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Validation of Product-Service Systems in Virtual Reality

by

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1. INTRODUCTION
2. RESULTS – METHODS AND PROTOTYPES
3. CONCLUSION

INTRODUCTION

PSS - Characteristics

- High complexity of PSS due to interdependent elements
- PSS have to be developed in an integrated manner
- Transition to a PSS provider has to be supported by a PSS development methodology

Product-Service Systems - Validation

- A validation methodology for PSS is a crucial factor for a successful development of PSS [1]
- The validation of PSS has not been in focus of PSS researchers [2]
- Some methods and tools for the validation of PSS have been introduced [3-16]

Previous work: SHP4PSS I

- A new method is required in order to:
  - Ensure a systematic approach
  - Enable a testing of early PSS concepts
- A concept for prototyping of PSS has been introduced as **SHP4PSS** [17]

Previous work: SHP4PSS II

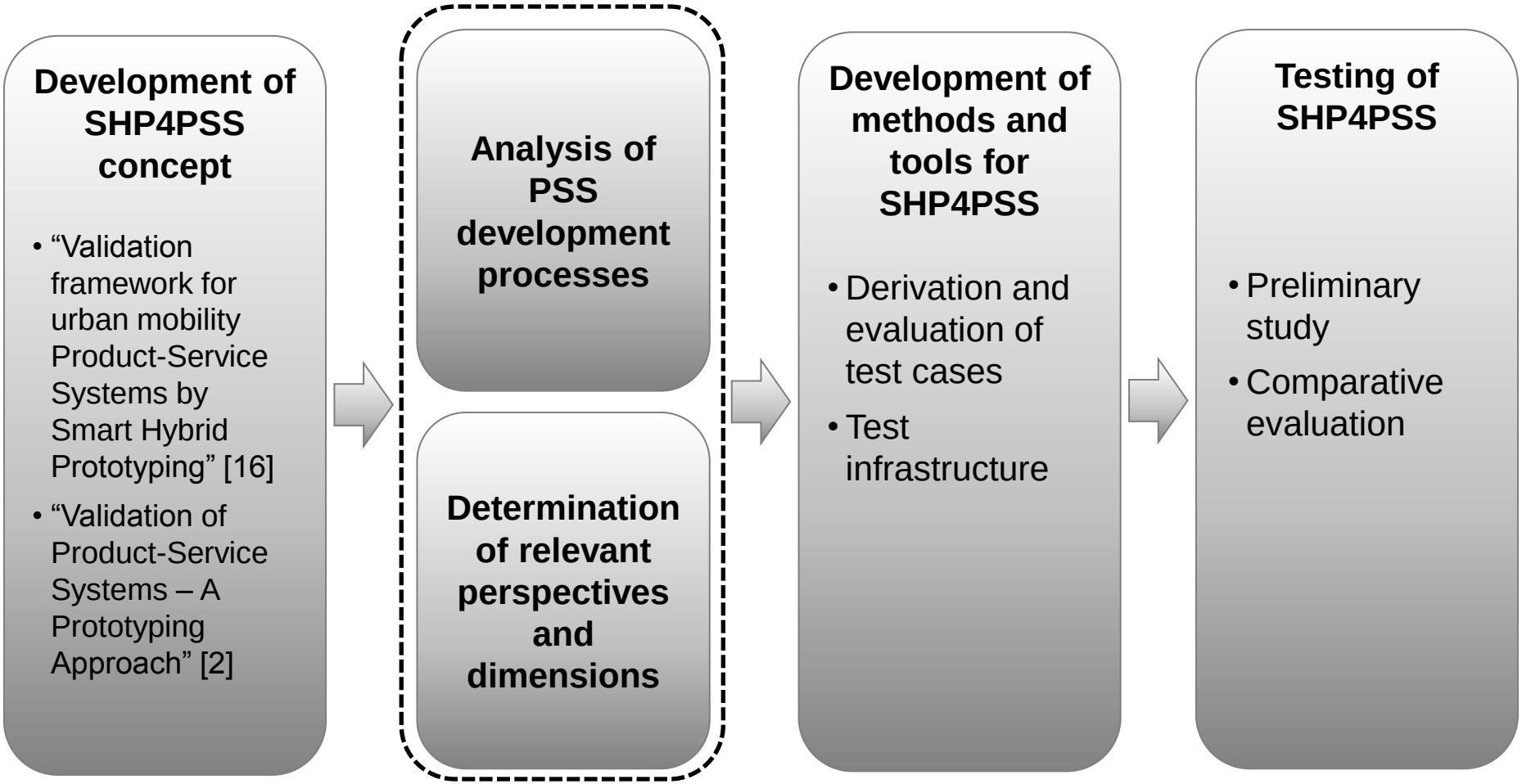
- Main idea is to use the Smart Hybrid Prototype (SHP) approach
  - Integrates physical prototypes and digital models in Virtual Reality (VR)
- Enable an experiencing of PSS for an urban mobility use case with a pedelec (e-bike) as a core product

- Product centered perspective is enhanced with additional elements :
  - Smartphone App to rent the pedelec and integrate further services
  - Pedelec station to park and rent pedelec

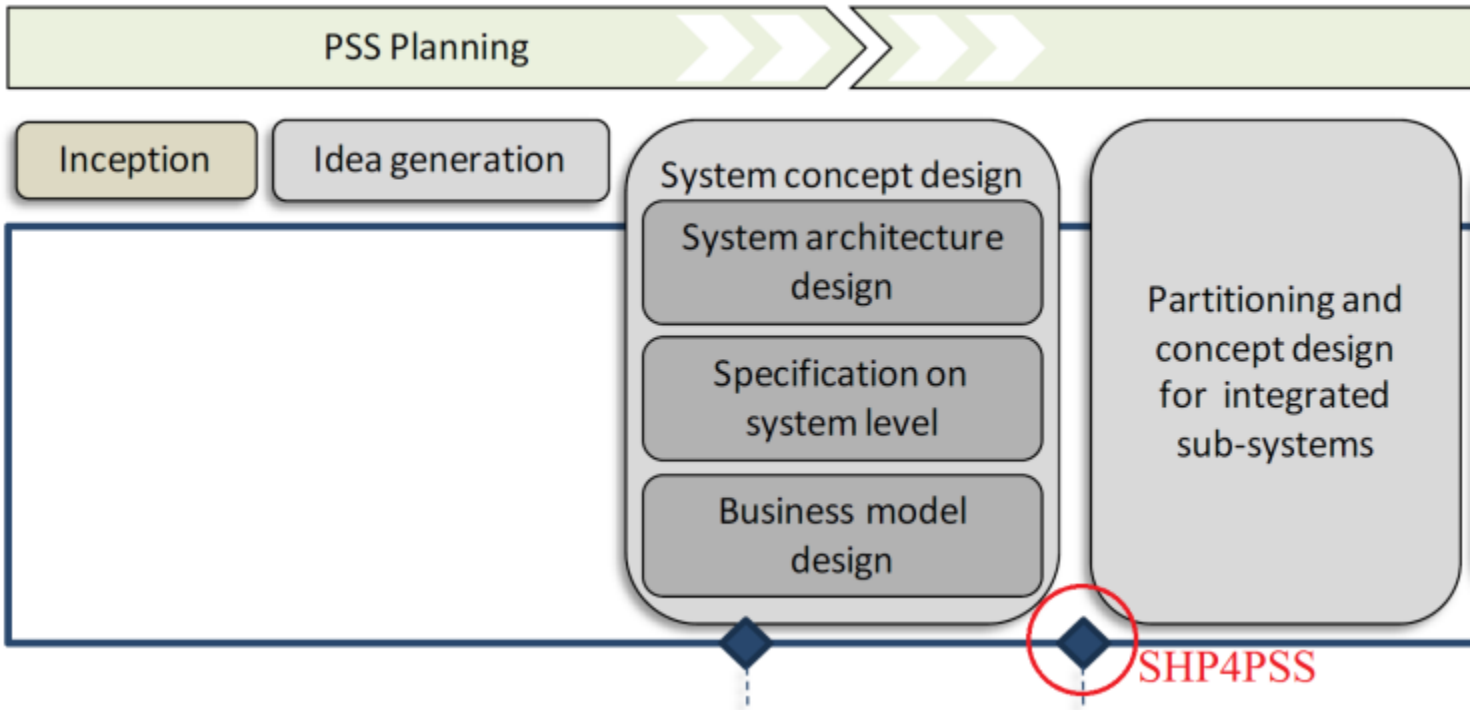
RESULTS I

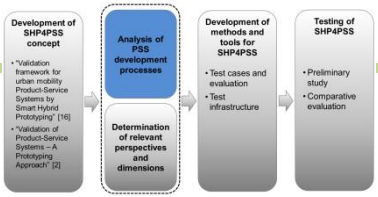
METHODS AND PROTOTYPES

SHP4PSS development - Overview



SHP4PSS in the PSS V-Model [3]





Validation dimensions and perspectives of PSS

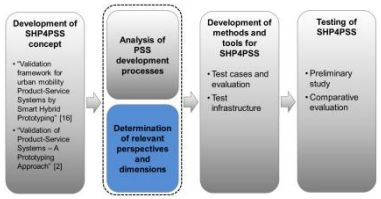
- *Burger* et al. [17] derived in a study ten clusters which should be considered for providers of technical services
- *Stark* et al. [18] determined three critical perspectives regarding the validation of mechatronic systems

Table 1. Relevance of validation dimensions for perspectives of PSS.

Dimensions	Perspectives		
	Customer	Developer	Decider
1. Process	◕	●	◑
2. Concept	◕	◕	●
3. Resources technology	◔	◕	◑
4. Resources employee	○	◕	◕
5. Contact to customers	◑	◑	◑
6. Customer acceptance	◕	◑	●
7. Interaction	◕	●	◑
8. Customer reaction and emotion	◑	◑	●
9. Technical requirements	◑	●	◑
10. Variables service environment	◑	◕	◑

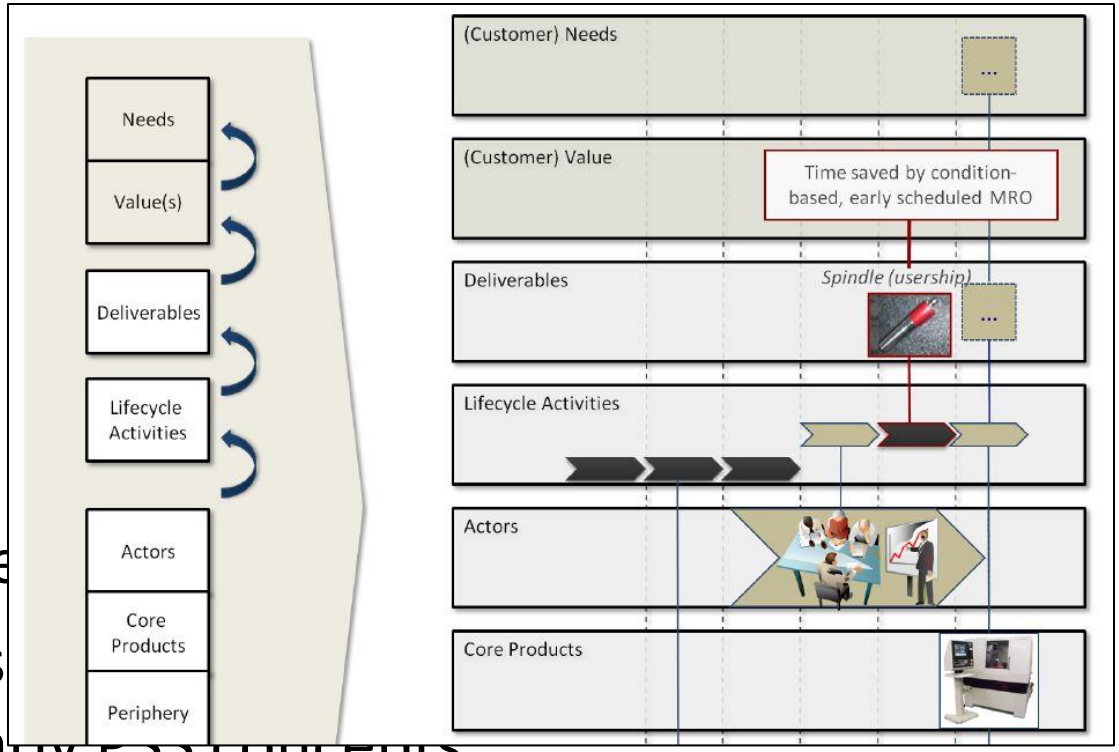
Nomenclature

○ no importance
◔ minor importance
◑ medium importance
◕ high importance
● very high importance

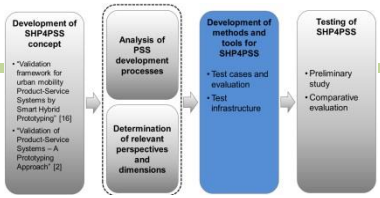


Test case matrix

- Basis is PSS-Layer Method [3]



- New me
- Enables test cases from early PSS concepts



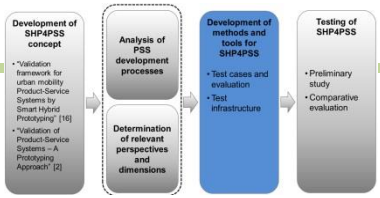
Evaluation matrix

Table 4. Evaluation matrix.

Process phase	Criteria		
	effort	safety	[…]
1. Reservation of the pedelec	e.g. *10*	e.g. *-3*	[…]
2. Go to the pedelec			
3. Examination of damages			
4. Open lock at the station			
5. Remove pedelec of charging station			
6. Usage of the pedelec			
7. Defect while usage			
8. Return the pedelec			

Nomenclature

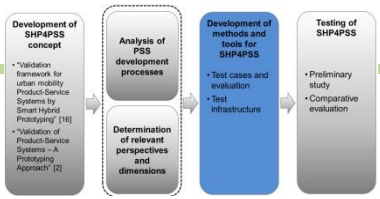
10	The criterion has a strong positive characteristic in this phase.
6	The criterion has a positive characteristic in this phase.
3	The criterion has a slight positive characteristic in this phase.
0	The criterion has no effect characteristic in this phase.
-3	The criterion has a slight negative characteristic in this phase.
-6	The criterion has a negative characteristic in this phase.
-10	The criterion has a strong negative characteristic in this phase.



Evaluation with SHP4PSS

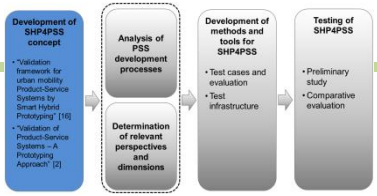
- Two important objectives for the evaluation with SHP4PSS:

1. The feasibility of the method as well as the test procedure itself needs to be surveyed
2. The method needs to be compared with another validation method for PSS



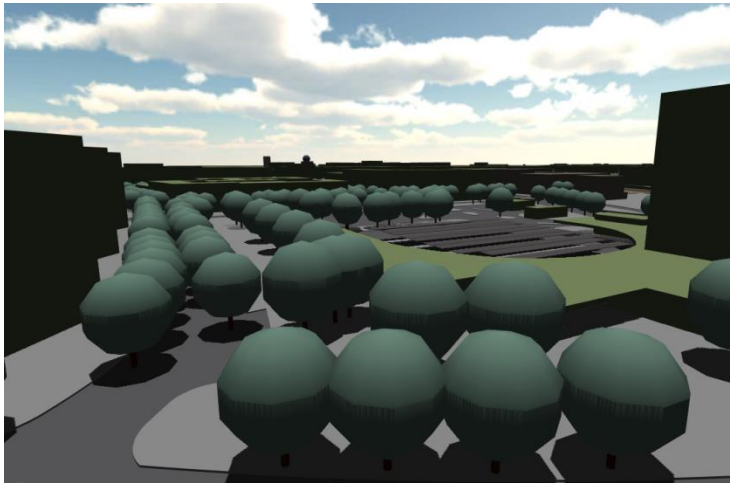
Concept of the prototype

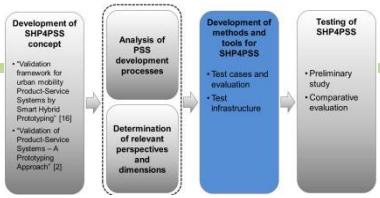
The prototype includes pneumatic hexapods and an electric motor to enable a realistic experience during the use phase



SHP4PSS – digital models

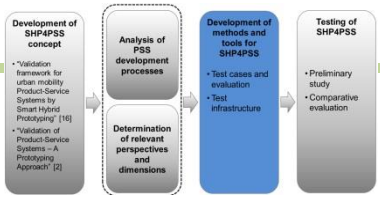
- A digital city model of Berlin and a digital charging station for the pedelecs has been developed and integrated in Unity software



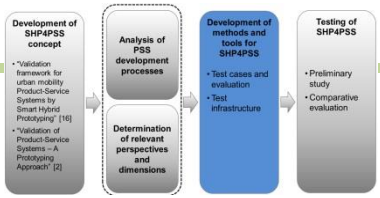


SHP4PSS – smartphone app

Additional input of other devices, e.g. the smartphone, has to cause a correspondent effect in the simulation

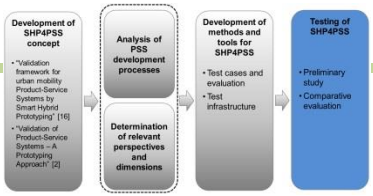


SHP4PSS – smartphone app

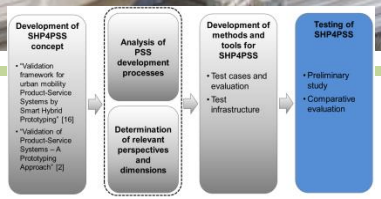


SHP4PSS – interaction device

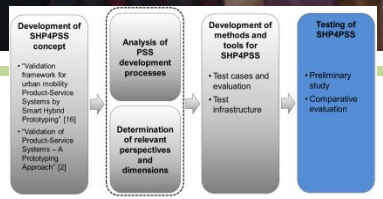
- In addition to the virtual model of the pedelec, the hybrid prototype which will realize the interaction with VR has been constructed



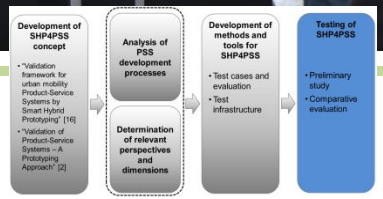
SHP4PSS – pre-study



SHP4PSS – pre-study



SHP4PSS – pre-study



CONCLUSION

Conclusion and Outlook

- Conclusion
  - Development and implementation of necessary methods and tools – respectively infrastructure – for **SHP4PSS**
  - A comprehensive comparative evaluation will be conducted to provide quantitative and qualitative data
  - A qualitative preliminary study indicates realistic experience of the use case

- Next steps:
  - The evaluation with a group of probands is the most important aspect (customer perspective)
  - The dissemination in industry, including workshops and interviews (acceptance of managers and developers)
  - Development of a further validation method (between low and high fidelity)
  - Modularization of the prototype

Thank you.

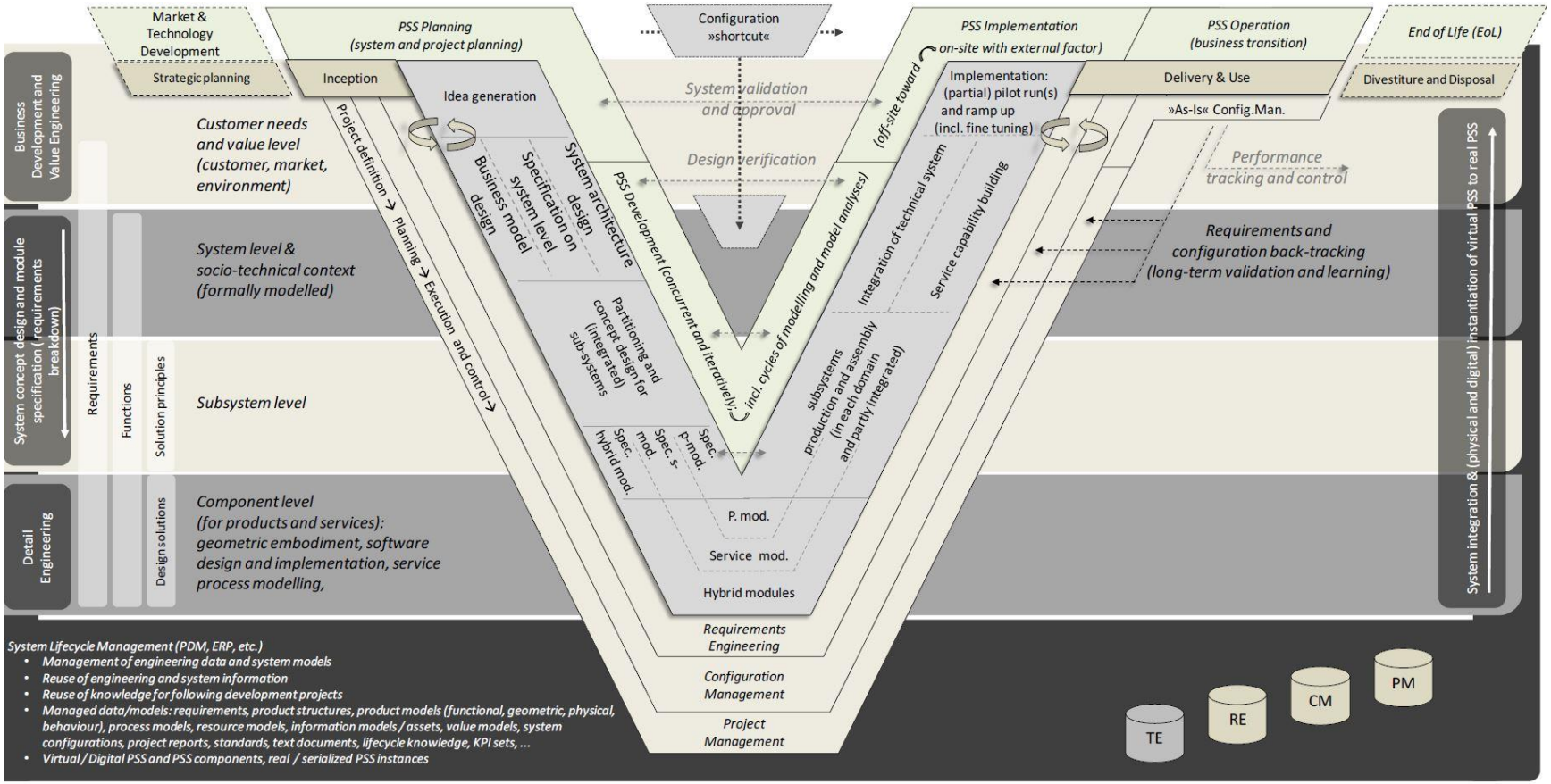
Questions?

Framework of the evaluation for SHP4PSS

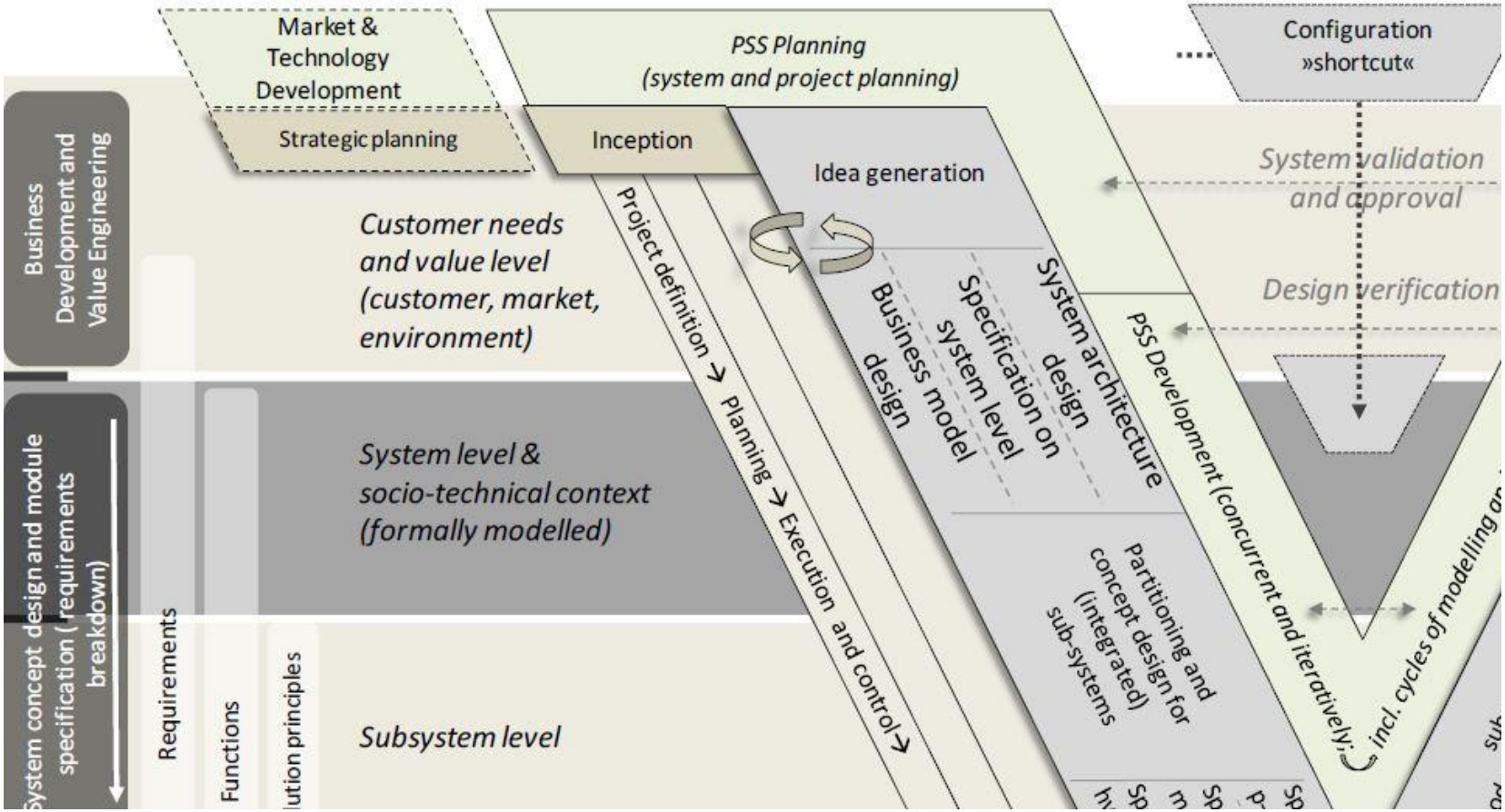
Table 3. Framework of the evaluation for SHP4PSS.

Validation of test case with SHP4PSS	Validation of test case with utility analysis for PSS [24]
Test group: min. 12 probands	
Procedure: • Welcome and explanation of the objectives • Introduction to the VR with an exercise • Explanation of the test case • Experiencing of the test case in VR	Procedure: • Welcome and explanation of the objectives • Introduction to the utility analysis with an exercise • Explanation and hand out of the visual and textual explanation of the test case
Evaluation of the test scenario due to given matrix and criteria Questionnaire regarding the method and standard data regarding the probands	
Standardized questionnaires regarding immersion and presence due to SHP4PSS	-
Empirical analysis and interpretation of the results	
Impact analysis of immersion and presence regarding the test results	Comparison with the results of the first study [24]

PSS V-Model


Market & Technology Development
Strategic planning
PSS Planning (system and project planning)
Inception
Idea generation
Configuration »shortcut«
PSS Implementation
on-site with external factor)
PSS Operation (business transition)
End of Life (EoL)
Delivery & Use
Divestiture and Disposal
»As-Is« Config.Man.
Implementation: (partial) pilot run(s) and ramp up (incl. fine tuning)
System validation and approval
Design verification
(off-site toward
Performance tracking and control
Business Development and Value Engineering
Customer needs and value level (customer, market, environment)
Project definition → Planning → Execution and control →
Business model design
System level specification on
System architecture design
PSS Development (concurrent and iteratively)
incl. cycles of modelling and model analyses)
Integration of technical system
Service capability building
Requirements and configuration back-tracking (long-term validation and learning)
System concept design and module specification (requirements breakdown)
Requirements
Functions
Solution principles
System level & socio-technical context (formally modelled)
Subsystem level
Partitioning and concept design for (integrated) sub-systems
Spec. hybrid mod.
Spec. s-mod.
Spec. p-mod.
subsystems production and assembly (in each domain and partly integrated)
Detail Engineering
Design solutions
Component level (for products and services): geometric embodiment, software design and implementation, service process modelling,
P. mod.
Service mod.
Hybrid modules
System integration & (physical and digital) instantiation of virtual PSS to real PSS
Requirements Engineering
Configuration Management
Project Management
TE
RE
CM
PM
System Lifecycle Management (PDM, ERP, etc.)
Management of engineering data and system models
Reuse of engineering and system information
Reuse of knowledge for following development projects
Managed data/models: requirements, product structures, product models (functional, geometric, physical, behaviour), process models, resource models, information models / assets, value models, system configurations, project reports, standards, text documents, lifecycle knowledge, KPI sets, ...
Virtual / Digital PSS and PSS components, real / serialized PSS instances

PSS V-Model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Configuration »shortcut«
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Design verification
Business Development and Value Engineering
Customer needs and value level (customer, market, environment)
Project definition → Planning → Execution and control →
Business model design
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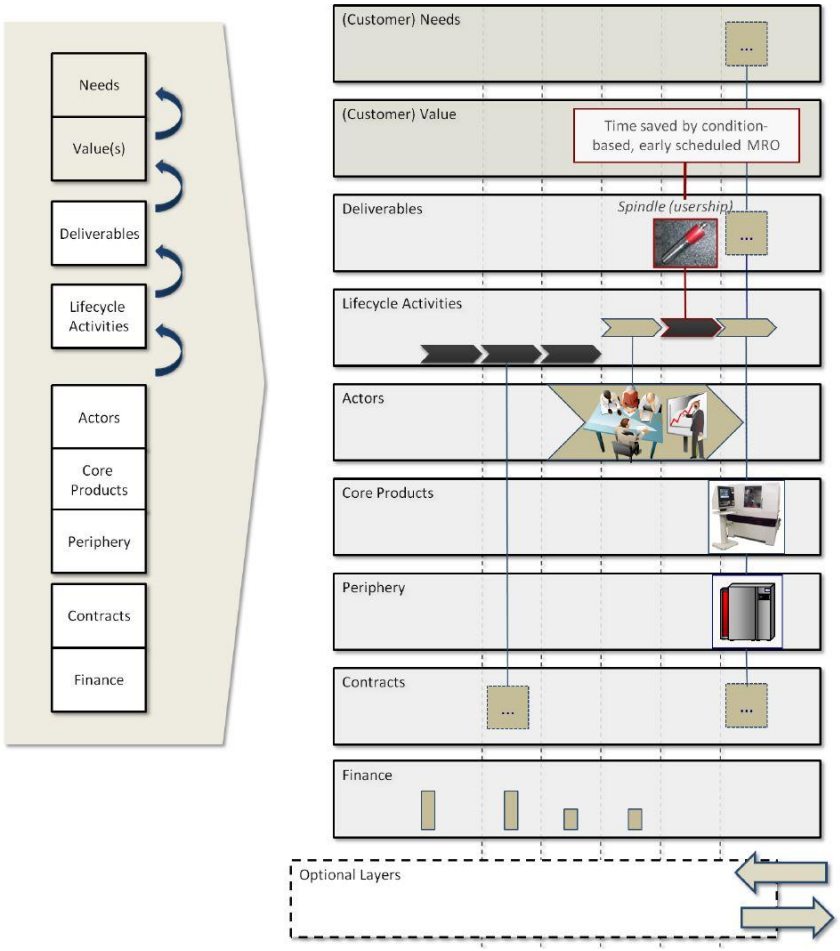
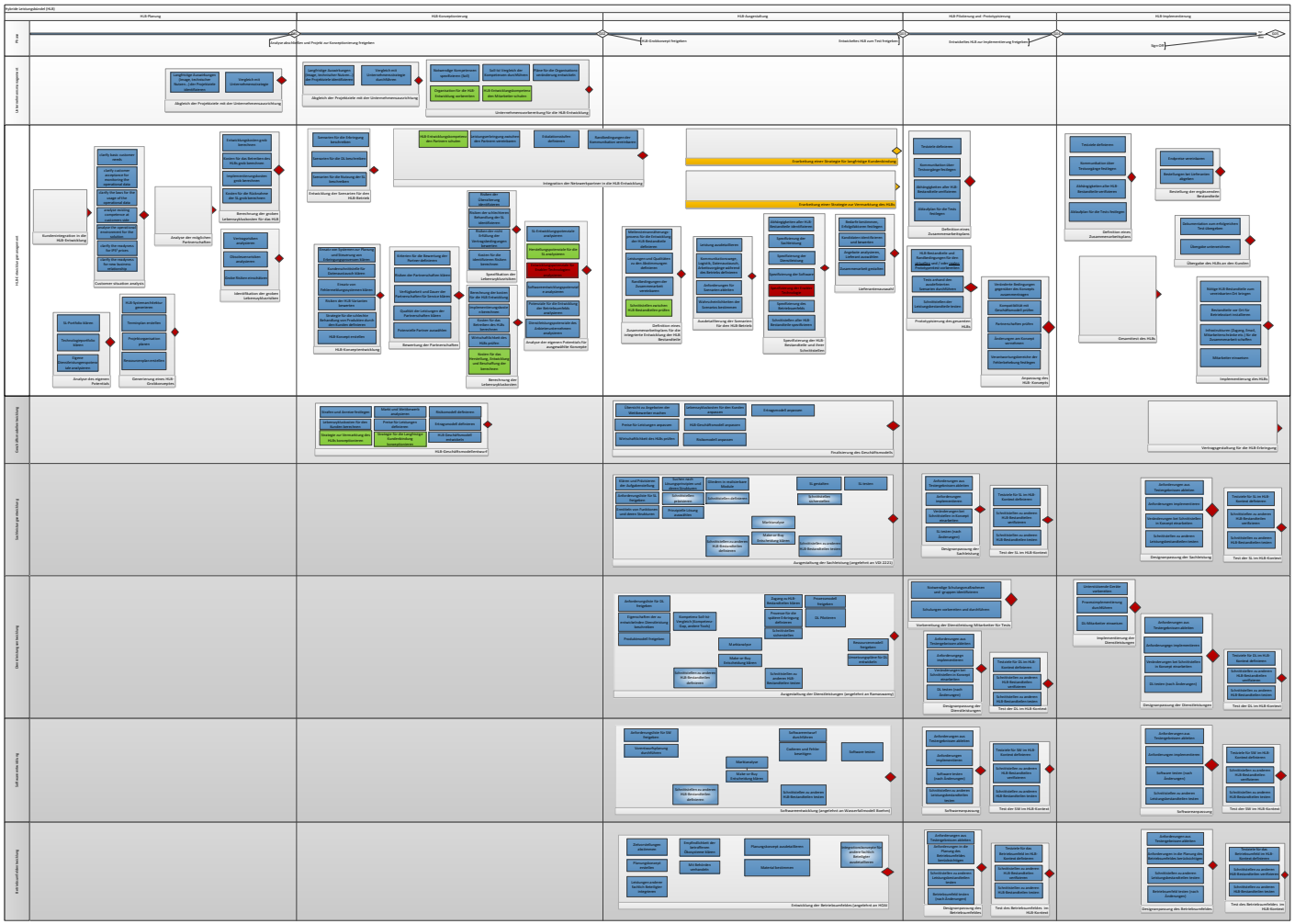
System architecture design
PSS Development (concurrent and iteratively; incl. cycles of modelling
System concept design and module specification (requirements breakdown)
System level & socio-technical context (formally modelled)
Requirements
Functions
Partitioning and concept design for (integrated) sub-systems
Subsystem level

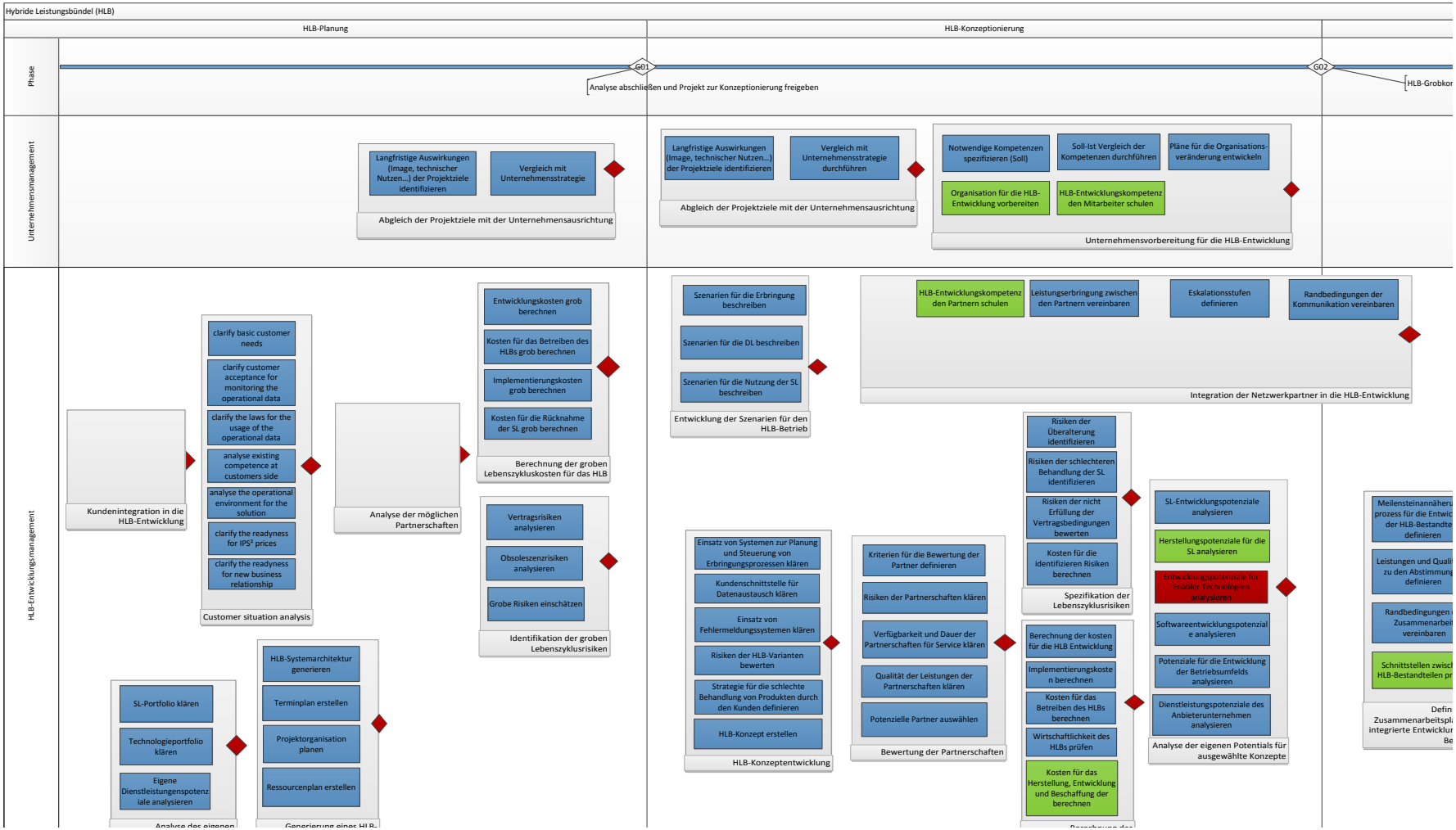
PSS Layer Method



PSS development process



PSS development process



SHP4PSS – Why PSS specific?

Different system elements – it is not only the product!

- Variants with smartphone app
  - How to book (NFC, QR-Code, Bike Number)
  - Services during use phase (defect, accident, navigation, shopping, tourist information)
- Variants of the infrastructure
  - Test free floating system vs. stations
- Community for bike sharing (two-seater)
- Business models
  - Stations for apartment blocks or companies

Validation and verification

In everyday language, validation is the answer to the question: Is the right product being developed?

Validation originally means checking the validity of a measuring method in empirical social research, i.e. the extent to which test results actually register what is intended to be determined by the test. Transferred to technical systems, it is to be understood as meaning testing whether the product is suitable for its intended purpose or achieves the desired value. The expectations of the technical expert and the user come into the equation here. Validation comprises, for example, checking whether the description of an algorithm coincides with the problem to be solved. It generally does not have to be carried out in a formal manner.

In everyday language, verification is the answer to the question: Is a correct product being developed?

Verification means generally demonstrating the truth of statements. Transferred to technical systems, it is to be understood as meaning checking whether the way in which something is realized (for example a software program) coincides with the specification (in this case with the description of algorithms). When checking the validity of a program, reference is also made to program verification. The verification is generally realized in a formal manner.

PSS Prototyping

A PSS-prototype integrates tangible and intangible elements of the entire system in a single prototype. Due to the considerably differences of the PSS elements, yet high interdependencies, new hybrid prototyping approaches are indispensable. These have to integrate diverse aspects, like physical and virtual, in order to facilitate the complex interaction between elements of a PSS. Therefore, explorative prototypes enable an externalization of first ideas and concepts in early PSS development phases, like planning and concept phase, to discuss and reflect mental pictures. Evolutionary prototypes are intended to visualize and validate PSS solutions or intermediate results along the PSS design process. Furthermore, experimental prototypes can be used at all development stages to test properties of the PSS.

Blended Prototyping

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