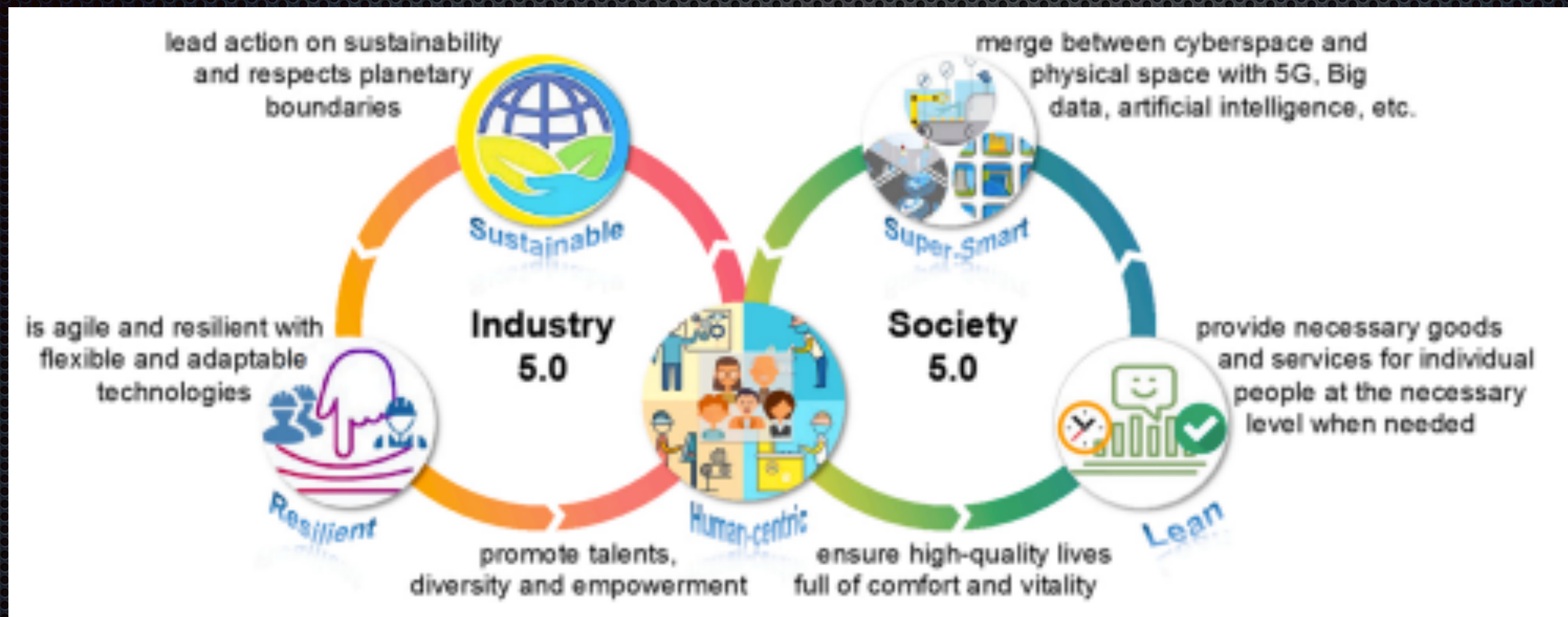




If I4.0 is at the end of the tunnel, what is on the way?







S. Huang et al. « Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution ». In : Journal of Manufacturing Systems (2022).

“The Service Economy”



ISSIP Service Economics

Can you measure the new services economy the same old way?

Doug Morse
12/17/2014

Just looking at the principal economies in the world

United States

European Unity

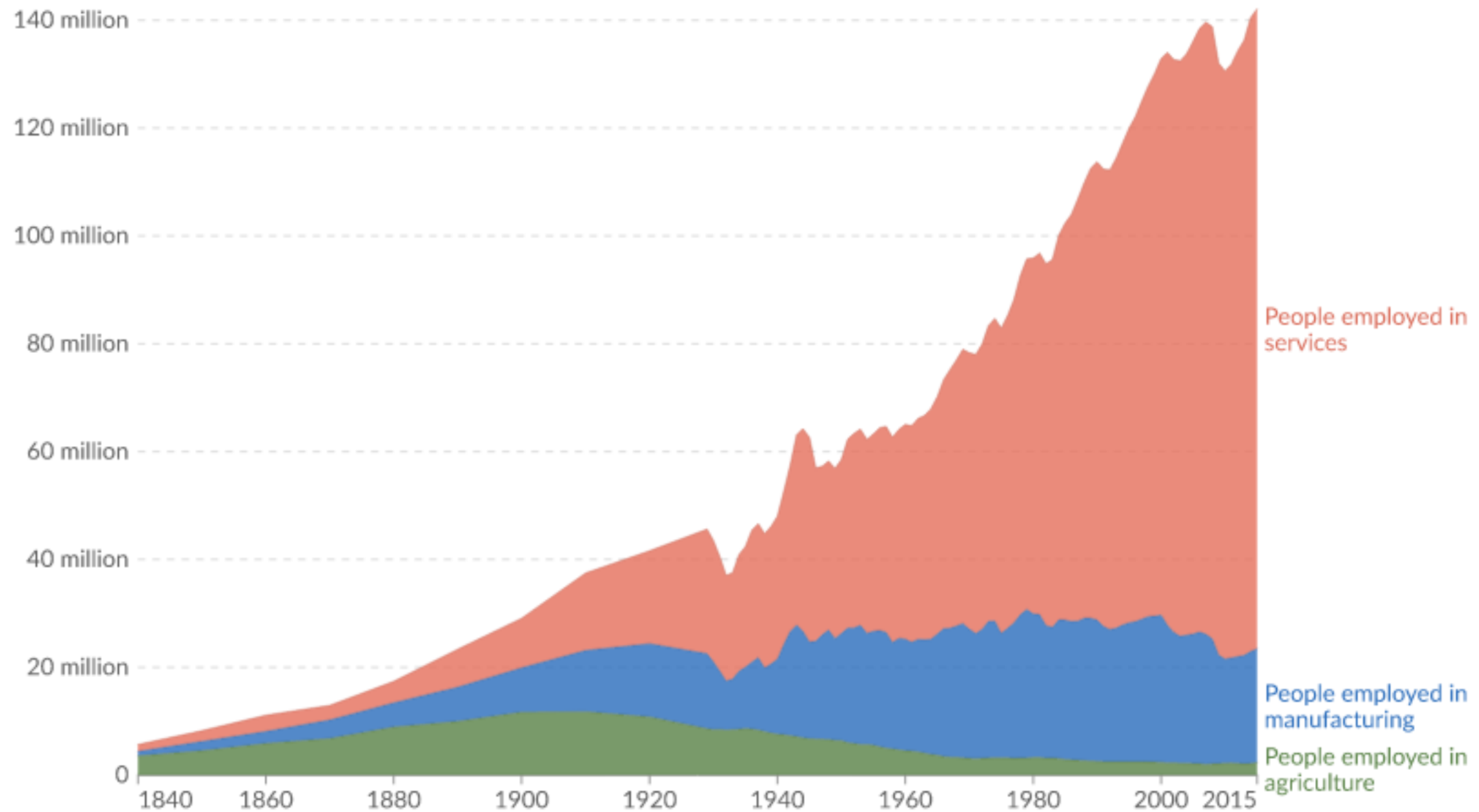
China



Employment by economic sector, United States, 1840 to 2015

Our World
in Data

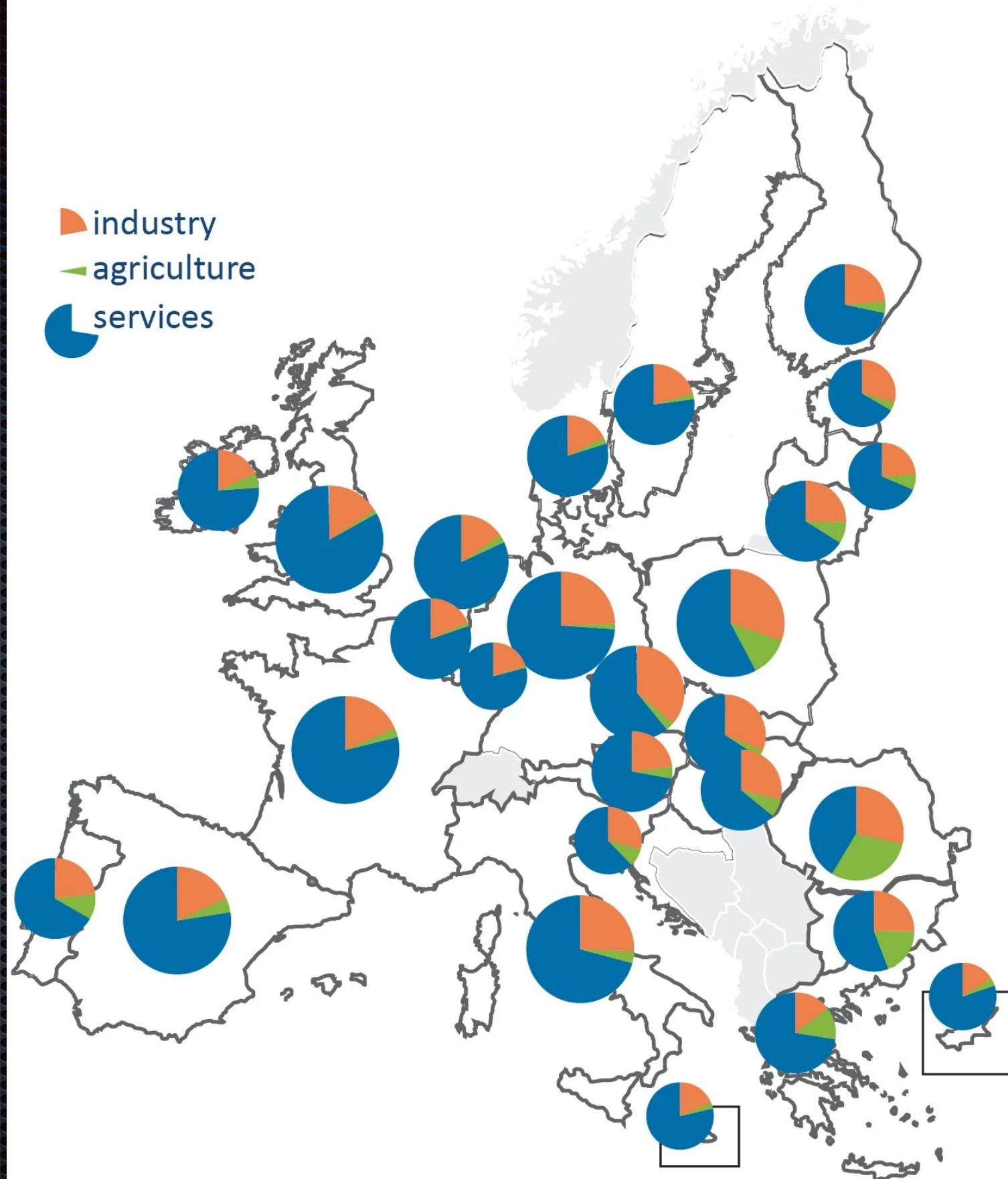
Number of people employed by economic sector.



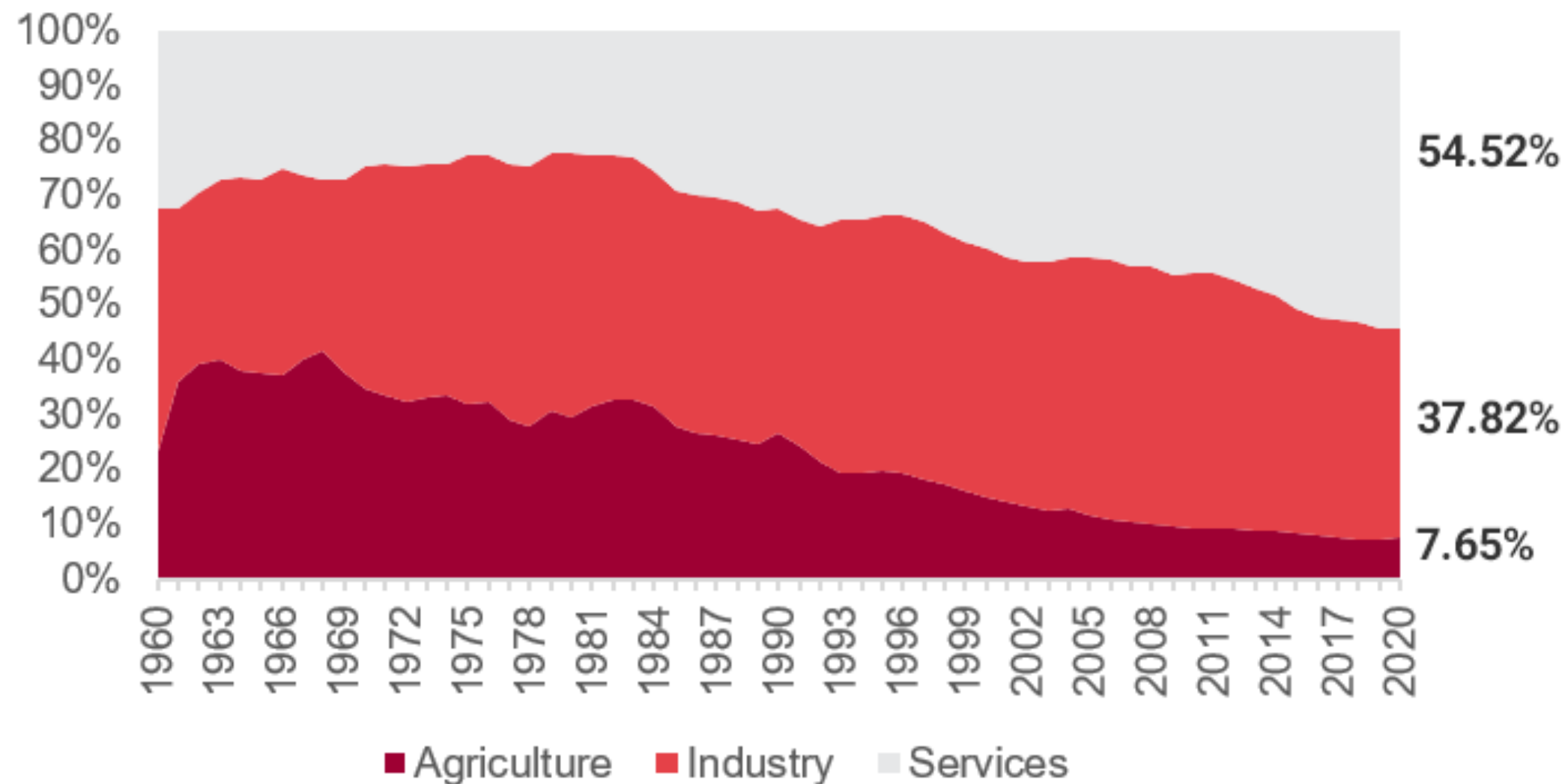
Data source: Our World In Data based on Herrendorf et al. (2014)

OurWorldinData.org/structural-transformation-and-deindustrialization-evidence-from-todays-rich-countries | CC BY

1. Employment in industry, agriculture and services - 2013



China's GDP Composition



Source: National Bureau of Statistics of China, China Briefing

Toward a Service Theory

Service Science, Management, Engineering, and Design (SSMED): Outline & References

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Abstract

The growth of the global service economy has led to a dramatic increase in our daily interactions with highly specialized service systems. These daily service interactions are both frequent and diverse, and may include retail, financial, healthcare, education, on-line, communications, technical support, entertainment, transportation, legal, professional, government, or many other types of specialized interactions. We often play the role of customer in these interactions, but we also play the role of provider at home and work. The purpose of these many interactions is to create (or sometimes to mitigate the destruction of) value of some type. On those especially busy days of creating or salvaging value, we all come to realize, perhaps reluctantly at first, that we live, work, and play by taking on a great many roles in a great many service systems, and that we are all, in fact, individual service systems ourselves - increasingly complex, multitasking, highly specialized, knowledge-intensive human service systems - in 'business' to interact with others and co-create value. And yet surprisingly few students graduating from universities have studied anything about service systems.

Service Science, Management, Engineering, and Design (SSMED), or service science for short, is an emerging discipline aimed at understanding and innovating service systems. Service systems are ancient, since the dawn of specialized knowledge and the division of labor, and are now rapidly evolving as costs plummet due to information and communication technologies (ICT) innovations that accelerate the creation of and sharing of specialized knowledge assets. Informal and formal service systems have been coevolving at an accelerating rate. Informal service systems depend more on traditional social systems and authoritative political systems (superordinate goal - which is why authority may appear "unfair"), and formal service systems depend more on monetary economic and strict adherence to legal system judgments (process without utility comparison - which is why bureaucracy may appear "unreasonable" or "out-moded"). Service systems exist and expand because of the value of the growing body of specialized

knowledge assets distributed across a growing population of specialized people, and because of the mathematical advantages of dependent win-win value co-creation (value propositions) and collective-win (governance mechanisms) interactions over purely independent 'do-it-all-myself' activities. Service systems (normatively) co-create value by applying specialized knowledge of diverse capabilities (provider perspective) and reciprocal needs (customer perspective) as they interact with and establish relationships or one time encounters with other service systems.

This paper sketches an outline and preliminary set of references to provoke discussions about the difficult challenge of integrating multiple disciplines to create a new and unique service science. The sketch outlines the theoretical and practical foundations of the emerging field of service science, as well as the types of expertise (both broad interactional and deep contributory) that are important to service science professionals. Service science professionals seek to create and improve service systems (and their associated value propositions, governance mechanisms, and service networks). A service science lab network is also described, that could someday provide real, virtual, and simulated world experiences to educate and provide practical work experiences for future service scientists, and students of other disciplines seeking a better understanding of service systems as well.

I. Theoretical and Practical Foundations

Today we increasingly depend on interactions with others to survive and thrive. Mass collaboration and competition with people from anywhere on the planet is becoming "the new normal." As customers, interdependent on and demanding more of others and ourselves, we live in and cocreate a world of accelerating social, technological, economic, environmental, and political complexity. We seek to change these aspects of our world to better meet our wants, needs, and aspirations. Individually and collectively, we, as customers, demand and participate

Succeeding through service innovation

A service perspective for education, research, business and government



A White Paper based on

- Cambridge Service Science, Management and Engineering Symposium (July 2007)

- The consultation process (October – December 2007)

Succeeding through service innovation

A service perspective for education, research, business and government



A White Paper based on
- Cambridge Service Science, Management and Engineering Symposium (July 2007)
- The consultation process (October – December 2007)

"Service systems are dynamic configurations of people, technologies, organizations, and shared information that create and deliver value to customers, providers, and other stakeholders. They form a growing portion of the world economy and are becoming central to the way businesses, governments, families, and individuals work. Innovation, a term applied almost exclusively to technologies in the past, is increasingly used in relation to service systems."

SERVICE SCIENCE

The Foundations of Service
Engineering and Management



Robin G. Qiu

WILEY



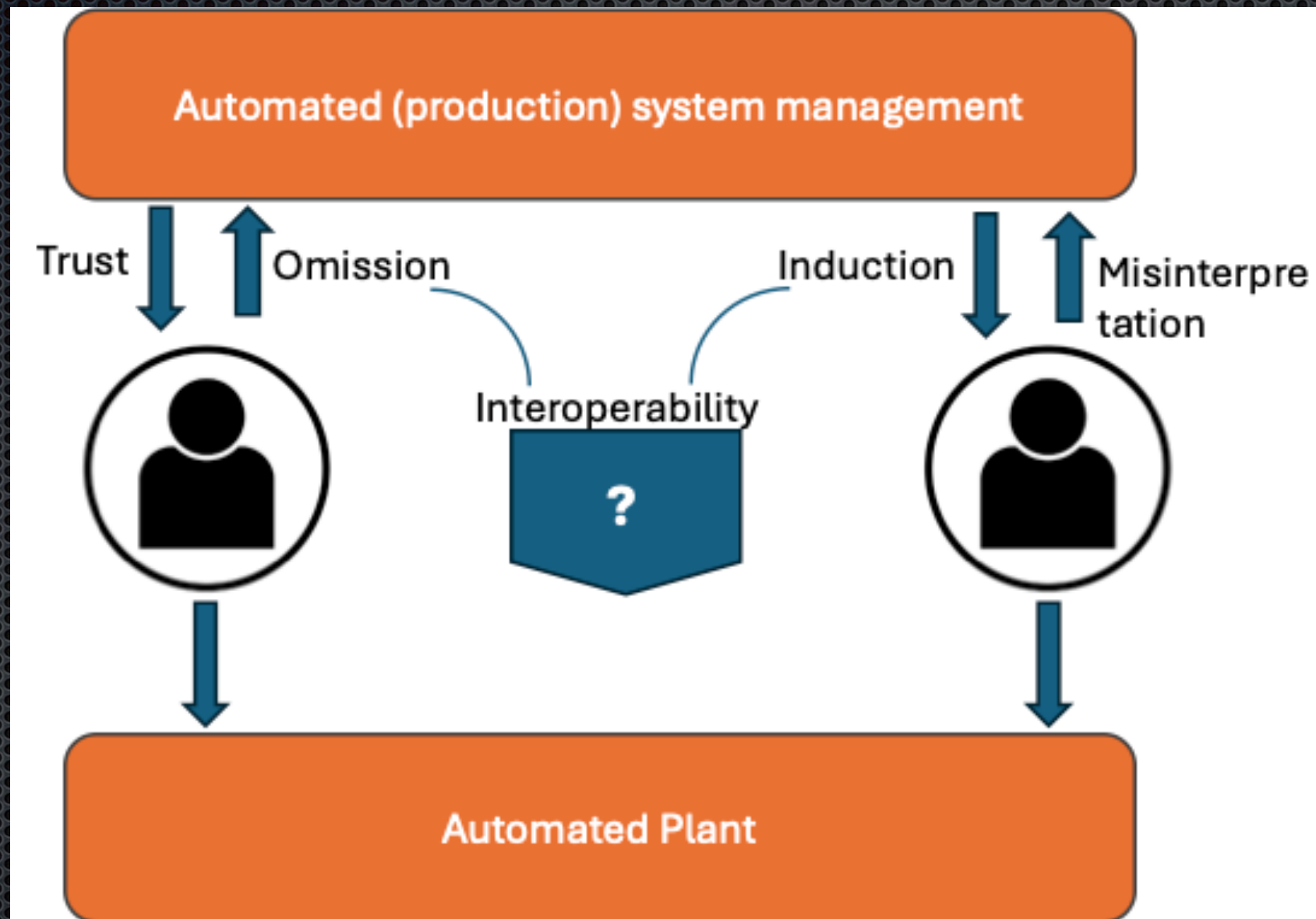
Service is considered as a transformation process in which both the provider-side and the customer-side people participate interactively, applying relevant knowledge, skills, and experiences in order to co-create mutual benefits for the service providers and their customers. Technically and socio-economically, the transformation process encompasses a series of service encounters that can be direct or indirect, consecutive or intermittent, physical or virtual, and brief or intensive. The value of the service depends on the socio-technical efficacy and effectiveness of all of the service encounters experienced throughout the service lifecycle.

Resuming its characteristics,

- service implies automated processes to fit a modern approach ;
- in its systemic view, service design should start composing viewpoints for the interaction between the service provider and contextual environment (customers included) ;

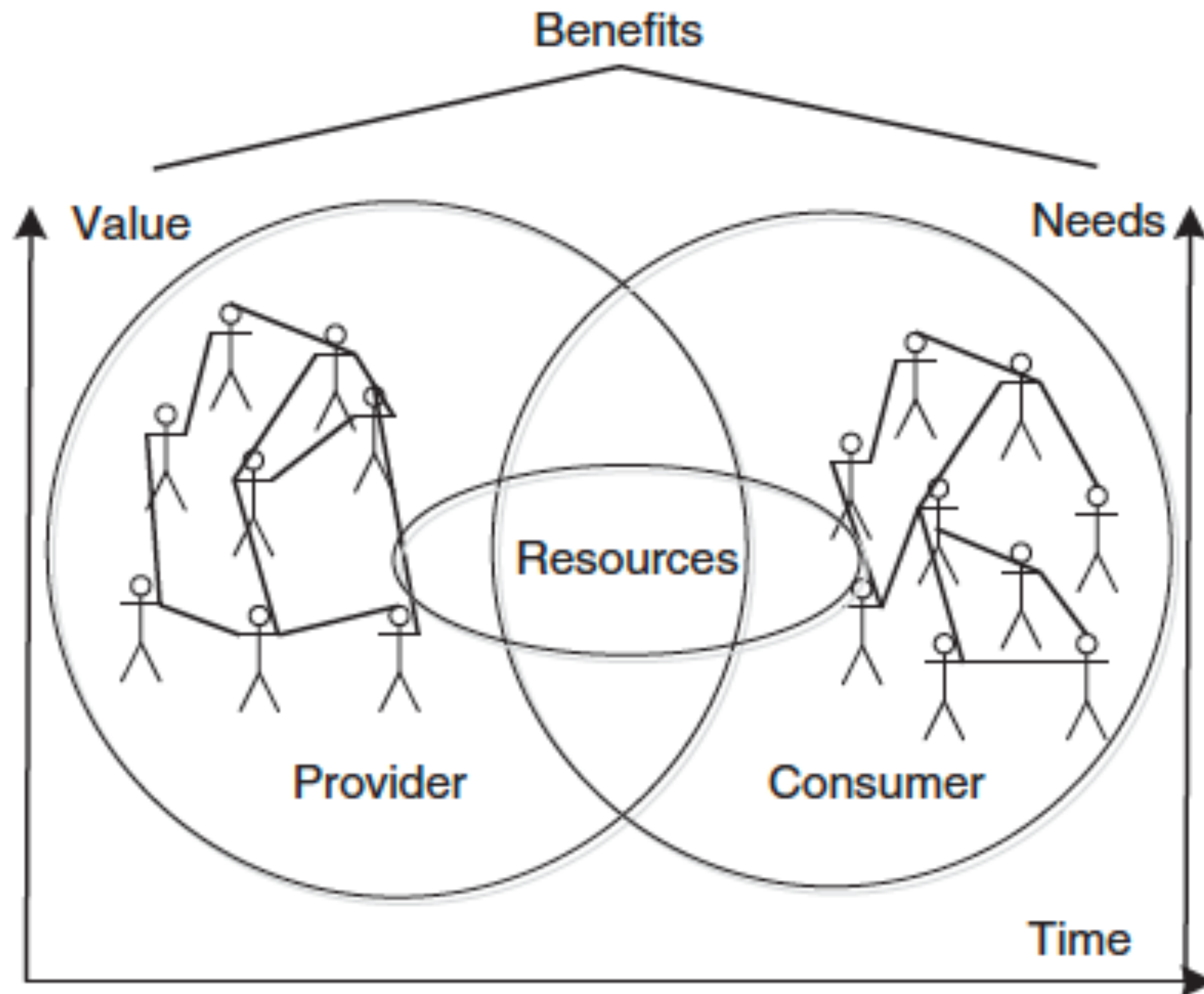
- the beneficial service relies on a transaction between the service provider and service customer that takes into account the "automation bias";
- in a more abstract view, the provider is a service network (a service composed of service organizations and agents), and the consumer is also segmented as a network (including individuals).

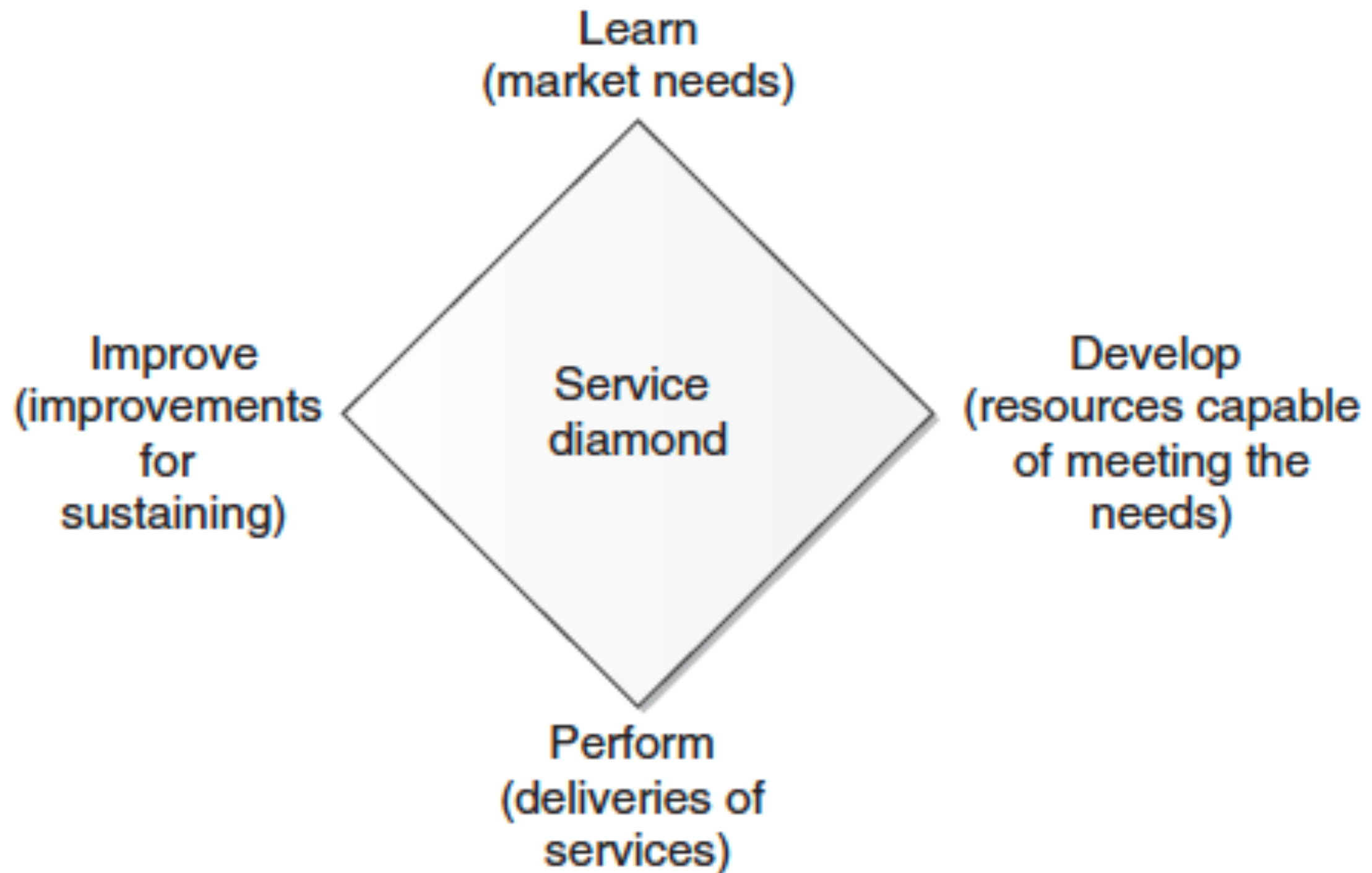
The Automation Bias

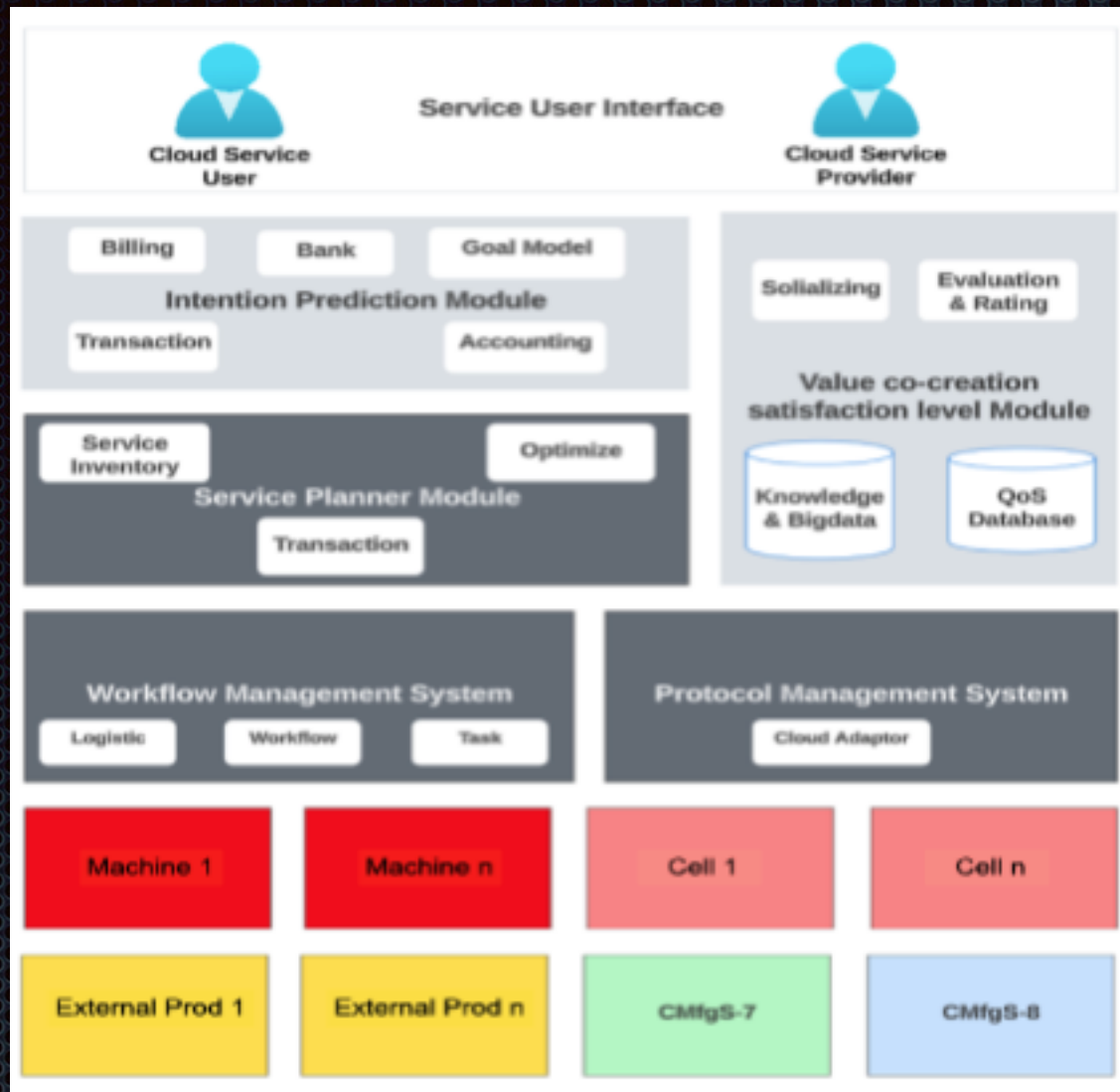




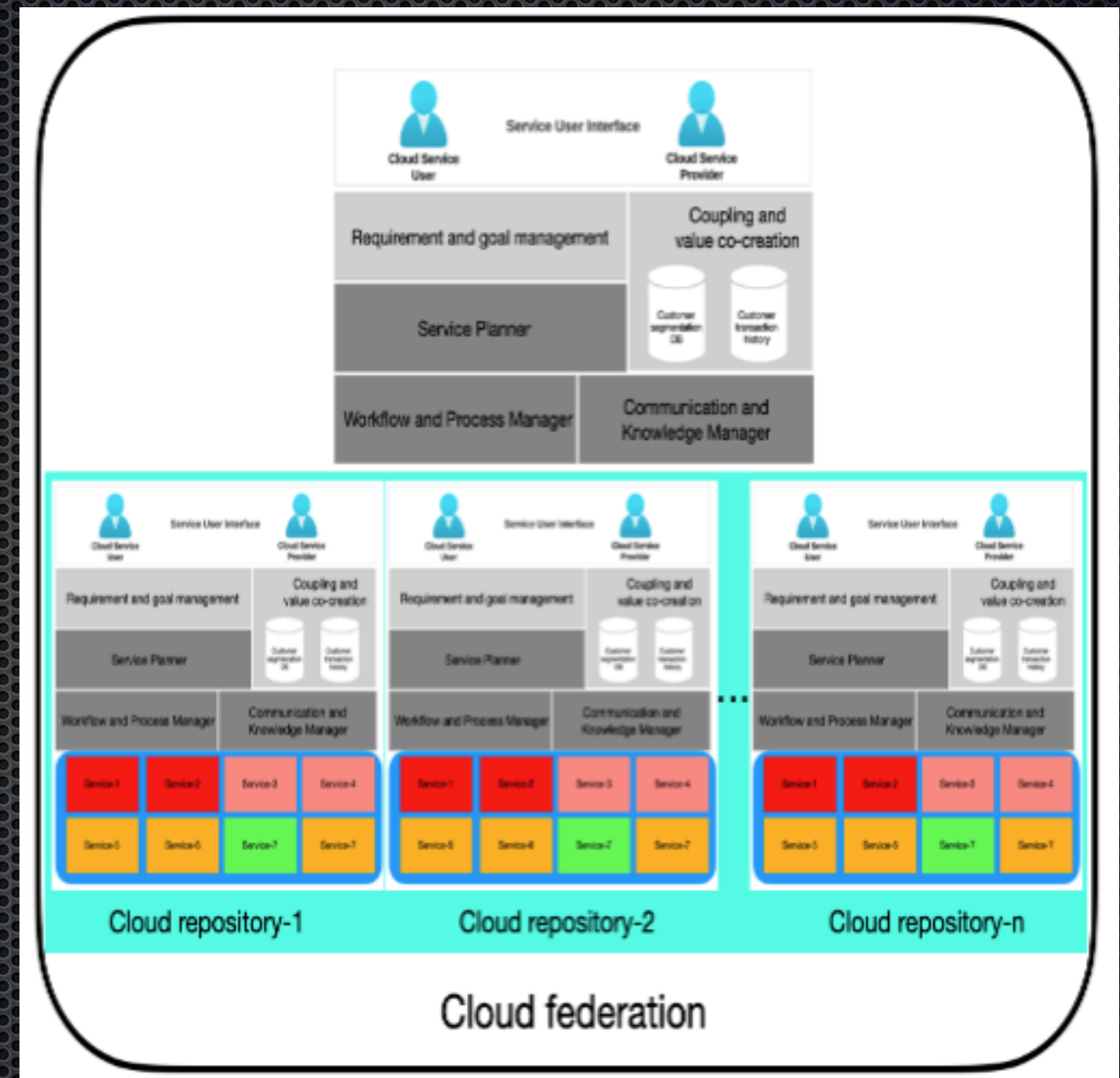
Service is a transformation process in which provider and customer networks participate collaboratively, applying relevant knowledge, skills and experiences, and sharing resources to co-create mutual benefits from their coupling. Technically and socio-economically, the transformation process encompasses a series of service encounters that can be direct or indirect (including other components from the contextual environment), consecutive or intermittent, physical or virtual, and brief or intensive. The value of the service depends on the socio-technical efficacy and effectiveness and should fit what was previously established in the design phase





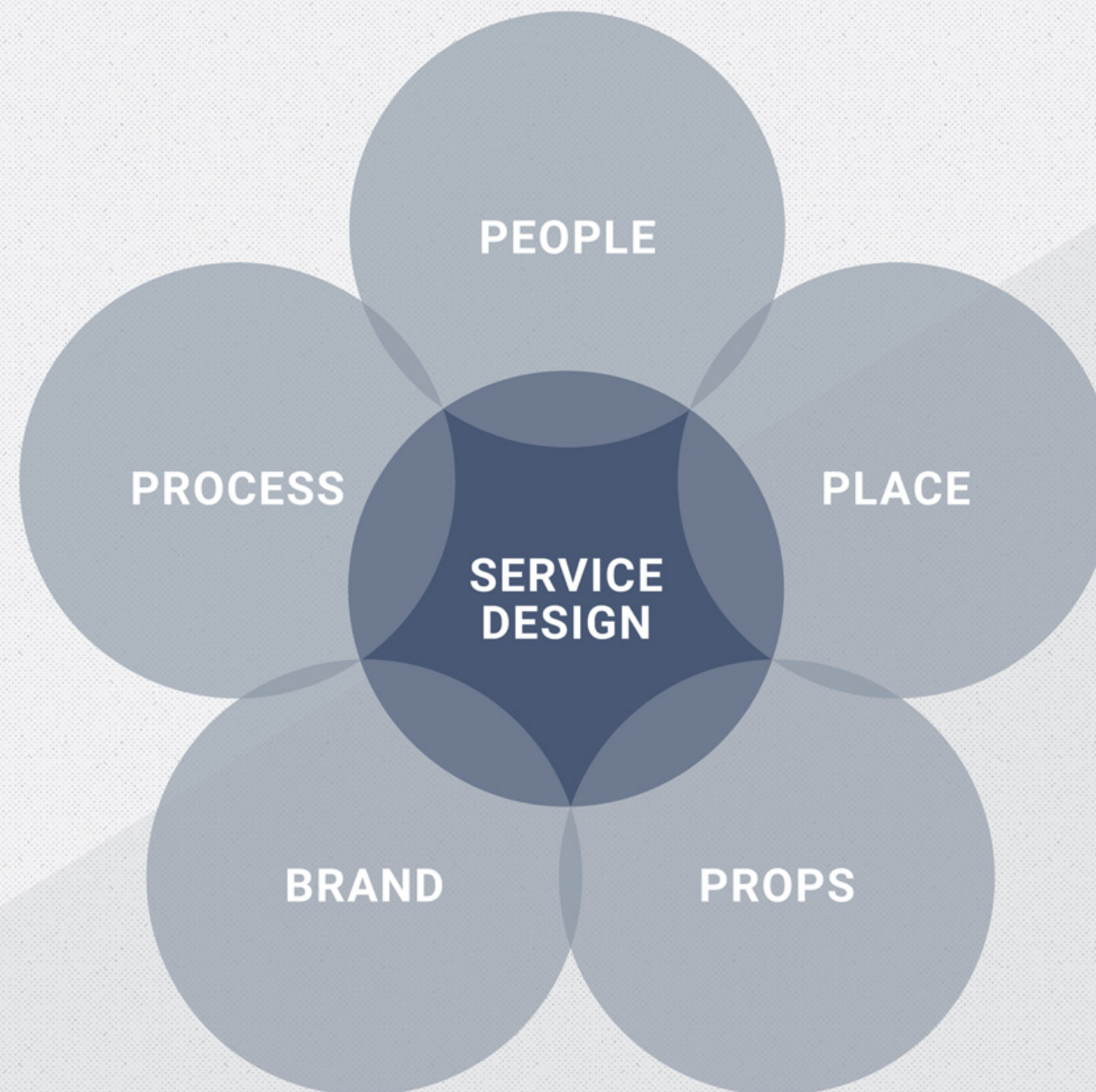


Single Arrangement

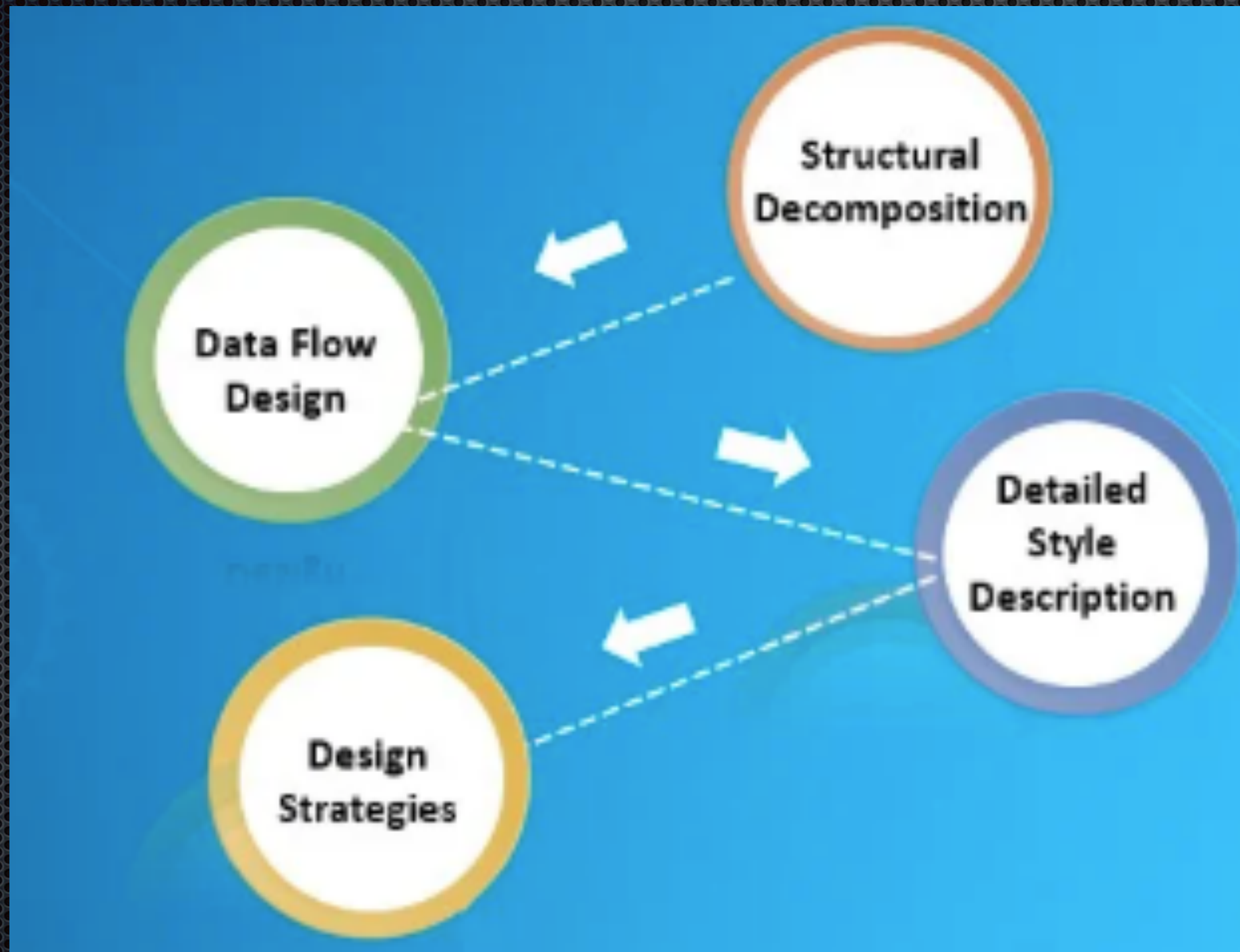


Service Federation

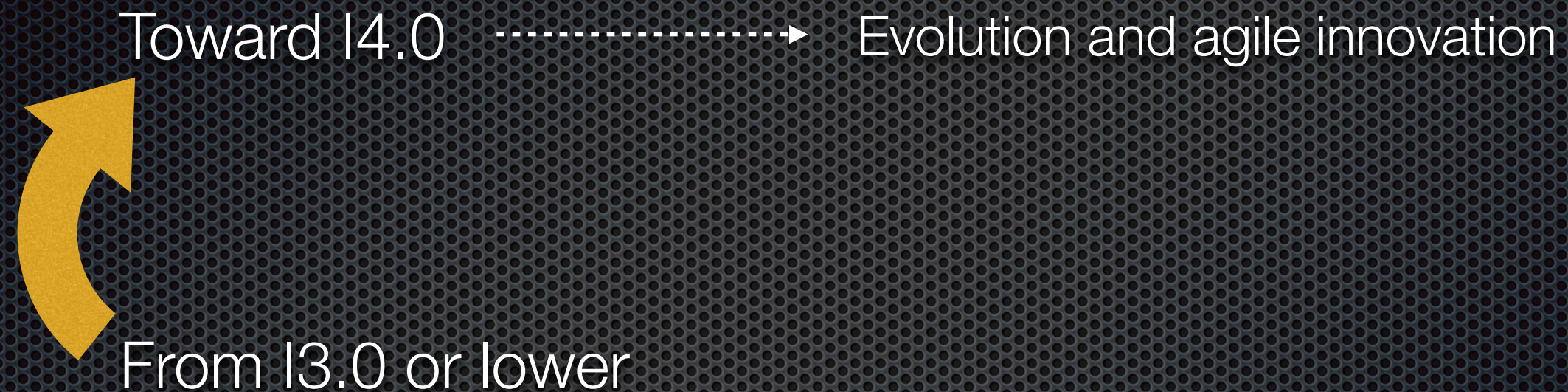
How to design service arrangements (federations)?



The functional-oriented approach



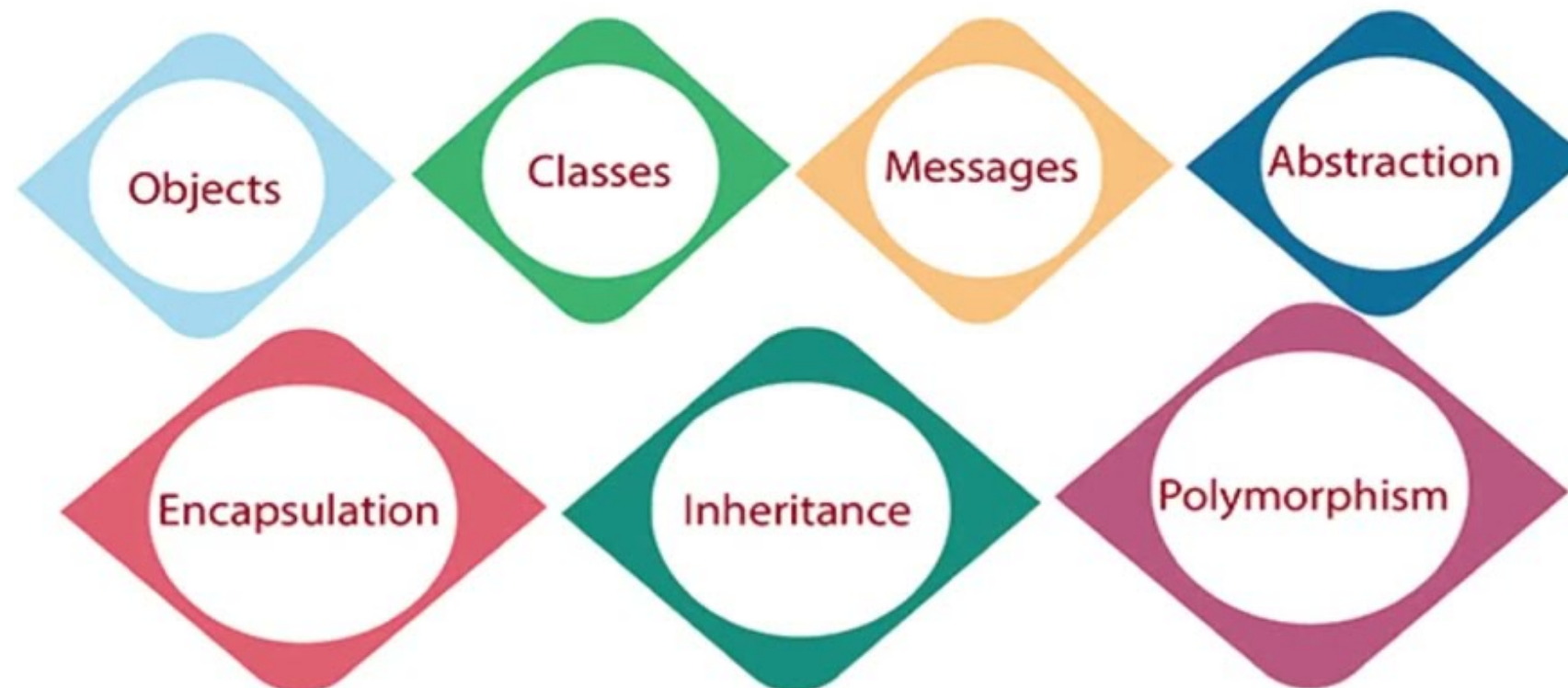
Organization and Production change



Vertical and horizontal evolution demand radical and incremental innovations

Object-Oriented Design

Object Oriented Design

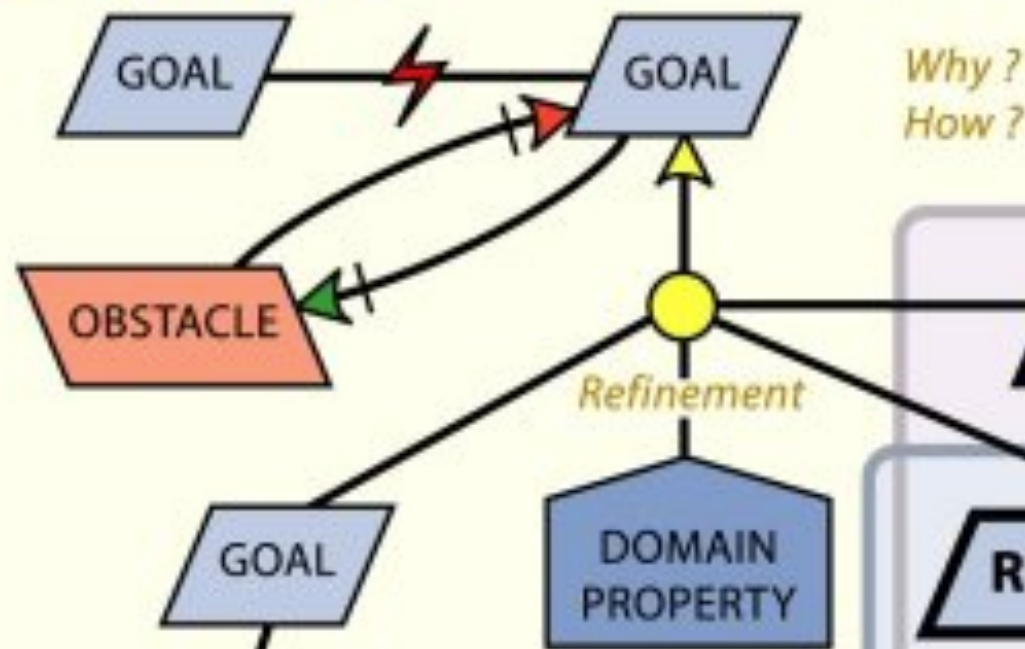


GODeF

Goal-oriented
Design
Framework

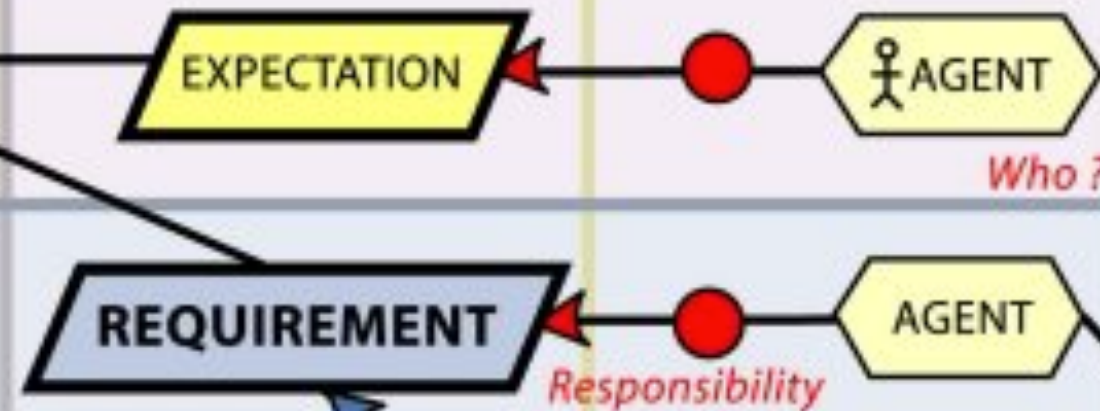


Goal modeling

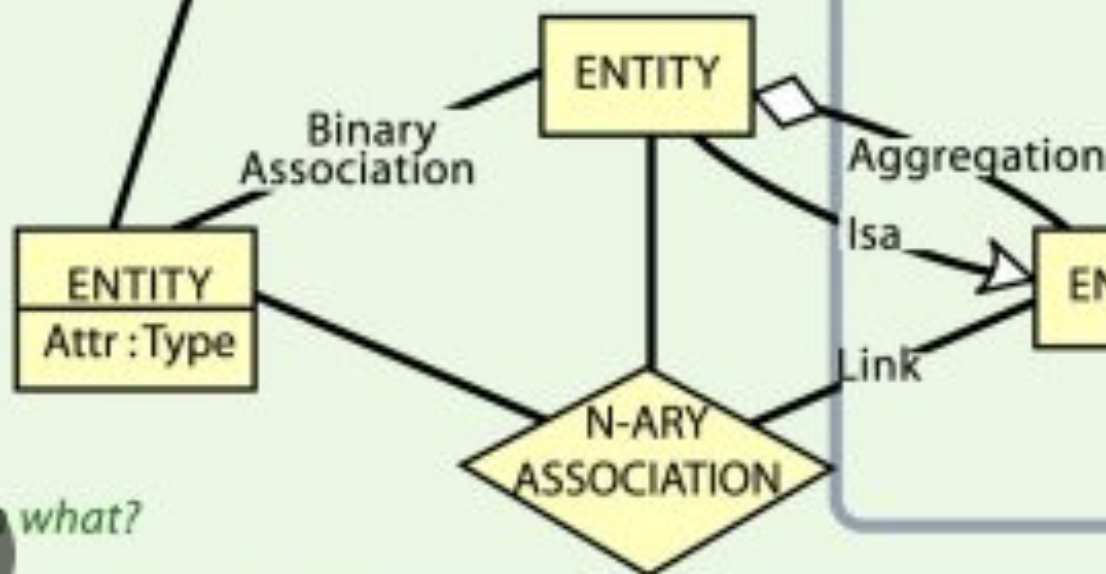


KAOS

Responsibility modeling



Concerns



On what?

Object modeling

Operationalization

Input

Output

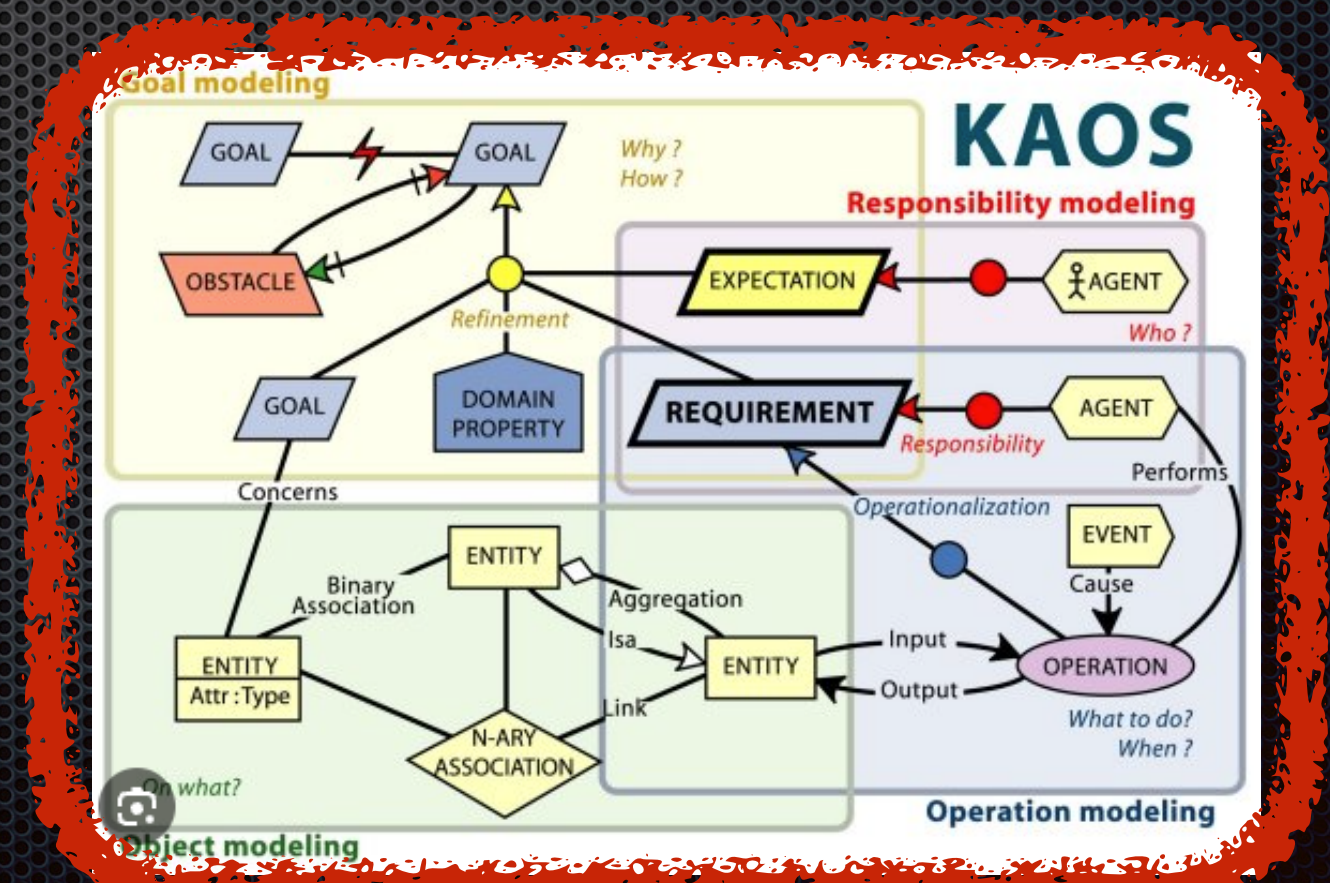
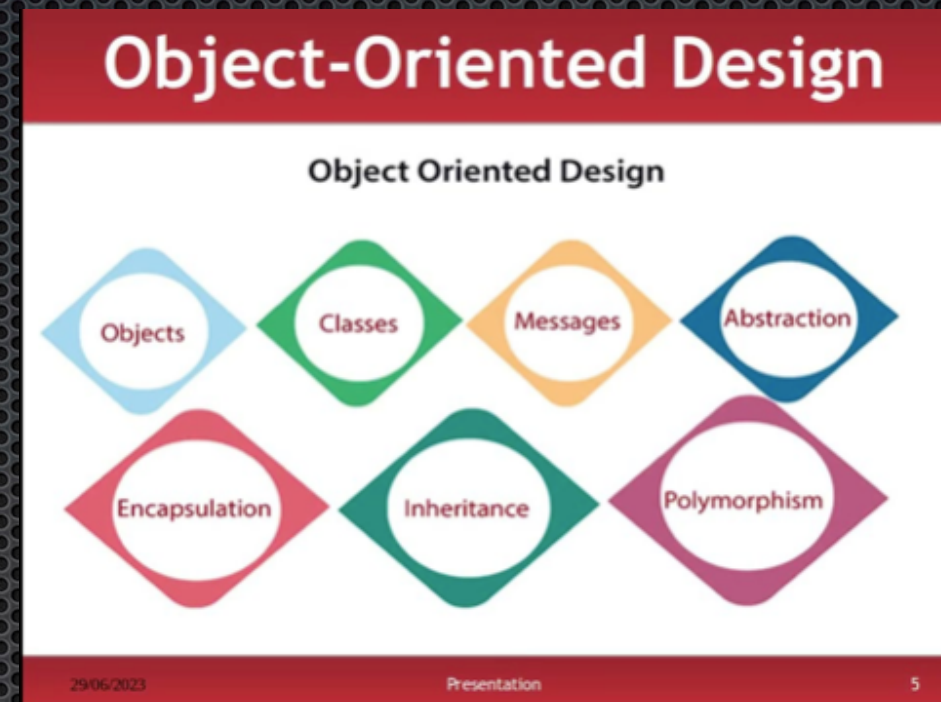
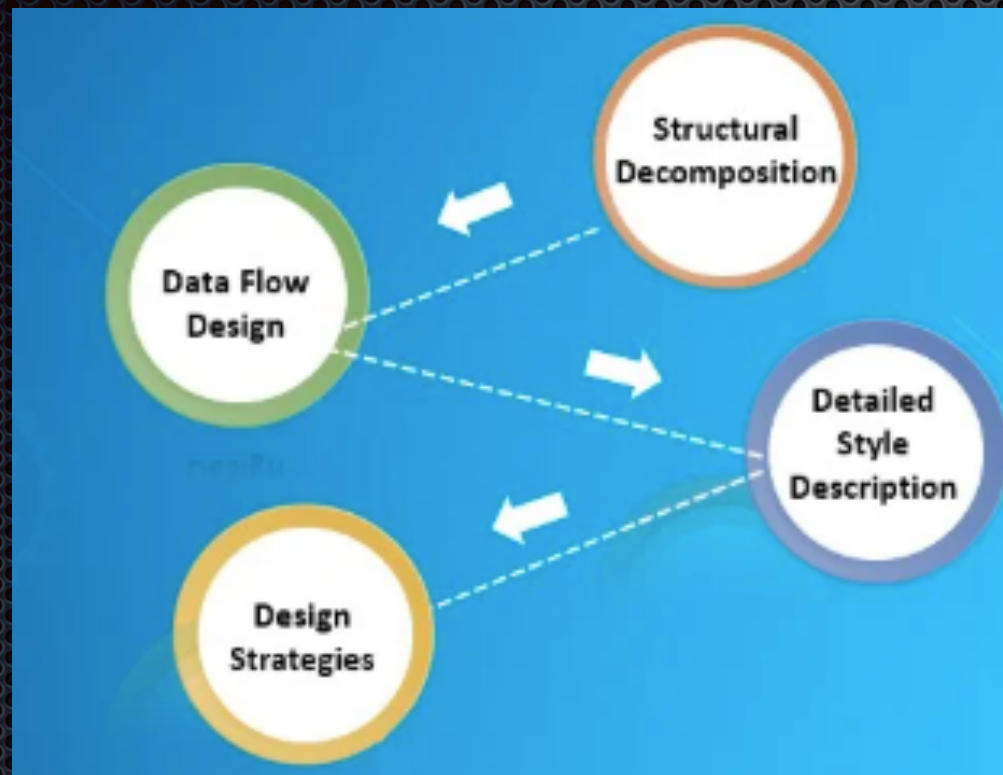
EVENT

Cause

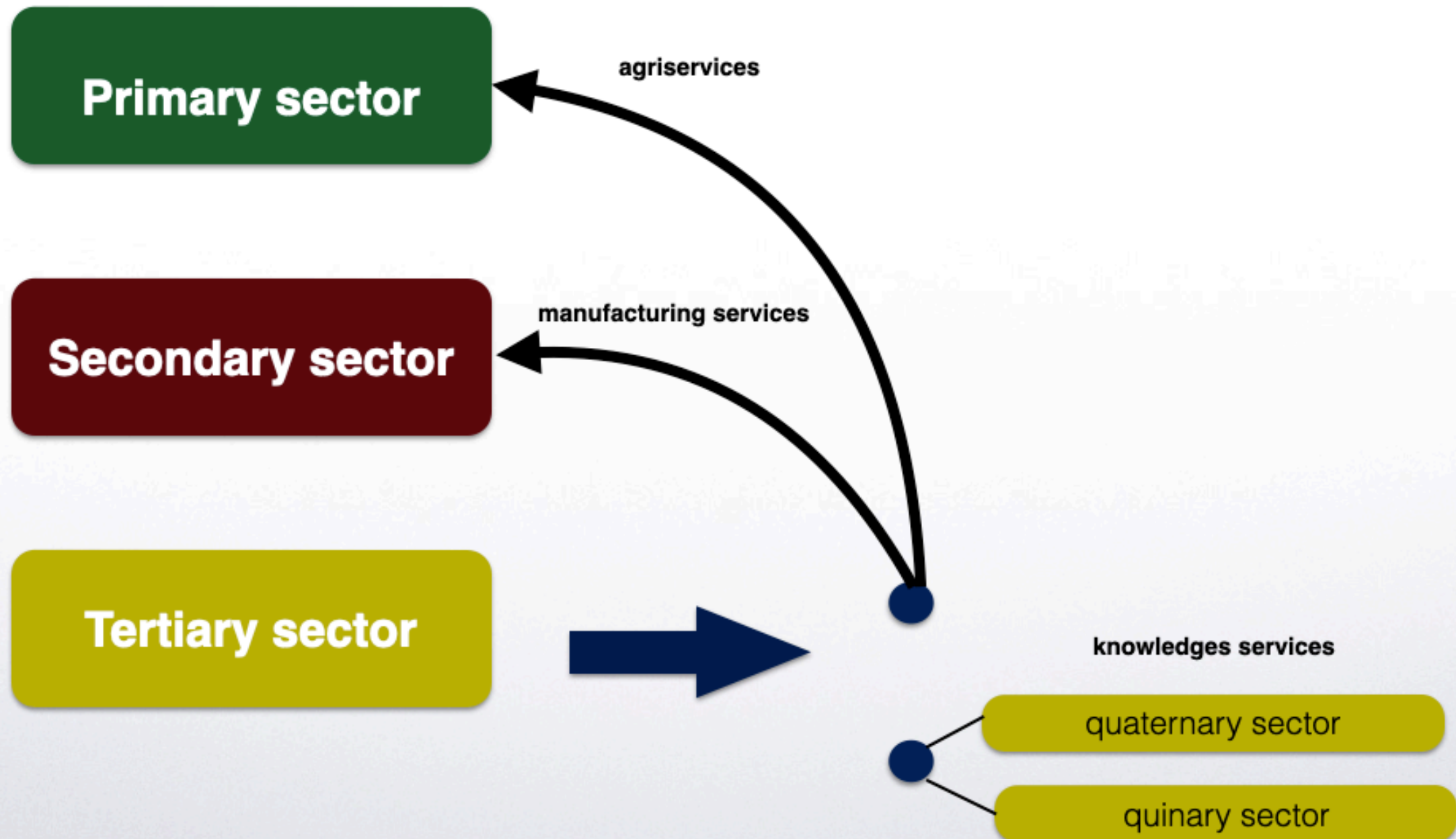
OPERATION

What to do?
When?

Operation modeling



Why service design needs
knowledge more than
functionality?





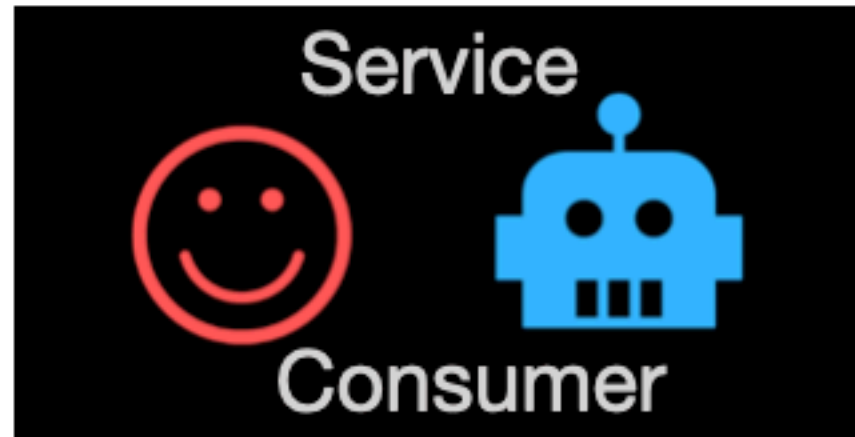
Given the application diversity, Service Science should provide a conceptual structure to services applied to any sector of the economy

Service Science

Ontological and conceptual
descriptions

Service
Management and
Engineering

Design methods



Quality



Content





Manufacturing IT Services

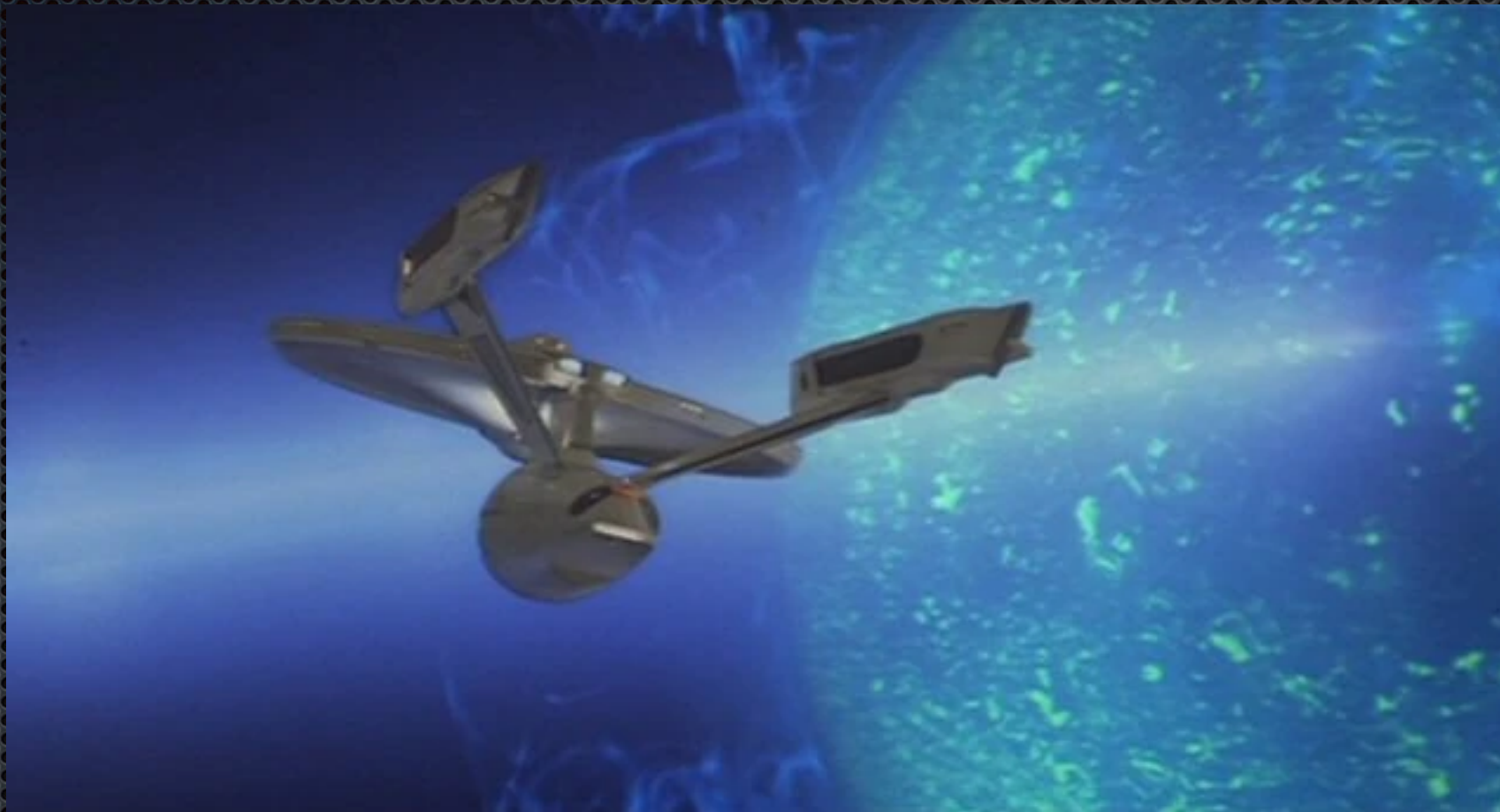
Service arrangements should operate processes , eventually with hardware resources of agents, and also deal with interactive transactions. That lead to the use of IT.

ITES

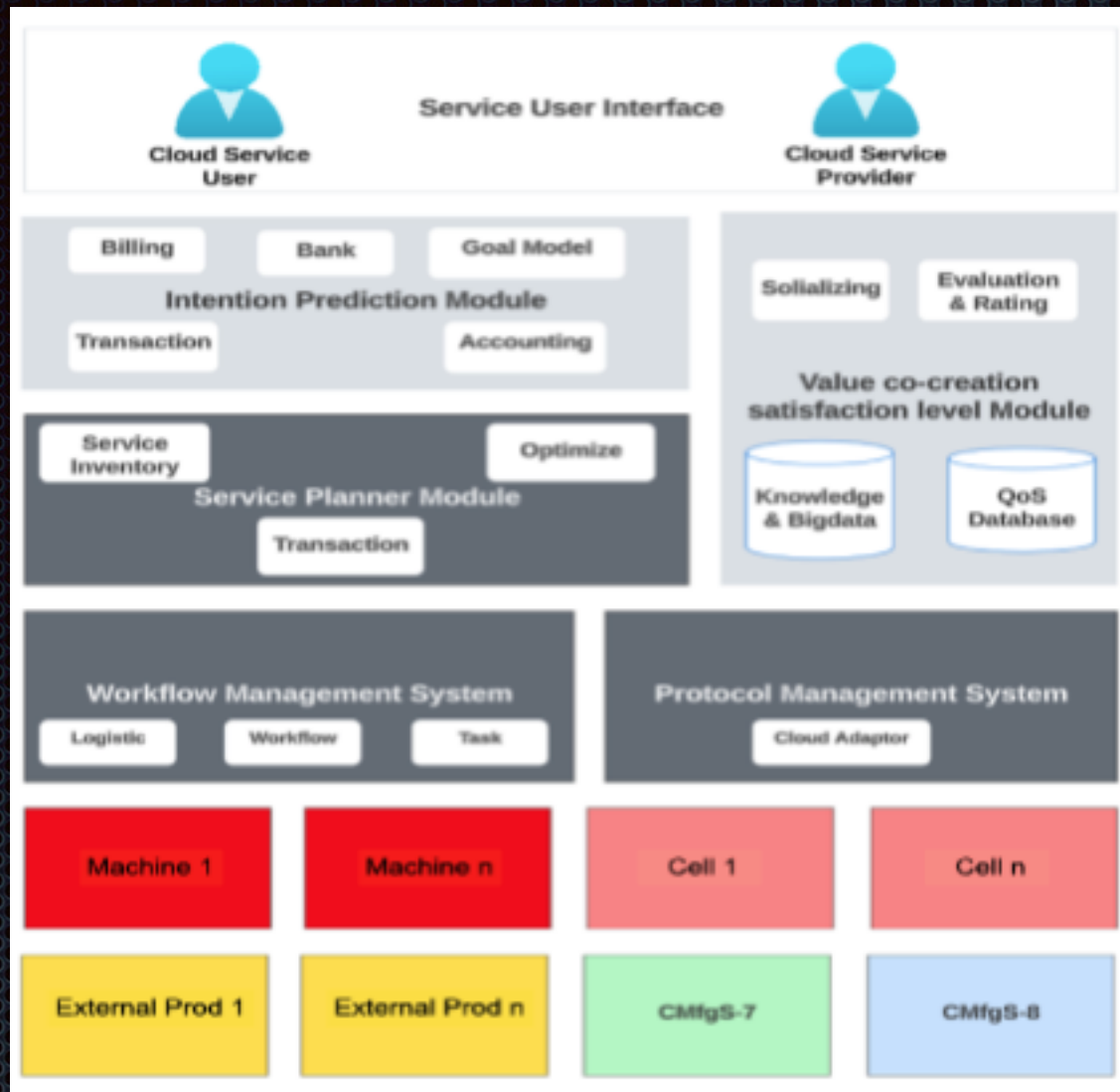


INFORMATION TECHNOLOGY ENABLED SERVICES

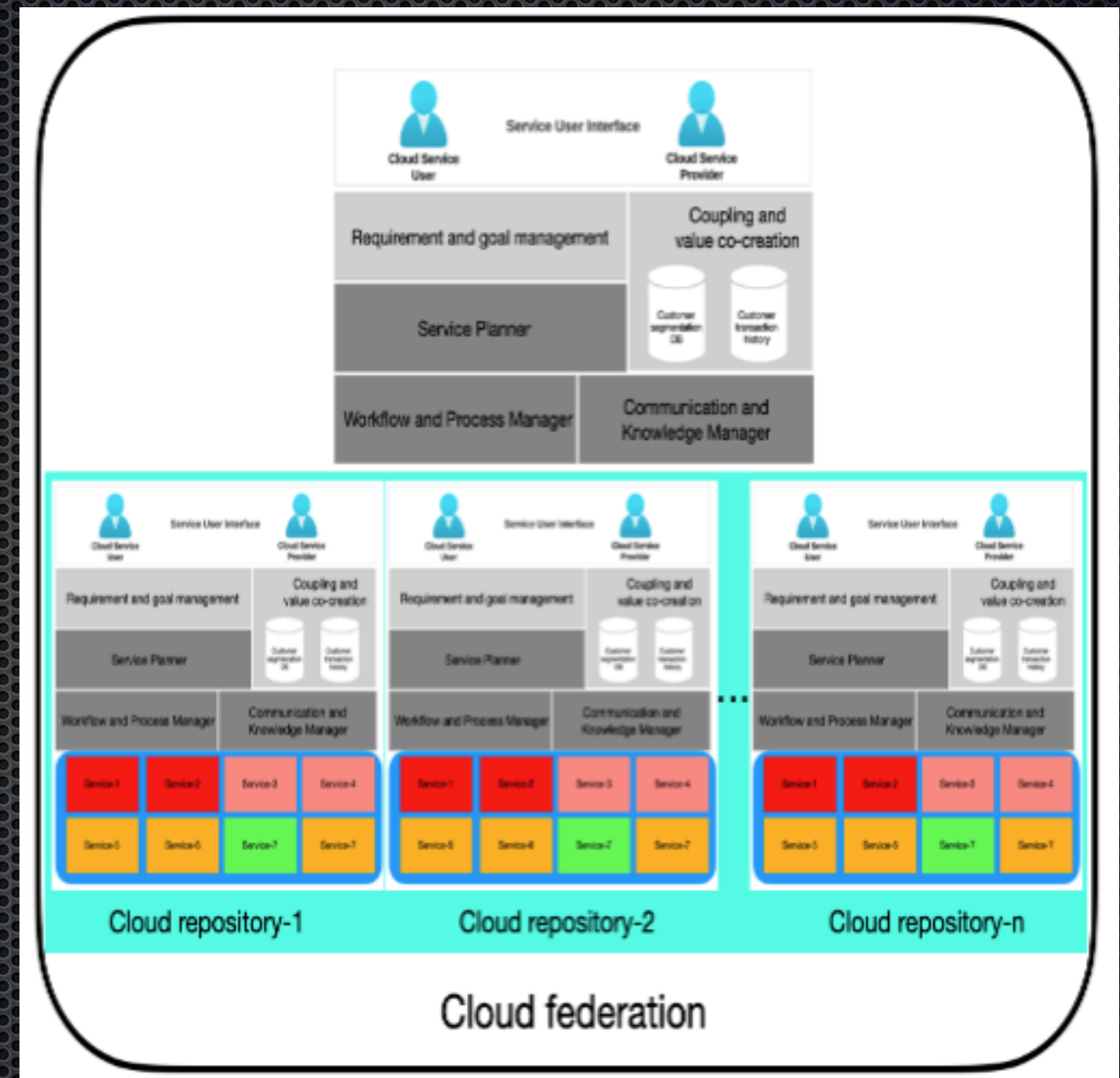
The final frontier...



Services must be modeled as systems



Single service system



Service Federation System

Systems engineering (SE) is a transdisciplinary approach and means to enable the realization of successful systems. Successful systems must satisfy the needs of their customers, users, and other stakeholders



Released 06 May 2024

**Guide to the Systems
Engineering Body of
Knowledge (SEBoK)**

Version 2.10



INCOSE definition could sound abstract and obvious at a first glance. On the other hand, if it is difficult to reach a successful target in product dominant approaches (it is different for software and IT), it is even harder to have that to as a result of a transdisciplinary approach, dealing with a target that is hybrid, mixing product and (IT-enabled) service.

Conclusion

We have enough reasons to summarize our lecture today saying that :

- Service-orientation is a tendency almost ubiquitous, reaching several areas of research, production, business, and education, participating in all economic activities ;
- Such tendency is supported by the dominance of service in the economy, especially in the third sector ;
- The evolution in production follows a line that conducts to digitalization, turning to have information as a basis in the current stage, and preparing to include back the humans in the future I5.0[12] ;
- Considering the complexity and interdisciplinary capacity, a Service Science Theory needs to be developed based on a consistent set of service concepts ;
- Service Management and Engineering should rely on Service Science and look for suitable methods to develop transdisciplinary IT-based arrangements to implement service ;
- Methods to support Service Design should merge with Systems Design and look for approaches that privilege knowledge over functionalities. The goal-oriented method is a good candidate, especially in the early requirements phase.

In next sub-lecture we will in more practical aspects of service design methods and architectures, specially the agent-based architecture and its relation with topics of the transdisciplinary approach, as Artificial Intelligence and I4.0.



5 Bibliography



- [1] A.D. CHANDLER JR. *The Visible Hand* : Belknap Press, 1977, p. 608.
- [2] J. SPOHRER et al. « Steps Toward a Science of Service Systems ». In : *IEEE Computer* 40.1 (2007). DOI : 10.1109/MC.2007.33.
- [3] S. HUANG et al. « Industry 5.0 and Society 5.0—Comparison, complementation and co-evolution ». In : *Journal of Manufacturing Systems* (2022).
- [4] J. SPOHRER et S. KWAN. « Service Science, Management, Engineering, and Design ». In : *International Journal of Information Systems in the Service Sector* 1.3 (2008).
- [5] white PAPER. « Succeeding from Service Innovation ». In : *Cambridge Service Science, Menagement and Engineering Symposium* (2007).
- [6] Robin QIU. *Service Science : The Foundation of Service Engineering and Management*. Hoboken, USA : John Wiley & Sons, 2014, p. 306. ISBN : 978-1-118-10823-9.
- [7] M. SUOHEIMO et al. *System Service Design*. New York, USA : Routledge, 2025. ISBN : 9781032817200.
- [8] R. PAWSON et R. MATHEWS. *Naked Objects*. NY, USA : John Wiley, 2002, p. 290. ISBN : 978-0470844205.
- [9] J. MYLOUPOLOS, L. CHUNG et E. YU. « Requiremnts Analysis : From object-oriented to goal-oriented ». In : *Communications of ACM* 42.11 (1999), p. 31-37.
- [10] J. MYLOUPOLOS, L. CHUNG et E. YU. « Reasoning About Alternative Requirements Options ». In : *Lecture Notes in Computer Scince* 5600 (2009), p. 801-397.
- [11] Tetsuo TOMIYAMA, Yoshiki SHIMOMURA et Kentaro WATANABE. « A Note on Service Design Methodology ». In : *Proc. of the ASME Design Eng. Technical Conf. on Computers and Information in Engineering*. 2004. URL : <https://api.semanticscholar.org/CorpusID:109140568>.
- [12] Shimon Y. NOF et Jose Reinaldo SILVA. « Perspectives on Manufacturing Automation Under the Digital and Cyber Convergence ». In : *Polytechnica* 1.1-2 (2018), p. 36-47. ISSN : 2520-8497. DOI : 10.1007/s41050-018-0006-0.

Concluding today's class...

- Service is closely related to production and society and stands for 12.000 years;
- The way it contributes evolves with production mode and strategy, and the Engineering methods follow;
- Future I4.0, I5.0 and Society 5.0 will be strongly based on (automated) service

Concluding today's class...

- Therefore, it is a challenge design services on current transdisciplinary perspective, which demands new methods and approaches;
- Goal-oriented is an alternative to introduce more knowledge on service design;
- New methods should be flexible and adapt to intensive innovation;



In the next class, we will advance on the matching between service and systems design, introducing **agent-based manufacturing** and its closure on **manufacturing_as_a_service**.

