IPIC 2023

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Athens, Greece

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Expanding the logistics Scope

PI Containers:
Assessment of Functions and Development from an Engineering Design Related Perspective

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Agenda

- Motivation
- Methodical Approach
- Systematic Literature Review
- Takeaways and Outlook

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Motivation

What does Wikipedia say about Physical Internet?

- “In logistics, the Physical Internet is an open global logistics system founded on physical, digital, and operational interconnectivity, **through encapsulation**, interfaces and protocols. The Physical Internet is intended to replace current logistical models.”
- “The Physical Internet does not manipulate physical goods directly, whether they are materials, parts, merchandises or yet products. It manipulates **exclusively containers that are explicitly designed for the Physical Internet** and that encapsulate physical goods within them.”
- “The Physical Internet **encapsulates physical objects in physical packets or containers, hereafter termed π-containers so as to differentiate them from current containers**. These π-containers are world-standard, smart, green and modular containers. They are notably modularized and standardized worldwide in terms of dimensions, functions and fixtures.”
- ....

Motivation

What does literature say about Physical Internet?

- “Physical Internet vision is introduced in 13 points. **Encapsulating merchandise in standard PI-container** sizes moving from point to point transportation to distributed multi segment transportation are among the 13 points […]”
- “Goods will be encapsulated in **designed-for- logistics standard, modular, smart and reusable PI-containers,** from the size of small cases up to that of cargo containers”
- “[…] **central pillars of the PI** involve also physical assets e.g. the **physical encapsulation of goods in modular, standard PI Container** and PI Hubs and other nodes in the network. “
- ….

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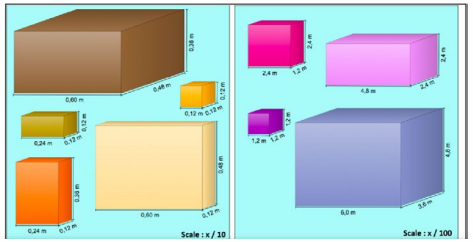
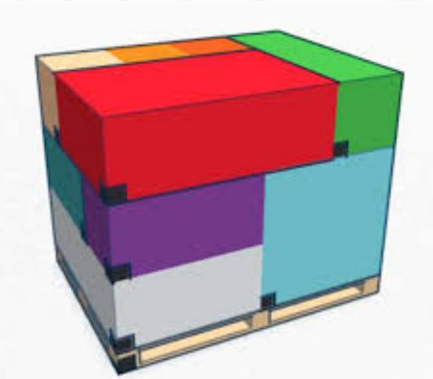
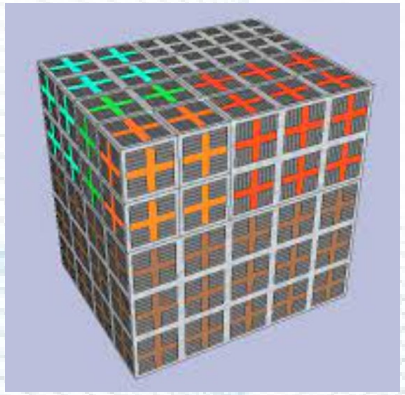
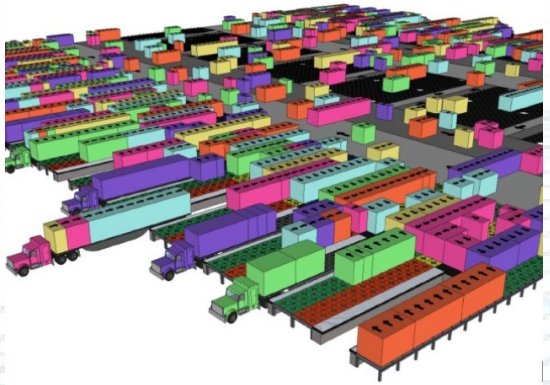
Motivation

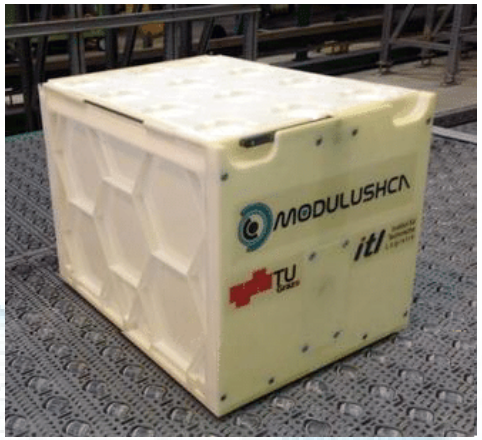


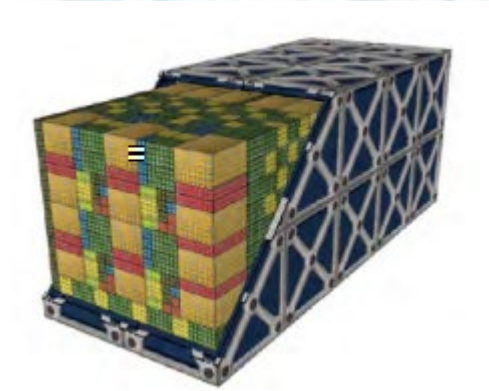
How does the PI Container look like?











How „physical“ is the PI Container?

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Methodical Approach

Systematic Literature Review

Problem Statement/problem Formulation — S1

- *Objective:* Clarification of the Research Question

Development of the review protocol — S2

- *Objective:* Setup of explicit inclusion/exclusion criteria

Data acquisition — S3

- *Objective:* Search of relevant Literature → **Review title**

Data screening — S4

- *Objective:* Screen for inclusion → **Review Abstract**

Data quality — S5

- *Objective:* Assess Quality → **Review Full-text**

Data Extraction — S6

- *Objective:* Validate and categorize data

Analysis and Syntheses — S7

- *Objective:* Findings of the Literature Review

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Systematic Literature Review

Problem Statement – S1

- RQ 1: How many works addressed the PI Container as a primary topic (including development over the last years)?
- RQ 2: What's the degree of abstraction of the PI Container treated in the different works?
- RQ 3: To what extent are physical aspects included in the design of the PI Container?

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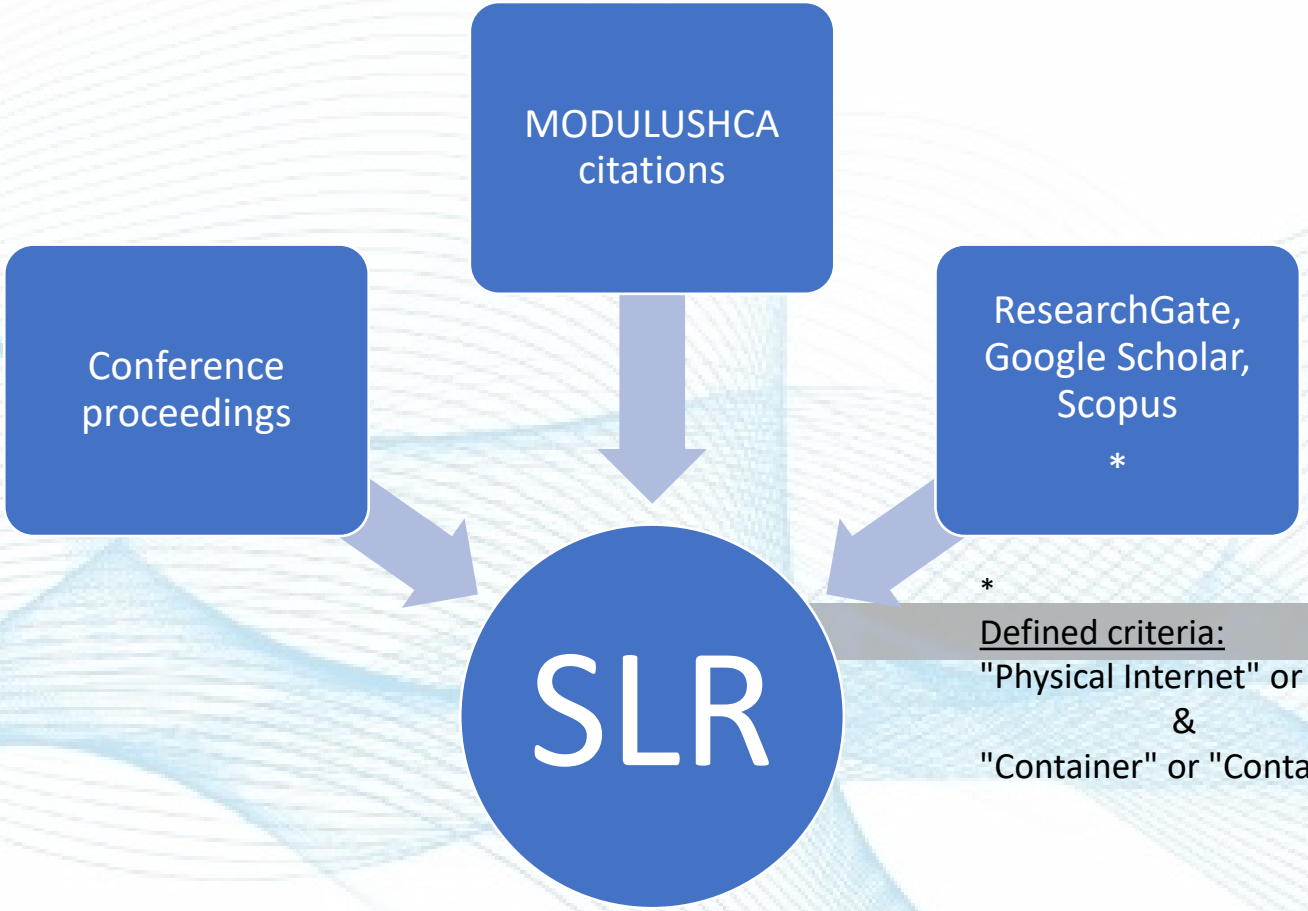
Systematic Literature Review

Development of the review protocol – S2



*

Defined criteria:

"Physical Internet" or "PI" or "π"

&

"Container" or "Containerization/Containerization"

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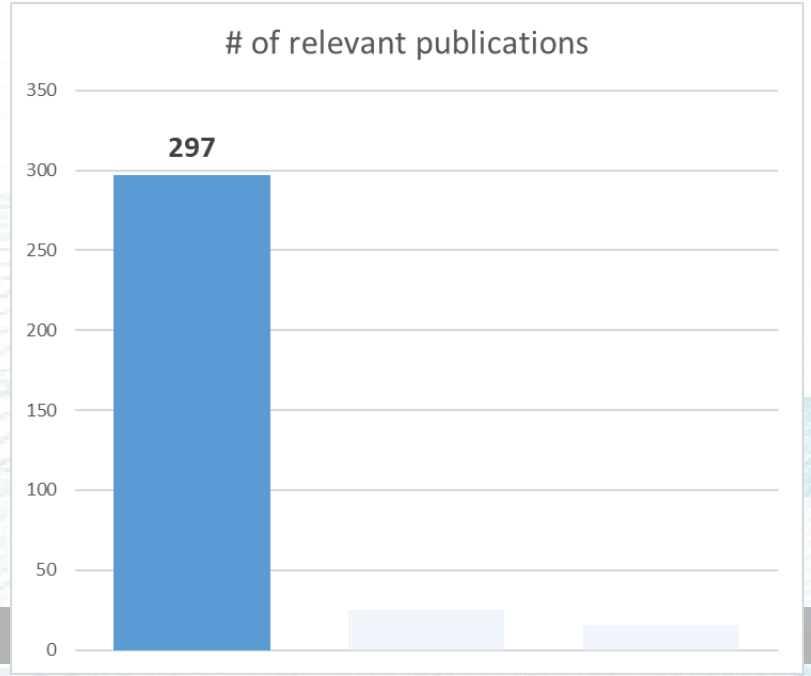
Systematic Literature Review

Data Acquisition – S3

- 297 publications after first „collecting“
  - 265 from IPIC and MODULUSHCA citations
  - 32 from ResearchGate, Google Scholar, Scopus



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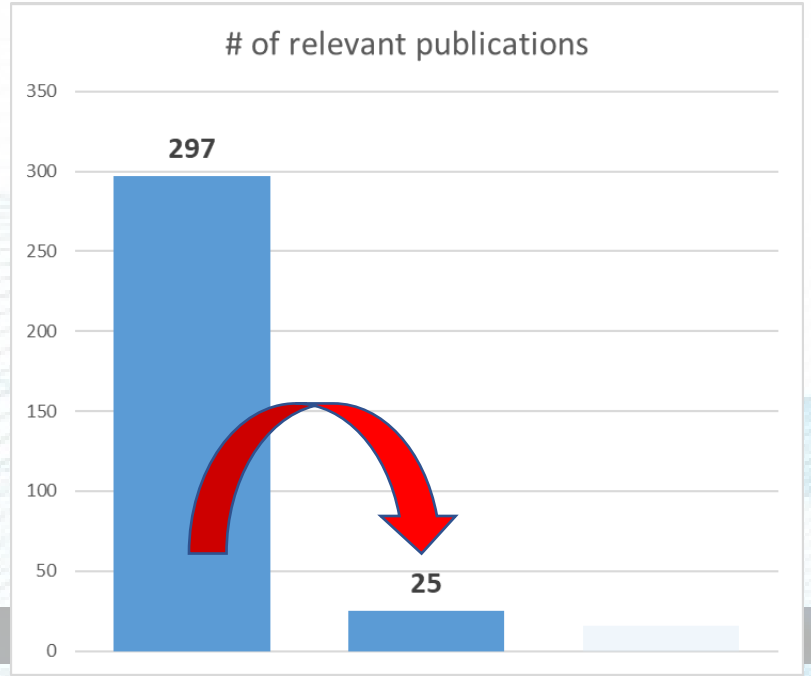
Systematic Literature Review

Data Screening – S4

- 297 publications after first „collecting“
  - 265 from IPIC and MODULUSHCA citations
  - 32 from ResearchGate, Google Scholar, Scopus

abstract review

- 25 relevant publications after abstract review



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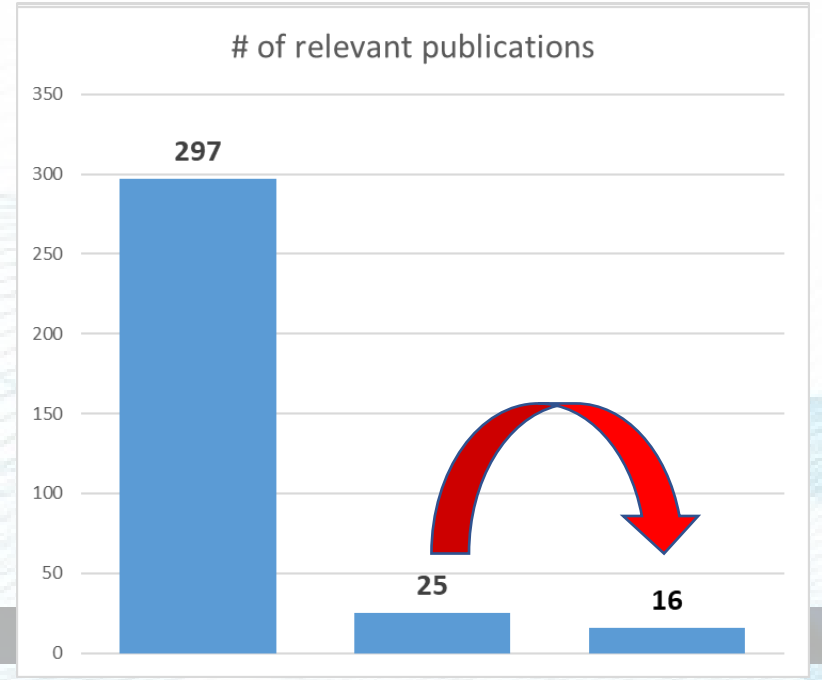
Systematic Literature Review

Data Quality – S5

- 25 relevant publications after abstract review

Source	PI Container as significant content	Comment
Montreuil et al. (2014)	✓	Introduction and development of the concept of Pi Container
Pach et al. (2014)	✓	PI Container as a Hexader for packaging simulations
Walha et al. (2014)	✓	PI Container with different dimensions, mathematical model
Tran-Dang et al (2015)	✓	PI Container with different dimensions for packaging simulations
Tretola et al. (2015)	×	Definition of Data Sets based on MODULUSHCA
Landschützer et al. (2015)	✓	Specific design and prototype of PI Container for field testing
Chakrouun et al. (2016)	×	General description of PI Container
Kapplmüller at al (2016)	✓	Specific design of a PI Container incl. spec. dimensions, and functions
Hao et al. (2016)	✓	General description of PI Container, function of PI Container in PI Hub
Salley et al. (2016)	×	General description of PI Container, focus on information exchange
Faugere et al. (2017)	✓	Description of dimensions and functions
Di Febbraro et al (2017)	✓	Mathematical Modell of PI Container incl, different dimensions
Krommenacker et al (2017)	×	General description of PI Container
Tran-Dang (2017)	✓	Description of functions of PI Containers, several simulations
Chargui et al. (2018)	✓	General description of PI Container, function of PI Container in PI Hub
Buckley et al. (2018)	✓	PI Container with different dimensions, mathematical model
Marino et al. (2019)	×	General description of PI Container
Bennekrouf (2019)	✓	PI Container with different dimensions for packaging simulations
Sternberg et al. (2020)	✓	General description of PI Container, packaging simulations
García-Arca et al. (2020)	×	Redesign of cardboard boxes, low relevance for PI
Tran-Dang et al. (2021)	×	General description of PI Container



- 16 relevant publications after quality check

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Systematic Literature Review

Data Extraction – S6

- RQ 1: RQ 1: How many works addressed the PI Container as a primary topic (including development over the last years)?
- Answer:

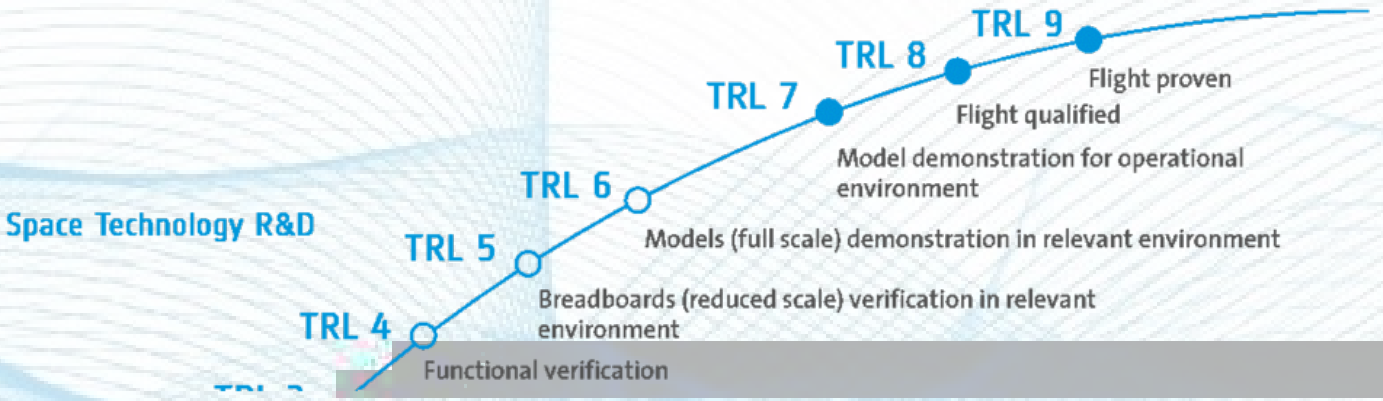
2014	2015	2016	2017	2018	2019	2020	2021	2022
Montreuil et al.	Landschützer et al.	Hao et al	Tran-Dang	Buckley et al		Sternberg et al.	Tran-Dang et al	
Walha et al	Tran-Dang et al	Kapplmüller at al	Di Febbraro et al	Chargui et al				
Pach et al.			Faugere et al					
3	**2**	**2**	**3**	**2**	**0**	**1**	**1**	**0**

Systematic Literature Review

Data Extraction – S6

- RQ 2: What's the degree of abstraction of the PI Container treated in the different works?

→ Technology Readyness Level (TRL)



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Systematic Literature Review

Data Extraction – S6

- RQ 3: To what extent are physical aspects included in the design of the PI Container?

→ Stages of Planning and Design Process*

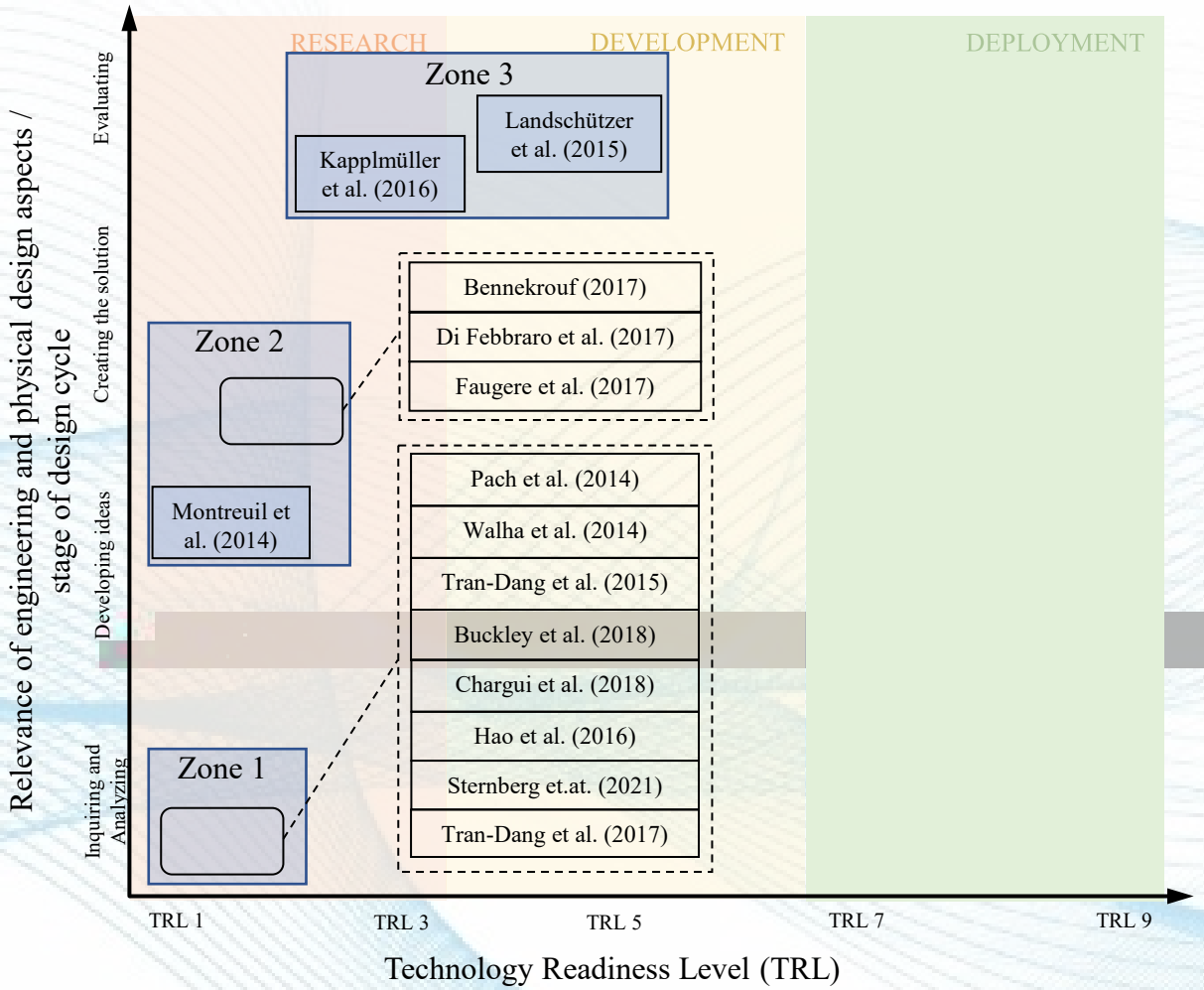
- Planning and clarify
- Conceptual design
- Embodiment design
- Detail design

*
Source: (Pahl, Beitz, 1996)

Systematic Literature Review

Data Extraction – S6

- RQ 2 + RQ 3:
- Answer:



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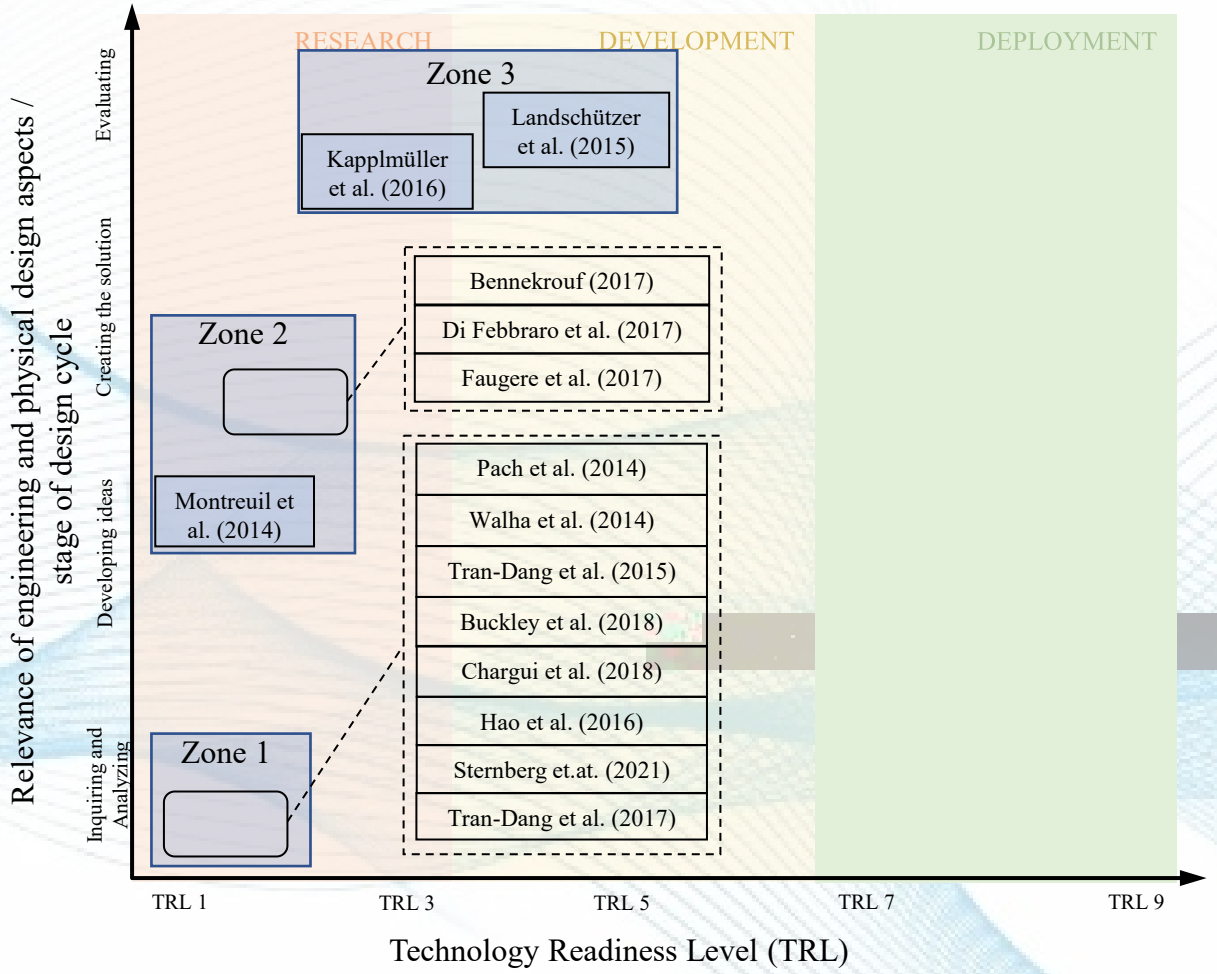
Systematic Literature Review

Analysis and Syntheses – S7



2014	2015	2016	2017	2018	2019	2020	2021	2022
Montreuil et al.	Landschützer et al.	Hao et al	Tran-Dang	Buckley et al		Sternberg et al.	Tran-Dang et al	
Walha et al	Tran-Dang et al	Kapplmüller at al	Di Febbraro et al	Chargui et al				
Pach et al.			Faugere et al					
3	2	2	3	2	0	1	1	0

"Although the PI Container is one of the main pillars of PI philosophy, just a few scientific publications focus on matching PI Containers for real-world application by developing, designing, building and testing PI Containers in real-life scenarios."

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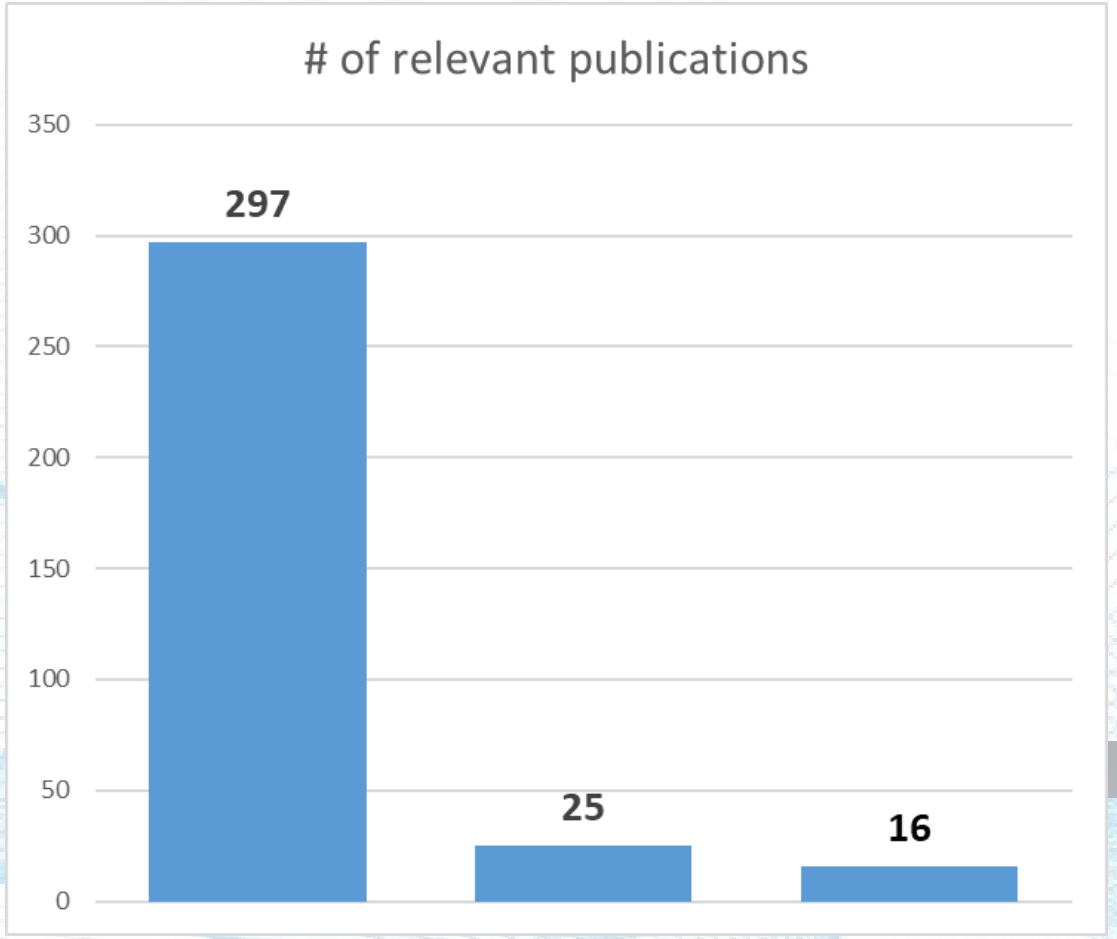
Takeaways and Outlook

- The PI container still seems to be seen as an object in the virtual world.
- There is less effort to develop a physical PI Container recorded.
- Still there is a need for new approaches and design suggestions to find Use Cases where the introduction of PI Container would lead to an benefit.
- Possible follow up research topics:
  - Definition and description of specific Use Cases, where the usage of PI Boxes can result in an increase of efficiency (including all physical aspects)
  - Methodical design of a PI Container which can fulfil the requirements of the Use Case (including prototypical implementation)
  - Definition of conditions and processing of a field test of the designed PI Container

Summary



- Little effort to develops „physical“ PI Container recorded
- No solution for market introduction TRL > 5 available
- decreasing research effort on PI Container over the years

→ There is still a lot to do.

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