Introduction to design science methodology

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Slides based on Wieringa, R.J. (2014) *Design science methodology for information systems and software engineering.* Springer Verlag

Outline

- Design problems and knowledge questions
- The design cycle
- The empirical cycle

Design science

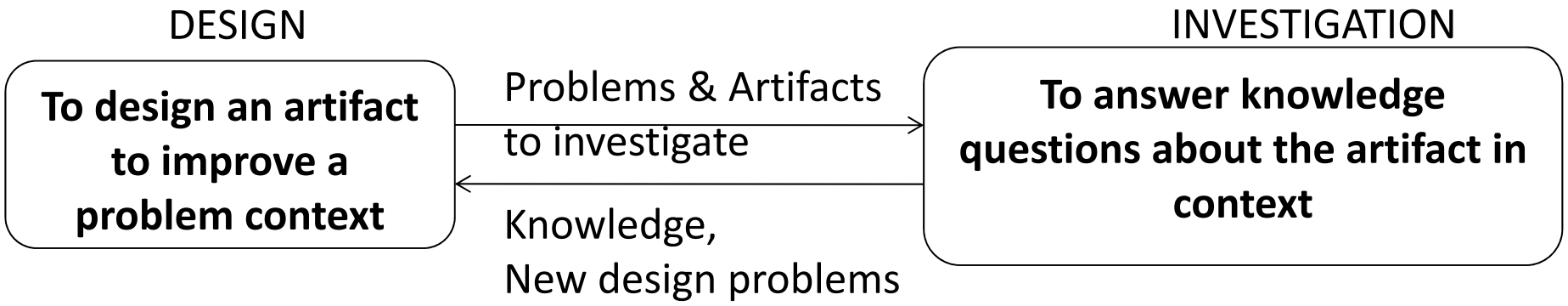
- Design science is the **design** and **investigation** of artifacts in context

- Examples
  - Design and investigation of a method for user interface design for genomic databases
  - Design and investigation of an ontology-based extension of OO-method
  - Design and investigation of deep learning system to classify pathologies in X-rays of the lower back
  - ….

DESIGN PROBLEMS AND KNOWLEDGE QUESTIONS

Your examples

Two kinds of research problems in design science



Design software to estimate Direction of Arrival of plane waves, to be used in satelite TV receivers in cars	• *Is the DoA estimation accurate enough in this context?* • *Is it fast enough?*
Design a Multi-Agent Route Planning system to be used for aircraft taxi route planning	• *Is this routing algorithm deadlock-free on airports?* • *How much delay does it produce?*
Design a data location regulation auditing method	• *Is the method usable and useful for consultants?*

Change the real world

Change your knowledge

Heuristics

Design problems

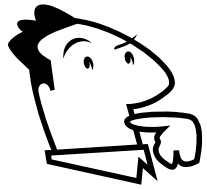
- √ To change the world
- √ Solution is design
- √ Many solutions
- √ Evaluated by usefulness
- √ What is useful depends on stakeholder goals
- √ Degrees of utility

Doing

Knowledge questions

- √ To change your knowledge
- √ Answer is a proposition
- √ One answer
- √ Evaluated by truth
- √ What is true depends on the real world
- √ Degrees of certainty

Thinking



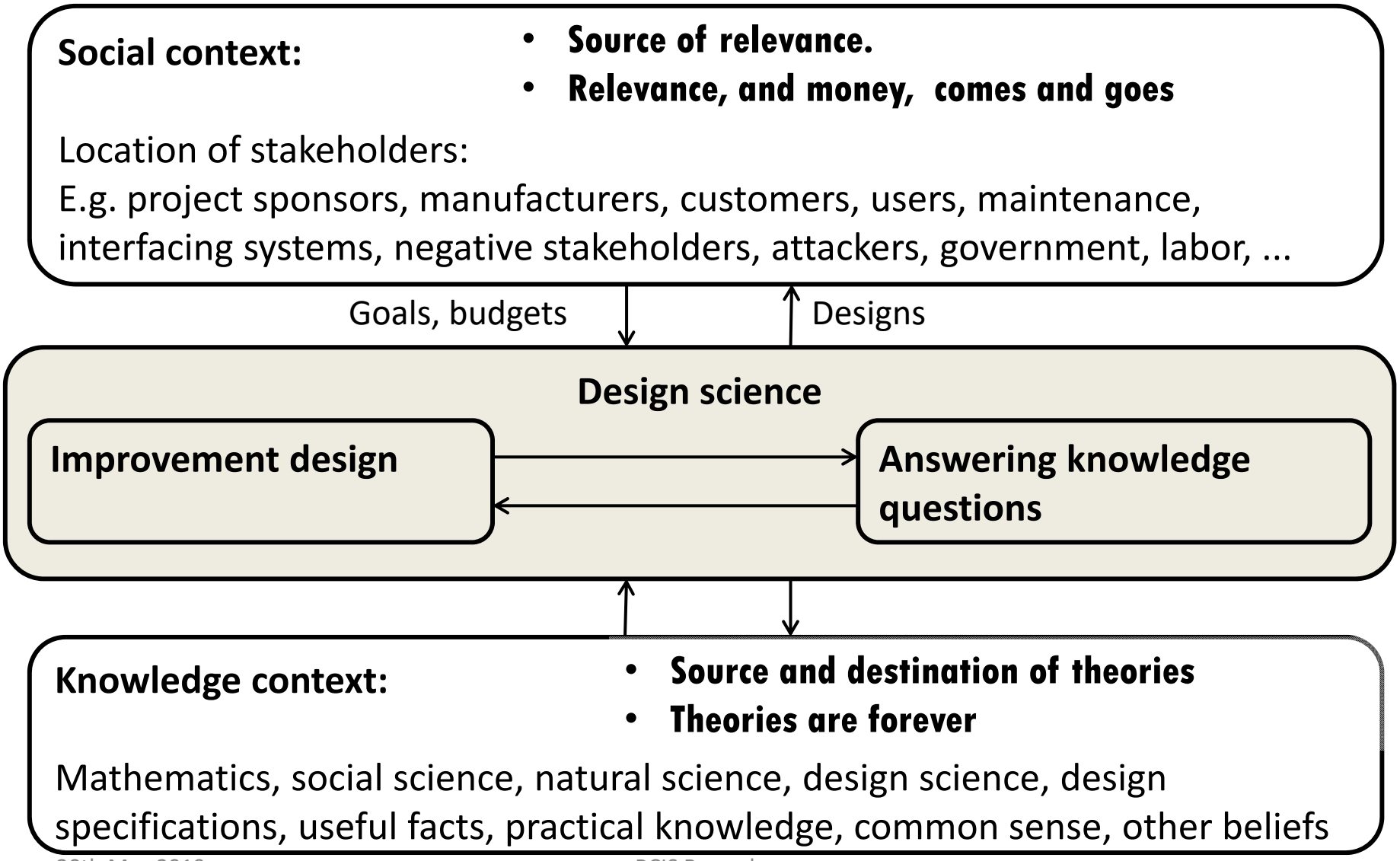
Nesting of problems

- To solve a design problem:
  - Study the problem
  - Test the proposed solution
- To answer a knowledge question:
  - Design your research

Your examples revisited

Framework for design science

- Stakeholders may not know they are stakeholders



Stakeholders

- A **stakeholder** of a problem is a biological or legal person affected by treating a problem.
  - *People, organizations, job roles, contractual roles, etc.*

- Stakeholders may not know that they are stakeholders
  - They may accept the problem as normal
  - There may not be a problem at all … but you think/hope that there is an improvement opportunity

Checklist by role (Ian Alexander http://www.scenarioplus.org.uk/papers/papers.htm > A taxonomy of stakeholders)

System under Development

- Normal operator (end user)
- Operational support
- Maintenance operator

Immediate context

- Functional beneficiary (client)
- Roles responsible for interfacing systems

Wider context

- Political beneficiary (who gains status)
- Financial beneficiary
- Negative stakeholder (who is/perceives to be hurt by the product)
- Threat agent (who wants to hurt the product)
- Regulator

Involved in development

- Champion/Sponsor
- Developer
- Consultant
- Purchaser (customer)
- Suppliers of components

These are just examples

Examples

- Design and investigation of a method for user interface design for genomic databases
  - Stakeholders: …….
- Design and investigation of an ontology-based extension of OO-method
  - Stakeholders: …..
- Design and investigation of deep learning system to classify pathologies in X-rays of the lower back
  - Stakeholders: …..

More examples

THE DESIGN CYCLE

The engineering cycle

- Problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Implementation evaluation

Stakeholders, goals, phenomena, evaluation, diagnosis

The engineering cycle

- Problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Implementation evaluation

Treatment = interaction between artifact and context

- Interaction between pill and patient
- Interaction between Software and its Context
- Interaction between method and its context of use

- You design the artifact in order to create a treatment

The engineering cycle

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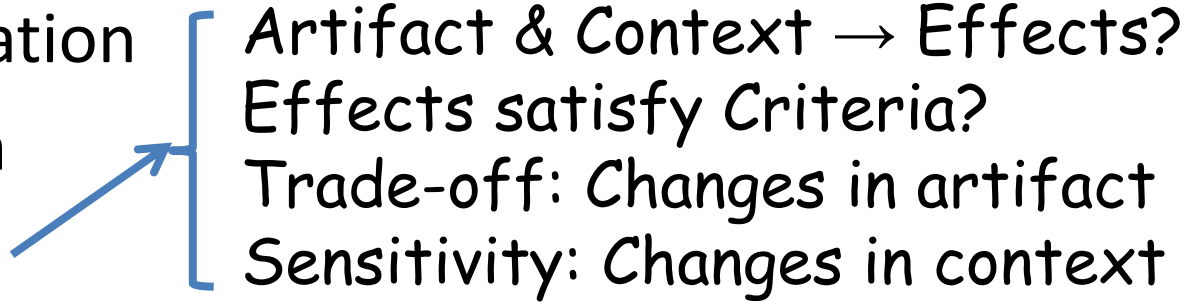


The engineering cycle

- Problem investigation
- Treatment design
- Design validation
- Treatment implementation → Transfer to practice! Commercialization, sale
- Implementation evaluation

The engineering cycle

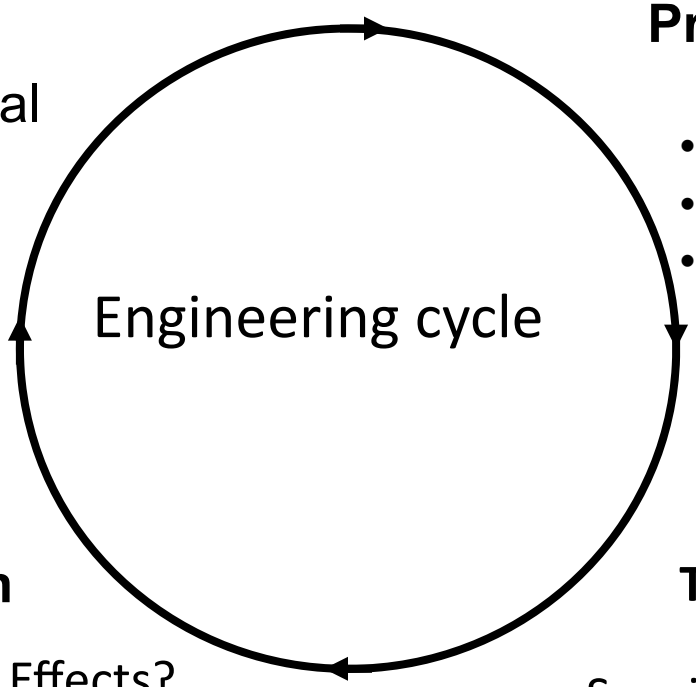
- Problem investigation
- Treatment design
- Design validation
- Treatment implementation
- Implementation evaluation

Phenomena: Artifact & Context → Effects?
Evaluation: Effects satisfy Criteria?

Where are we

Legend:
? Knowledge questions
! Tasks

Treatment Implementation
(transfer to the real world)



Implementation evaluation = Problem investigation

- Stakeholders? Goals?
- Phenomena? Causes? Effects?
- Effects contribute to Goals?

Treatment design

- Specify requirements!
- Contribution to goals?
- Available treatments?
- Design new ones!

Treatment validation

- Context & Artifact → Effects?
- Effects satisfy Requirements?
- Trade-offs for different artifacts?
- Sensitivity for different Contexts?

Where are we

Legend:
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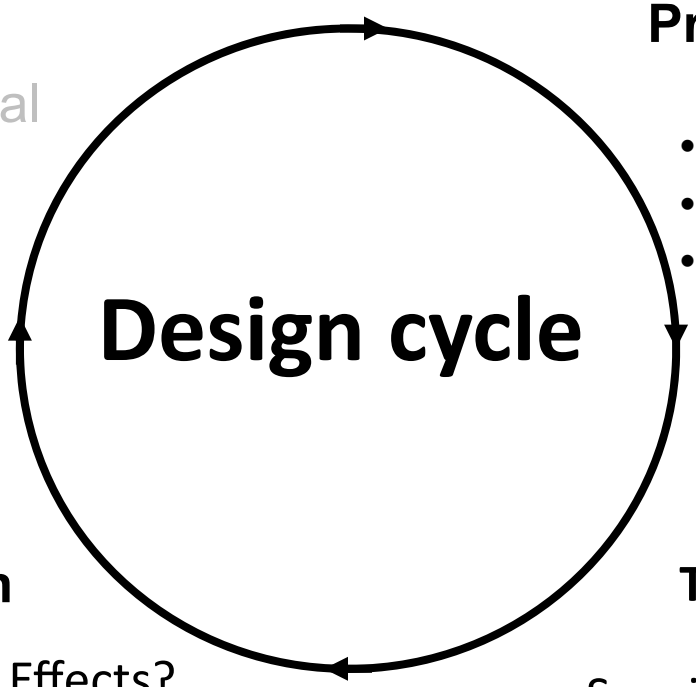
Treatment Implementation (transfer to the real world)



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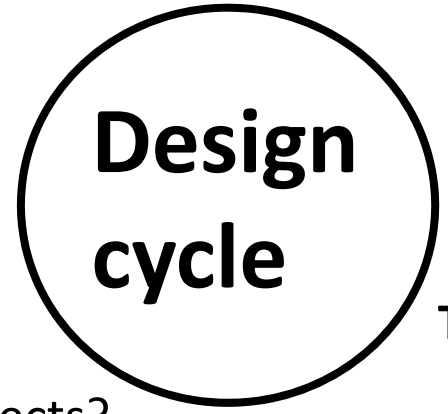
Knowledge questions that need empirical study

Treatment Implementation (transfer to the real world)



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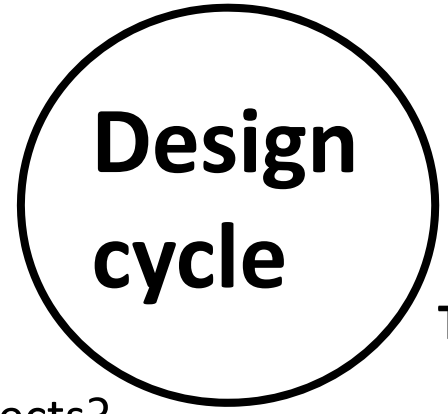
Outline of a thesis



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Chapter 1: Motivation
- Stakeholders, goal, phenomena, how bad

Chapter 2: Methodology
- Research questions
- Method(s) used to answer them

Chapter 3: Problem investigation
- Empirical research
- Literature survey about the problem

Chapter 4: Requirements for a solution
- Sources of the requirements
- Motivation in terms of stakeholder goals

Chapter 5: Survey of current solutions
- Literature survey (state of the art)

Chapter 6: My solution proposal

Chapter 7: Test 1
- Experiment

Chapter 8 : Test 2
- Experiment

Chapter 9: Summary, answers to research questions, discussion, future work

Outline of a thesis

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Chapter 2: Methodology

- Research goal: To improve some problem context by some artefact in order to contribute to some stakeholder goals
- Research questions
  - What are the problematic phenomena?
  - Specify & motivate the requirements for a solution ("What are the requirements?")
  - What solutions exist?
  - How good/bad are they?
  - Design a new solution ("what is a good solution?")
  - Does my solution in the intended problem context satisfy the requirements?
  - What happens if I change the design?
  - What happens if I change the context?
- Method(s) used to answer them

What are your research questions?

THE EMPIRICAL CYCLE

Nesting of cycles

Research project: **design cycle**

Problem investigation	
Treatment design	
Treatment validation	Knowledge problem investigation (How to do the validation?)
	Experiment design & validation (design and validate a prototype & test environment)
	Implementation (construction of prototype & test environment, lab or field)
	Evaluation (analyze results)
Implementation (tech transfer)	
Implementation evaluation (in the field)	

This is a very special engineering cycle, called the **empirical cycle**.

Nesting of cycles

Research project: **design cycle**

Problem investigation	Knowledge problem investigation (How to investigate the design problem?)
	Experiment design & validation (design and validate a prototype & test environment)
	Implementation (construction of prototype & test environment, lab or field)
	Evaluation (analyze results)
Treatment design	
Treatment validation	
Implementation (tech transfer)	
Implementation evaluation (in the field)	

This is a very special engineering cycle, called the **empirical cycle**.

The empirical research cycle

- This is the rational decision cycle applied to answer knowledge questions (empirical research questions)
  - Knowledge problem investigation
  - Research design
  - Design validation
  - Research execution
  - Results evaluation

- Knowledge problem investigation → Research questions, Unit of study
- Research design
- Design validation
- Research execution
- Results evaluation

- Knowledge problem investigation
- Research design → Survey, observational case, Experiment, Action case, Simulation, …
- Design validation
- Research execution
- Results evaluation

- Knowledge problem investigation
- Research design
- Design validation
- Research execution
- Results evaluation

Would this really answer our questions?
Risk assessment of doing the wrong thing to answer the questions

- Knowledge problem investigation
- Research design
- Design validation
- Research execution
- Results evaluation → Did this really answer our questions?
  Risk assessment of answering the questions incorrectly

- **Very detailed**
- **This integrates all checklists!**

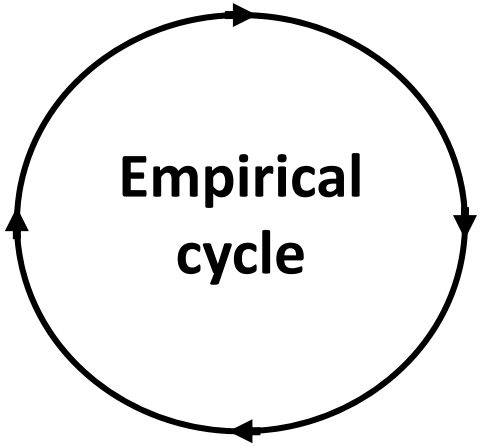
Analysis of results

12. Data?
13. Observations?
14. Explanations?
15. Generalizations?
16. Answers?

New research problem

Research execution

11. What happened?



Research problem analysis

4. Conceptual framework?
5. Research questions?
6. Population?

Research design validation

7. Object of study justification?
8. Treatment specification justification?
9. Measurement specification justification?
10. Inference justification?

Research design

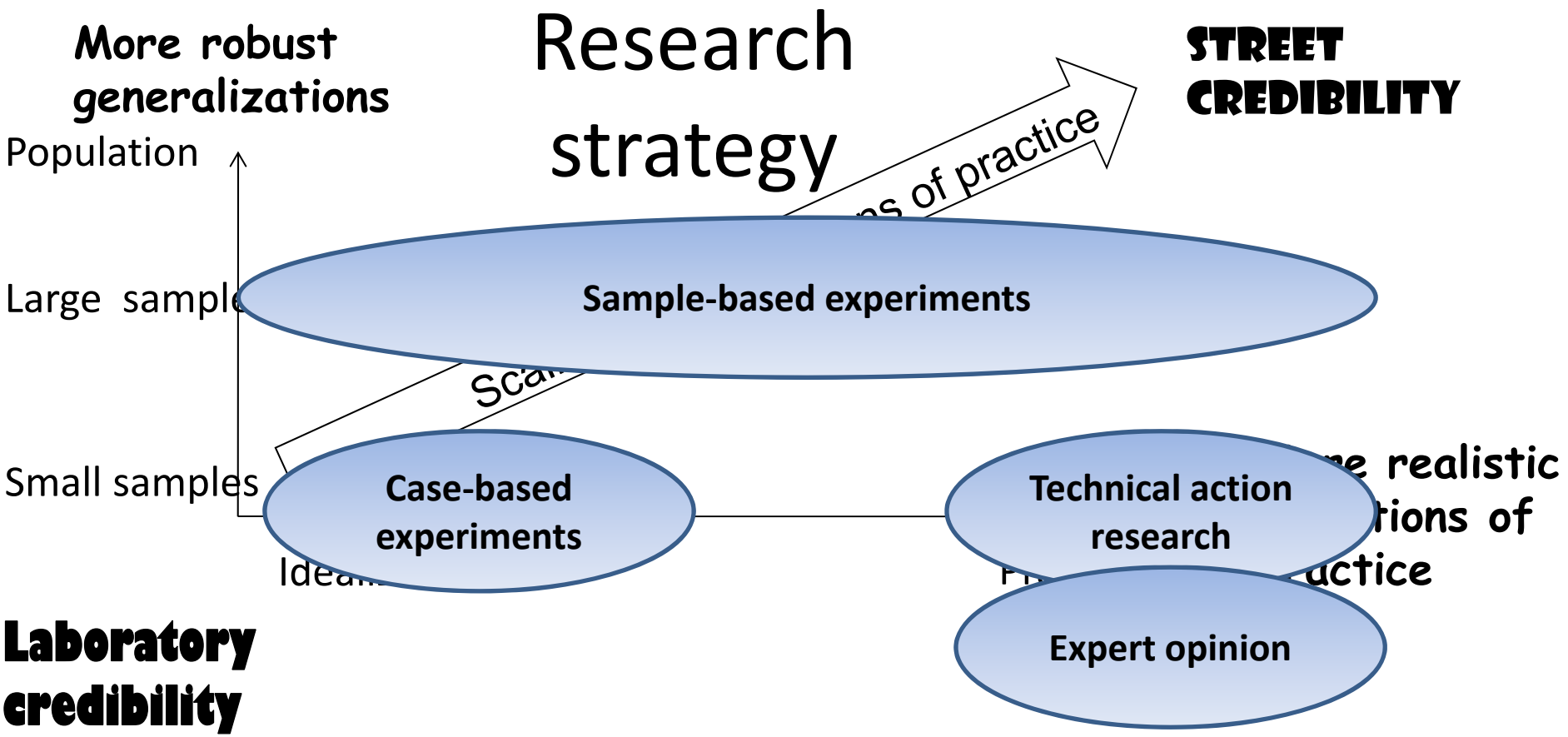
7. Object of study?
8. Treatment specification?
9. Measurement specification?
10. Inference?

Research designs and inferences

	Observational study (no treatment)	Experimental study (treatment)
Case-based: investigate single cases, look at architecture and mechanisms. Inference: Architectural explanation, generalization by analogy	**Observational case study**	• **Expert opinion** (mental simulation by experts), • **Case-based experiments** (simulations, prototyping), • **Technical action research** (experimental use of the artifact in the real world)
Sample-based: investigate samples drawn from a population, look at averages and variation. Inference: Statistical inference, causal explanation, possible architectural explanation and analogy	**Survey**	• **Sample-based experiments** (e.g. treatment group – control group experiments)

Problem investigation methods

Validation methods (depends on time and budget)



- Scaling up:
  - Expert opinion
  - Lab experiment (test experimental prototype in lab context)
  - Field experiment (test experimental prototype in field context)
  - TAR (apply your experimental solution in a real-world project)

- Questions
- Remarks
- Examples
- Discussion
- More information
- Extra slides
- Any other business
- Lunch