The Influence of Green Strategies Design onto Quality Requirements Prioritization

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Motivation

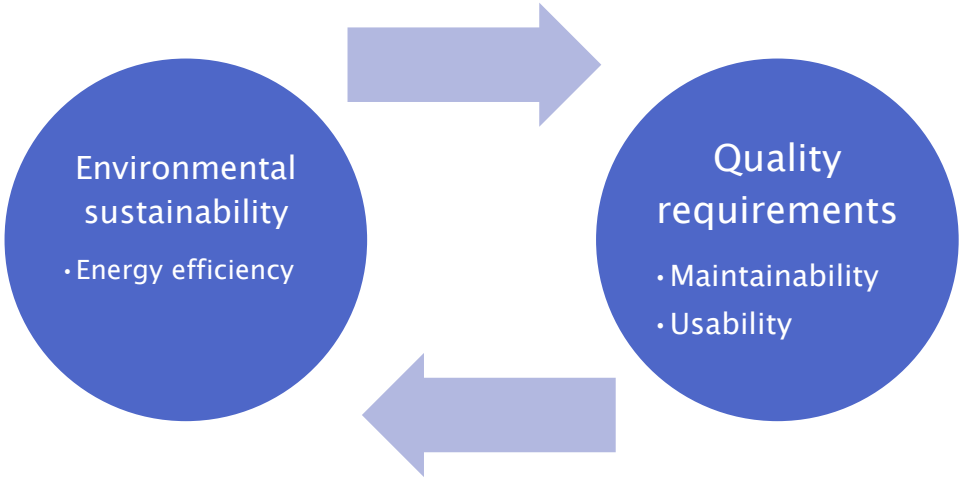
What about approaches that assist the inclusion of green strategies into the software design process?

- Green computing strategies & challenges. 2016
- Green computing strategies for improving energy efficiency in IT systems. 2014

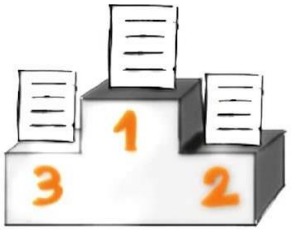
R. Chitchyan et al. Sustainability design in requirements engineering: State of practice. ICSE 2016.

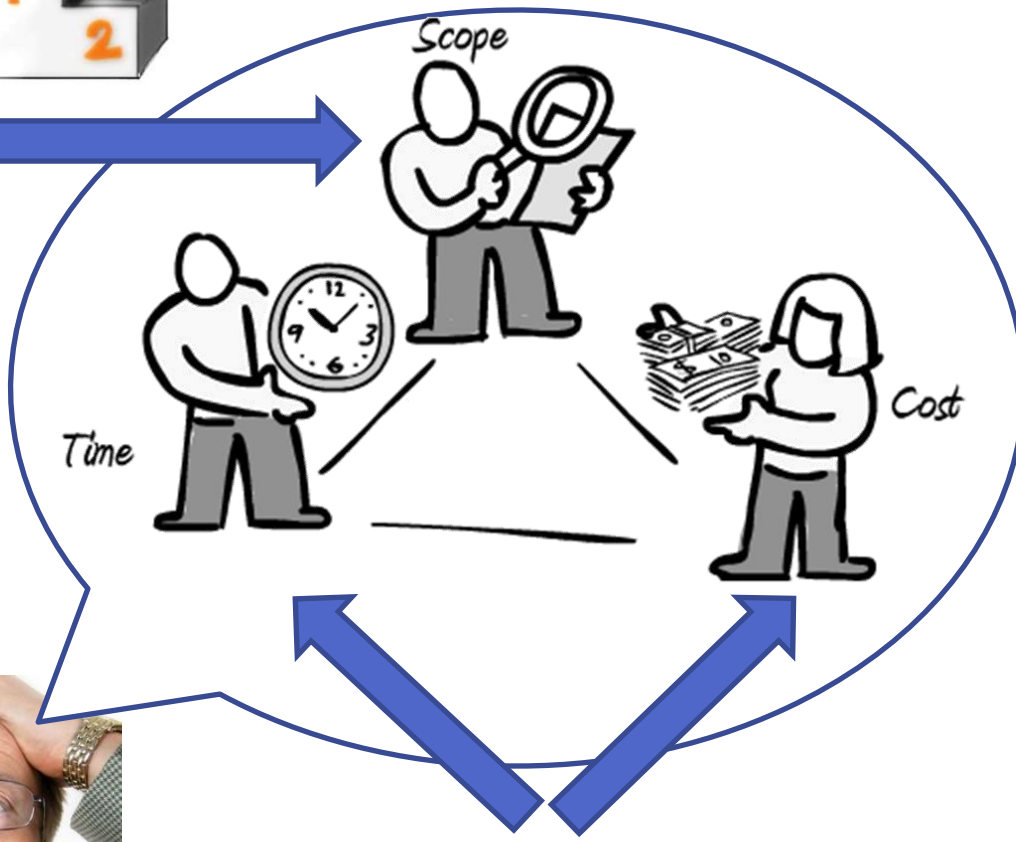
Motivation

- New trade-offs



Inability to implement all the requirements





Decision-makers

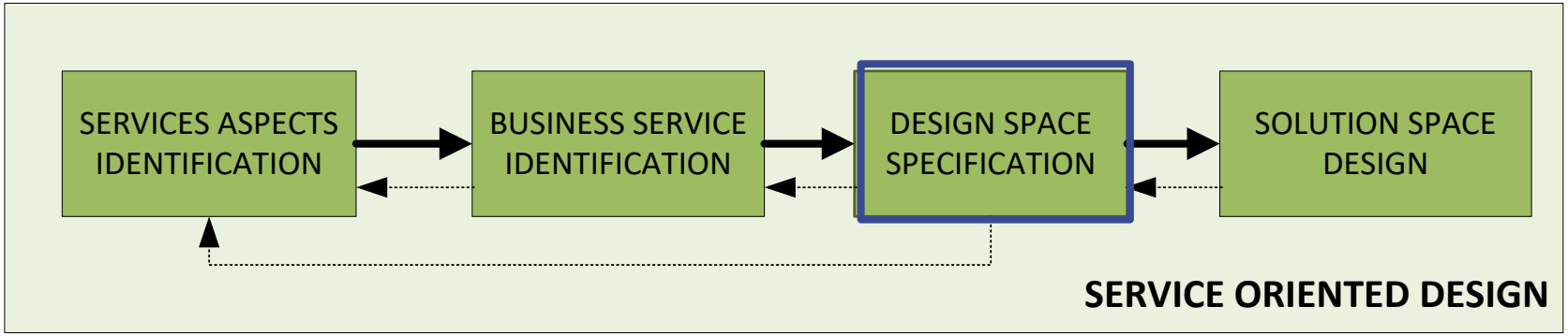
Agenda

1. Service Design Process:
   - Design space specification and refinement
2. Extended Green strategy model
3. Case study design: EV-Mobility
4. Data collection and results
5. Conclusions and future work

Service Design Process

- *Delivered software*
  - ***Inventory of services*** *that deliver independent functionalities*
  - ***Service-based application****, by composing available software services*

Service Design Process

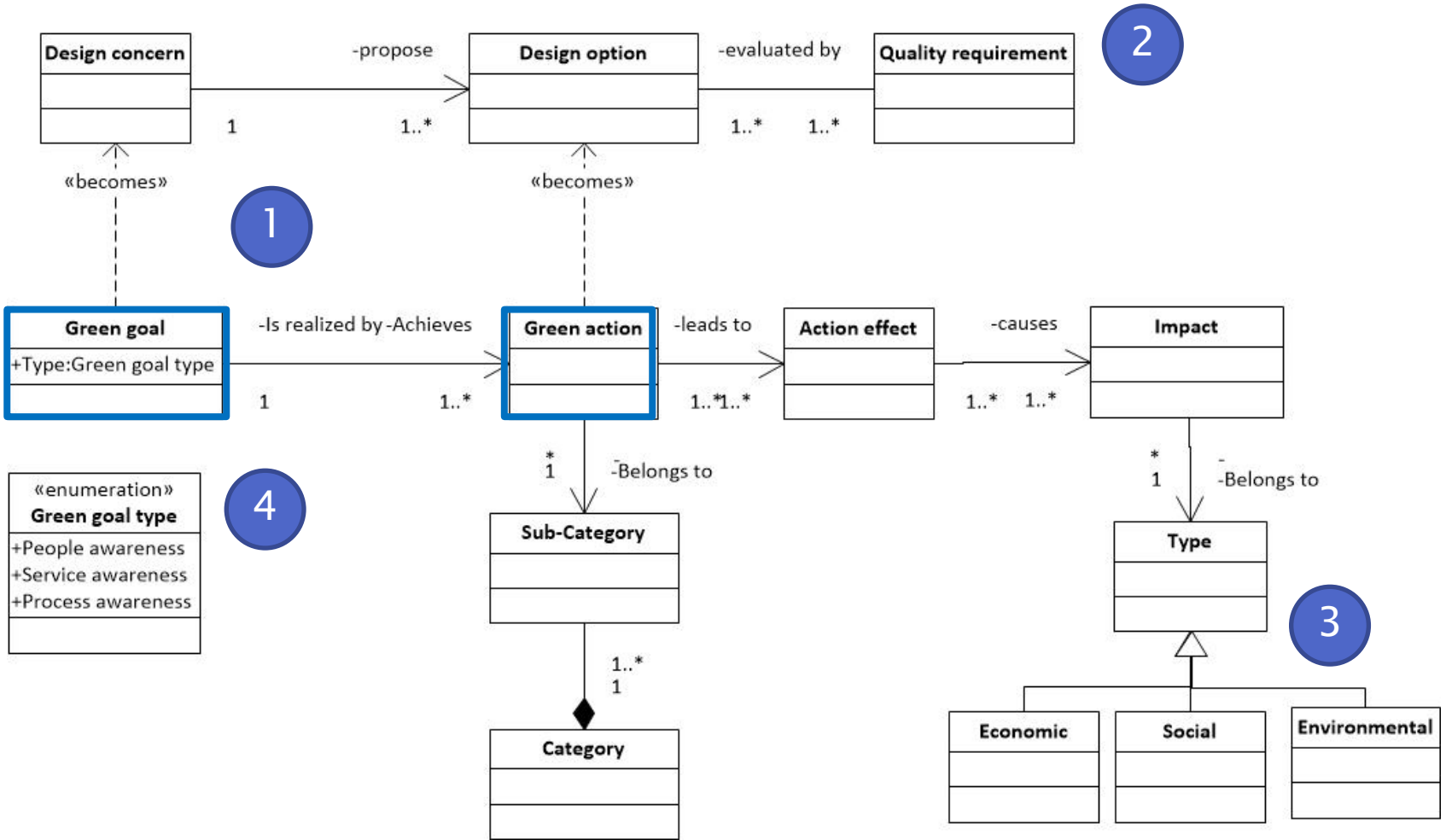


Concern (Design issue)		**Con#<number>: What was the concern that needed to be solved (by taking a decision)?**
Ranking criteria		Cr#<number>: what quality attributes have been used to select the decision based on the available options?
OPTIONS (Repeat for each option)	***Identifier:***	Con#<number>-Opt#<number>Name of the option
	Description	Short description of the option
	Status	Has this option been accepted or rejected?
	Relationship(s)	Indicate relationships with other options (by using their identifiers)
	Evaluation	To which extent does this option support ranking criterion Cr#<number>?
	Rationale of decision	Why has this option been accepted or rejected? (use the ranking criteria identifiers in the argumentation)

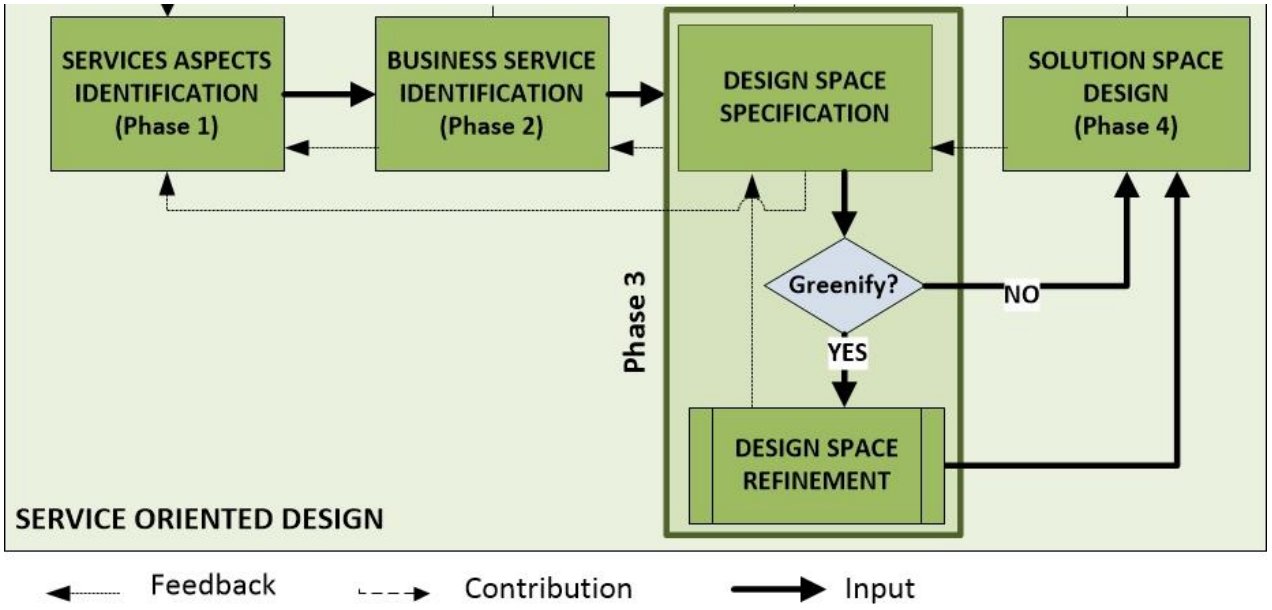
Extended Green strategy model

A green strategy is defined as a plan of **actions** intended to accomplish a specific **green goal.**

Global Development Research Center glossary of environmental terms

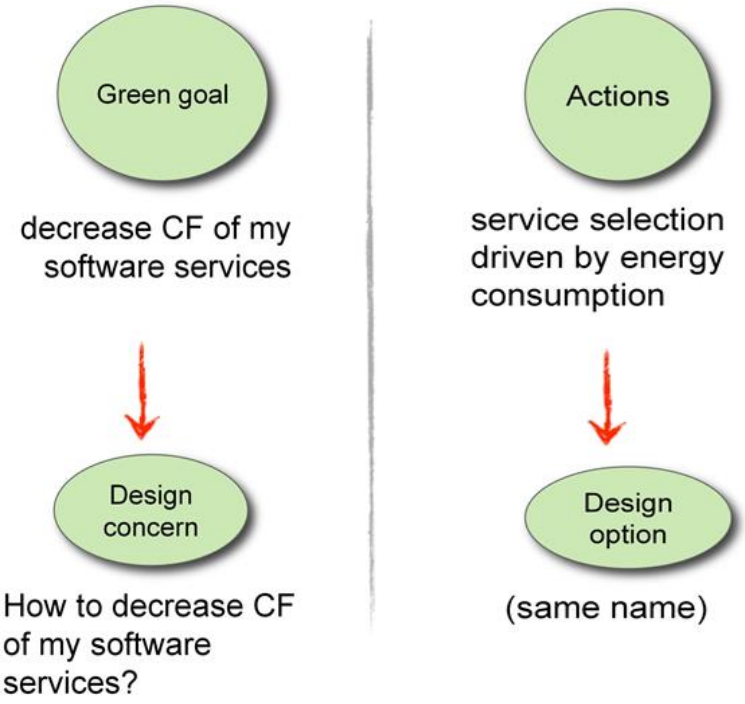


Design space specification



Design space refinement

1) Extending the design space



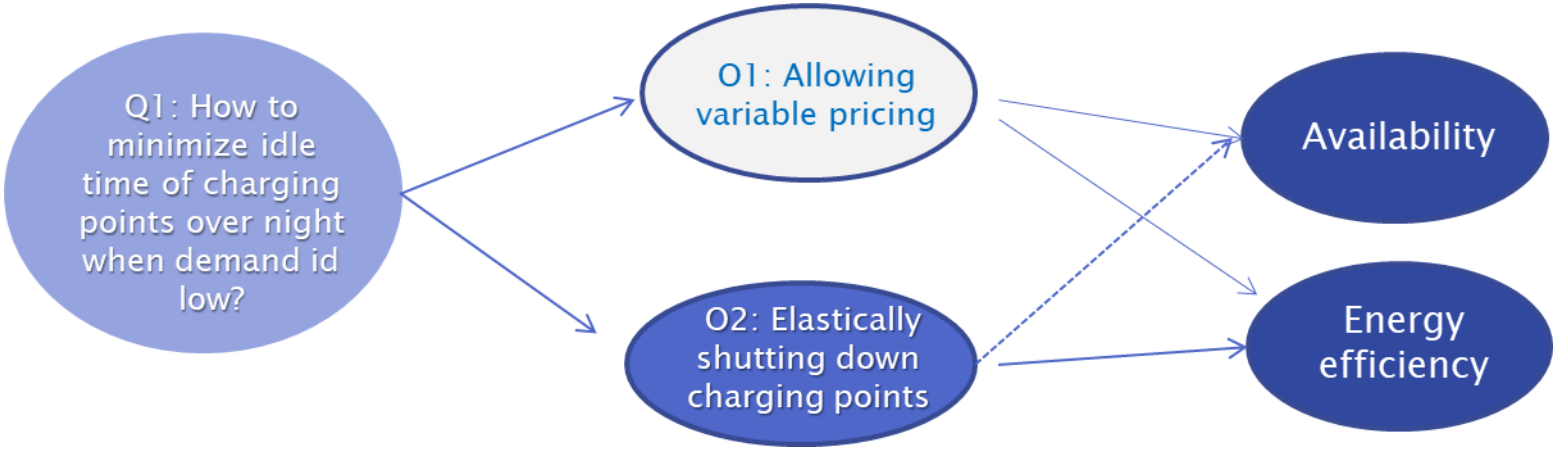
2) Challenging the already existing design decisions

Design space refinement

Field		Description
Unique ID		*Give a unique ID for this strategy*
Short Name		*Give a short name for this strategy*
Type of Green Strategy:		*Identify whether it is a service awareness strategy or people awareness strategy.*
Description		*Description of the strategy in terms of goals and actions*
Action i	**Description**	
	Environmental, social, economic Impact	
Relevancy:		*Explain the relevancy of the green strategy for your business domain.*
Dependencies with other service aspects:		*Explain if the green strategy has any influence on your service aspects*
Diagram		*Graphical representation of the strategy*

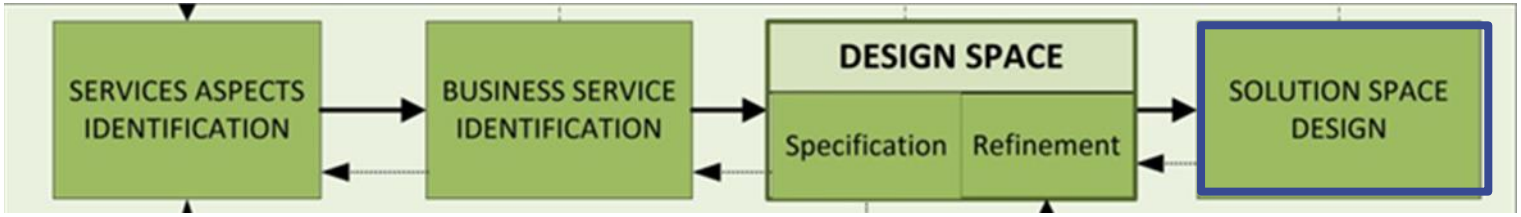
Design space

Question-Options-Criteria (QOC) notation



Service Design Process

Set of candidate business services and design decisions made during design space exploration



- Identifies which **candidate services** must be designed as **software services** to support the initial usage scenarios,

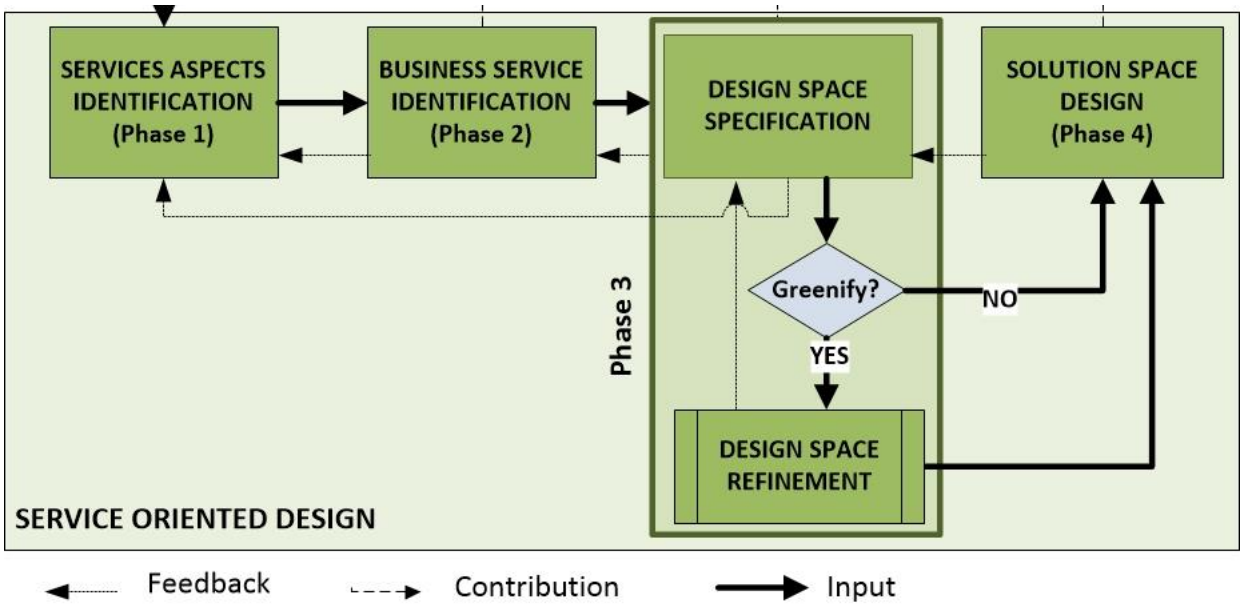
- Defines views that show:
  - how they can be composed in SBAs and
  - how they should interact to deliver the stated functionalities and qualities.

Agenda

1. Service Design Process
2. Extended Green strategy model
3. Empirical study design:
4. Data collection and results
5. Conclusions and future work

Goal

To investigate how the inclusion of green software strategies into a service design process can influence in quality requirements prioritization



Empirical study design

- RQ1: Which are the most Quality Requirements used by designers when green strategies are included into the design process?
- RQ2: How do Green Strategies influence on Quality Requirements prioritization

Case: E-Mobility project

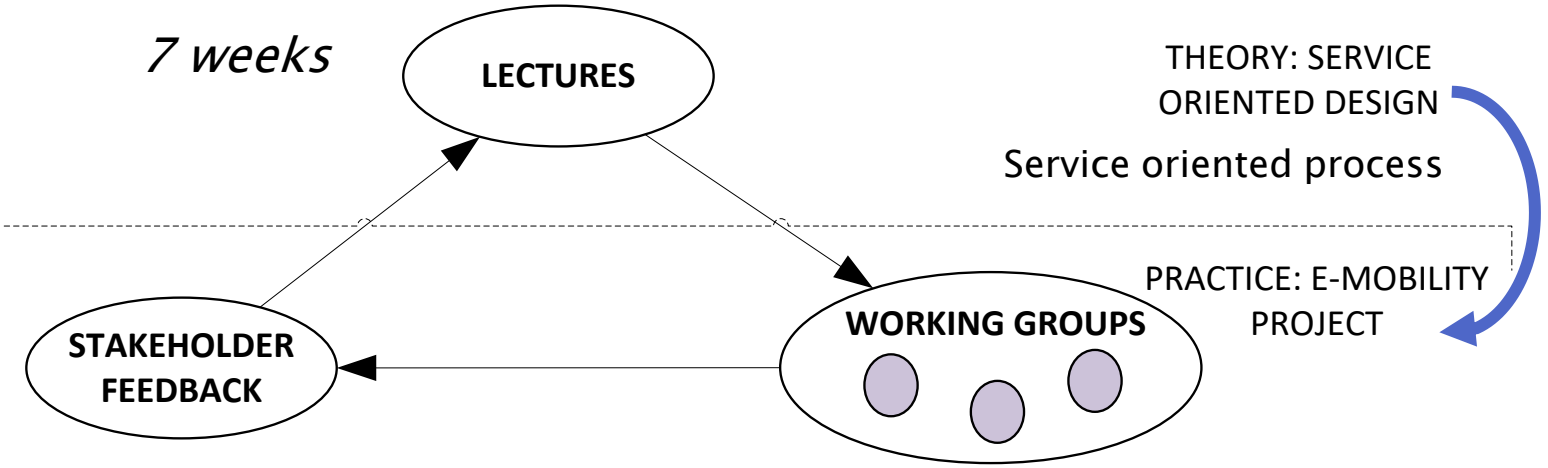
E-Mobility project focused on the design of **new software services** on top of an existing charging point management platform, with the overall goal to facilitate the adoption of EV's in the Dutch private market.

Stakeholders

- EV driver
- Fleet owner
- Charge point service provider
- Distribution service operator
- Energy supplier

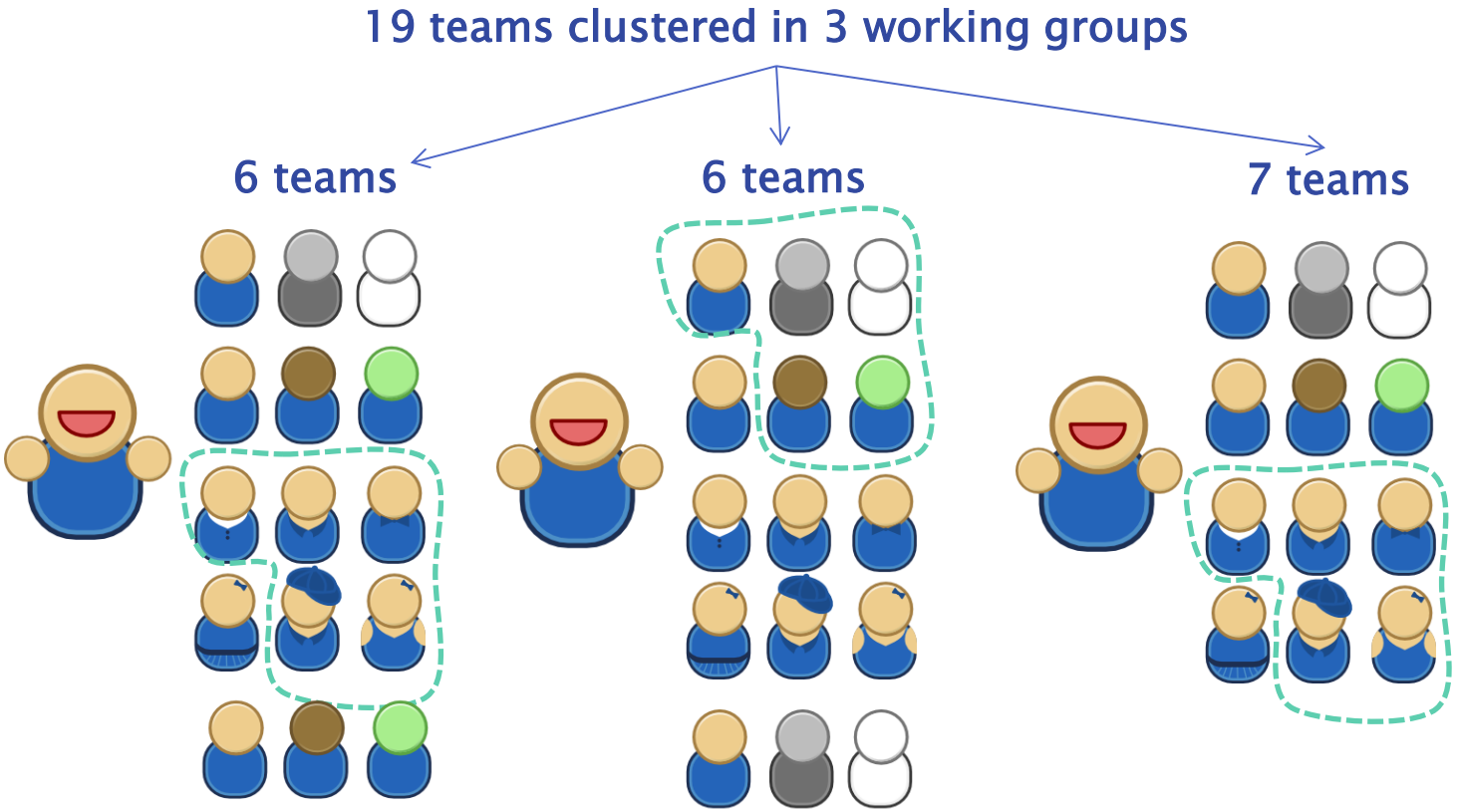
Empirical study design

Research context:



Empirical study design

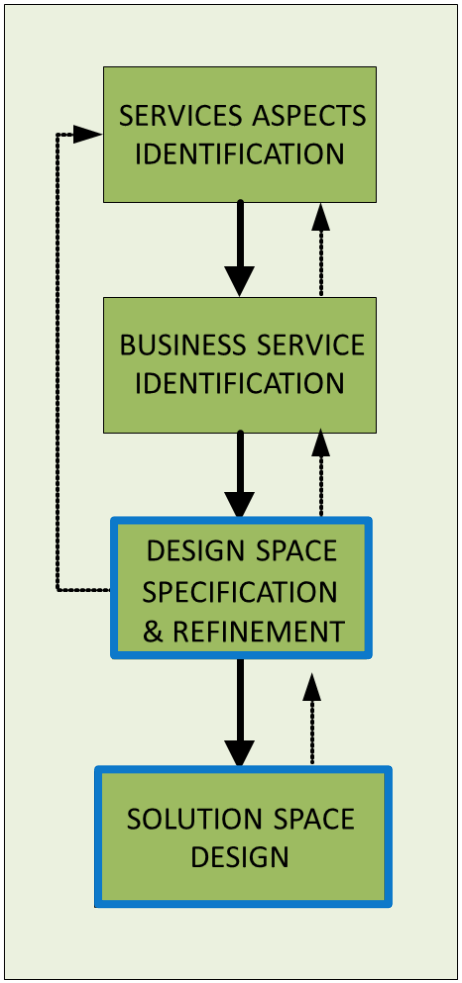
- **Subjects:** 95 master students (Two master programs: Information Science and SE and Green IT)



Data collection

Deliverable	Area of Interest	Average page length
D3: Design space	Design decisions tables, QOC	15
D4: Green strategies	Strategies descriptions, graphical representation	10
D5:Design space with Green	Design Decisions Tables(*), QOC, Mappings	35
D7: Solution space	Mapping of design space to solution space	3
Final report	Quality requirements list	4

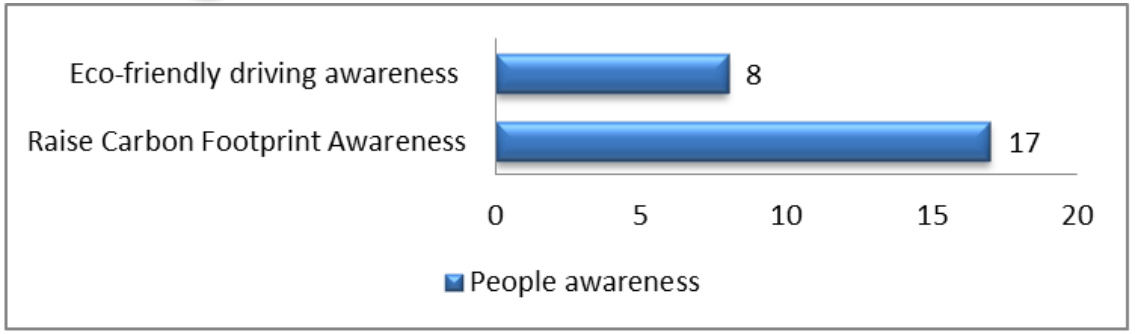
Data collection

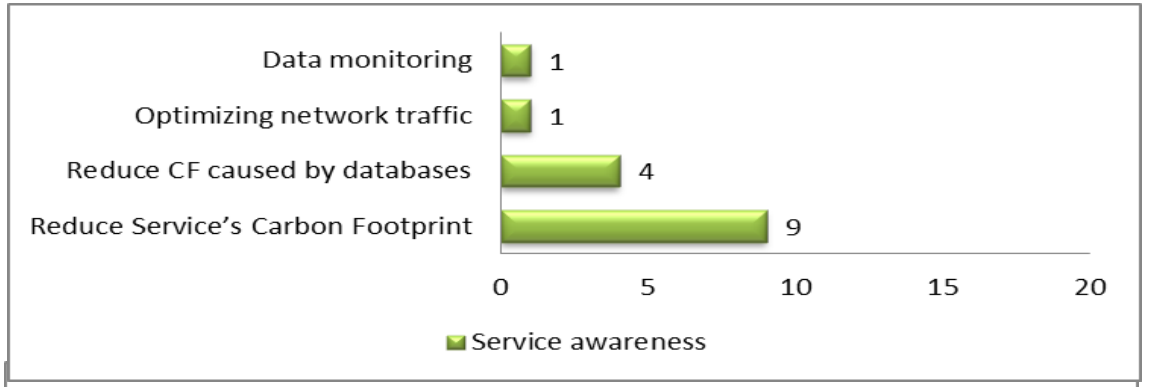


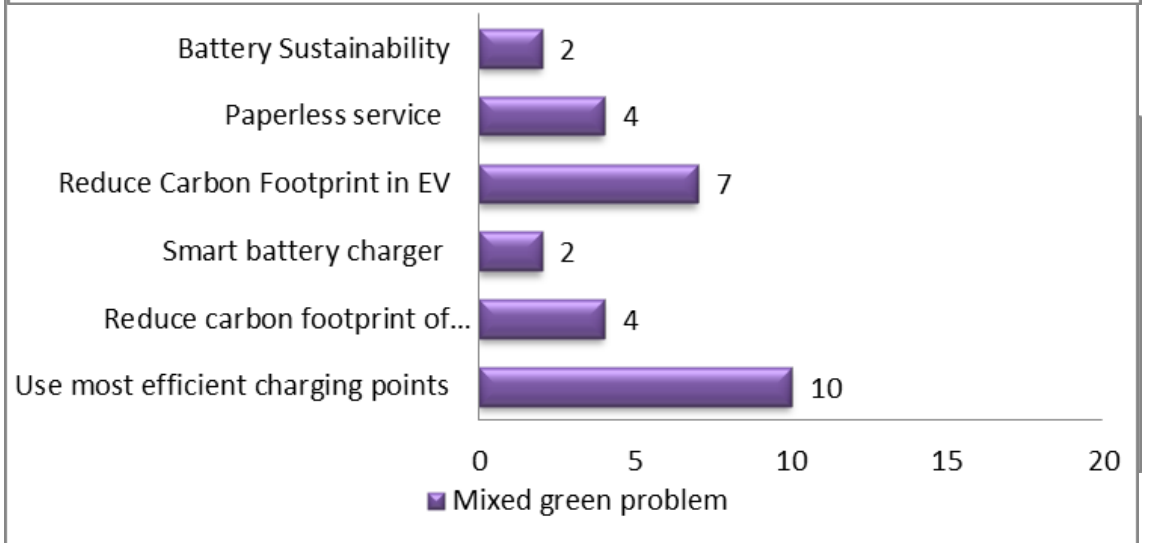
D3: Design space	Design decisions tables, QOC
D5:Design space with Green	Design Decisions Tables, QOC, Mappings
D7: Solution space	Mapping of design space to solution space

1. QRs that were **kept or added** when a green strategy was included in the design space
2. QRs that were **added** at the solution space design phase after including the green strategy

Green strategies







N. Condori Fernandez and P. Lago, Analysing Green Software Strategies within a Service Design Process. EnviroInfo 2017

Results

Domain-generic strategies

Category	Green strategy	Frequency
People awareness	Raise Carbon Footprint Awareness	17
Process awareness	Virtualization	3
Process awareness	Renewable energy source	2
Process awareness	Create a green cloud of energy	2
Service awareness	Reduce Service's Carbon Footprint	9
Service awareness	Reduce CF caused by databases	4
Service awareness	Optimizing network traffic	1
Service awareness	Data monitoring	1
People awareness /Service awareness	Paperless service	4

Data collection

Nominal data was collected

QR was considered as a **ranking criterion** for the **selection of design options** (introduced by the green strategies)

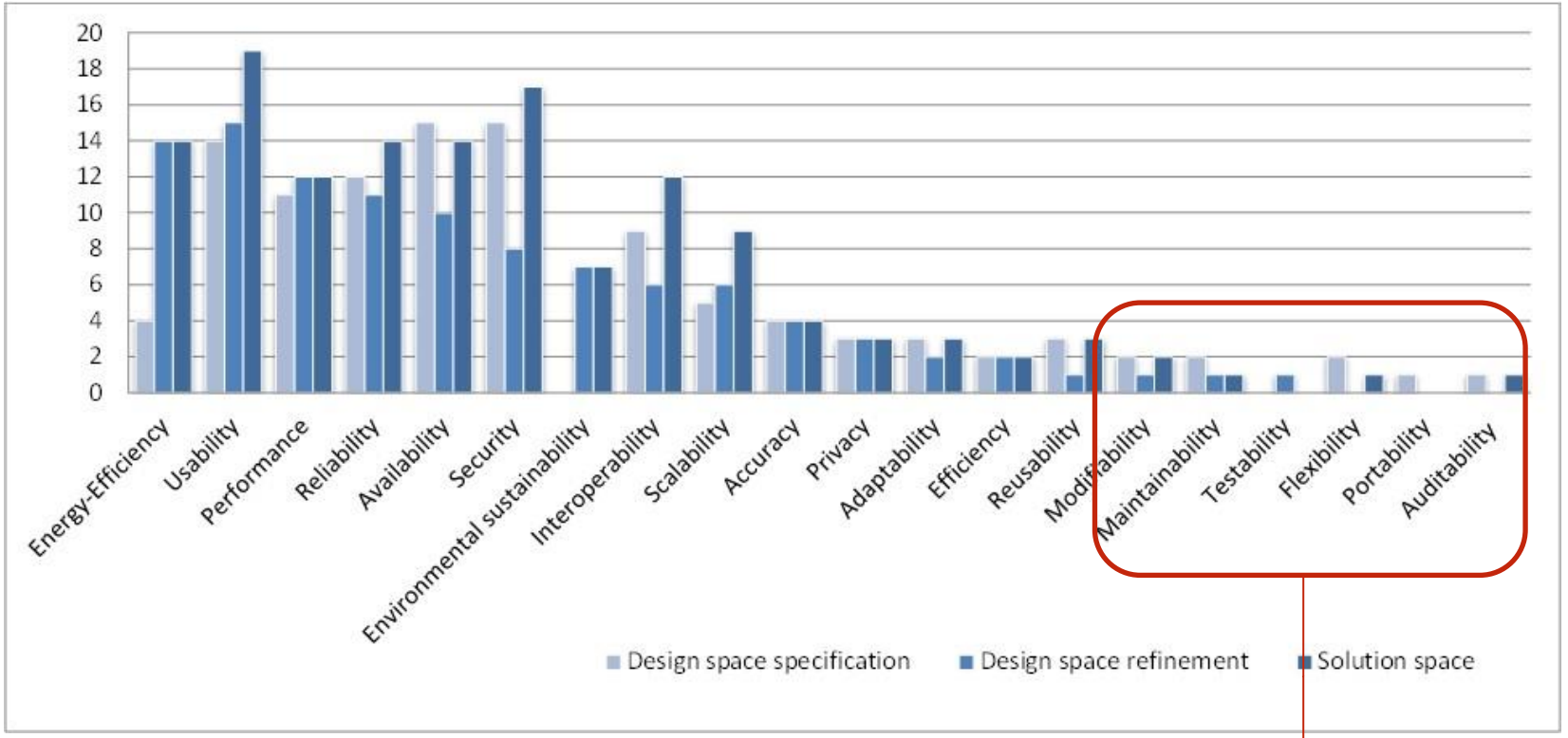
new QR was added in the solution space design phase due to the introduction of a green strategy

	QR1			QR2			…	QRn		
Team ID	p1	p2	p3	p1	p2	p3		p1	p2	p3
T_1	0	1	1	0	0	0		0	0	1
. .										
T_{19}										
Total										

p1=design space specification; p2=design space refinement; p3=solution space design

Results:

RQ1: Most used QRs when green strategies are included into the design process



Software Longevity

Results:

RQ1: Most used QRs when green strategies are included into the design process

	During design space refinement					
	Kept from		Added at		Added at	
	Design space specification		Design space refinement		Solution space design	
Energy-Efficiency	4	29%	10	71%	0	%
Usability	10	67%	5	33%	4	21%
Performance	10	83%	2	17%	0	0%
Reliability	9	82%	2	18%	3	21%
Availability	11	100%	0	0%	4	29%
Security	6	75%	2	25%	10	59%
Env Sustainability	0	0%	7	100%	0	0%
Interoperability	6	100%	0	0%	6	50%
Scalability	4	67%	2	33%	4	44%
Accuracy	4	100%	0	0%	0	0%
Privacy	2	67%	1	33%	1	33%

Results:

RQ1: Most used QRs when green strategies are included into the design process

	During design space refinement					
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	Design space specification		Design space refinement		Solution space design	
Energy-Efficiency	4	29%	10	71%	0	%
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Availability	11	100%	0	0%	4	29%
Security	6	75%	2	25%	10	59%
Env Sustainability	0	0%	7	100%	0	0%
Interoperability	6	100%	0	0%	6	50%
Scalability	4	67%	2	33%	4	44%
Accuracy	4	100%	0	0%	0	0%
Privacy	2	67%	1	33%	1	33%

QR is used for the selection of a design option that introduces a green action

Results:

RQ2: Green Strategies influence on Quality Requirements Prioritization

							Service awareness							
			Process awareness											
	People awareness											People awareness		
Qualities	G1	G5	G4	G9	G12	G13	G2	G6	G10	G3	G7	G8	G11	Count
Usability	11	3	3		1		3	2	1	1	1	2	2	11
Energy efficiency	4	2	2	2	1		5	2	1	2	3		1	11
Env Sustainability	5	2	2	1			1	1		3	1	2	1	10
Reliability	4		1	2			2	1		4	4		1	8
Performance	2		1	3		1	2		1	3	3	1		9
Interoperability	2		1				3		1	2	1	1		7
Availability	3		2	1			5		1	4	3			7
Scalability	1				1		2			1	2	1		6
Accuracy	3	1					2	1	1					5
Security	4		2	1						1	1			5
Privacy	3		2				1	1						4
Efficiency		1				1	1				1			4
Count	11	5	9	6	3	2	11	6	6	9	10	5	4	

G1: Raise Carbon Footprint awareness
G3: Reduce Service's Carbon Footprint
G7: Reduce Carbon Footprint caused by DB
G8: Paperless service
G9: Virtualization

G2: Use most efficient charging points
G4: Reduce Carbon Footprint in EV

Threats to validity

- Internal validity

Threat of **selection bias**:

– assigning the teams to the working groups randomly. Expertise level of tutors was similar.

Maturation and Plagiarism :

– weekly feedback from industrial stakeholders,

- weekly competition among working groups,
- a prize competition for the best project selected by the company

QRs that were identified in this study is limited to different sources of qualities.

- Construct validity

Our analysis for identifying QRs affected by the inclusion of green strategies may be threatened due to **QRs removed** during or after the design refinement **were not considered in this study**.

- External validity

– students had an industrial project featuring a real case.

– the project involved also a high number of domain-generic strategies.

Conclusions

- We conducted an empirical study in an academic setting but with a real-life industrial project from a smart transportation domain.

QRs	before	during	after
Usability, performance, reliability, availability, interoperability, and scalability	x		x
Security and interoperability			x
energy efficiency, environmental sustainability		x	

Conclusions

- We conducted an empirical study in an academic setting but with a real-life industrial project from a smart transportation domain.

People-awareness	Service-awareness
usability , reliability and security	Availability
privacy, availability and accuracy	

Future work

- Deeper analysis, including design options
- Replication would be beneficial to build empirical knowledge that can be reused for
  - developing green software, and
  - modernizing legacy software to address environmental issues

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