Universiteit Utrecht

[Faculty of Science
Information and Computing Sciences]

On Whose Shoulders We Stand:

Theory *testing* or theory *building* in requirements engineering research

Keynote REFSQ Doctoral Consortium
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Utrecht University

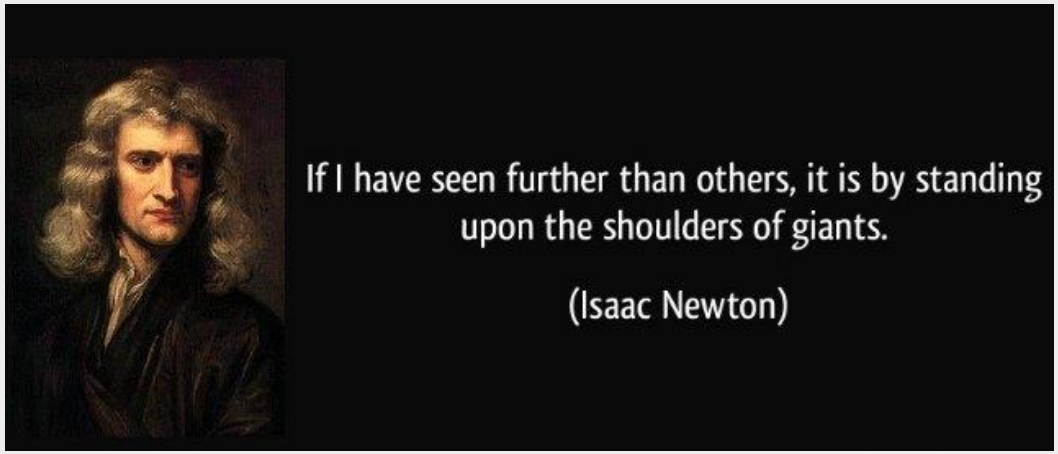
Outline

1. Your contribution a theory?
2. Theory development
3. Theory in Design Science
4. Example of Theory building research
5. Conclusion and discussion

For this presentation I stand on the shoulders of many colleagues.

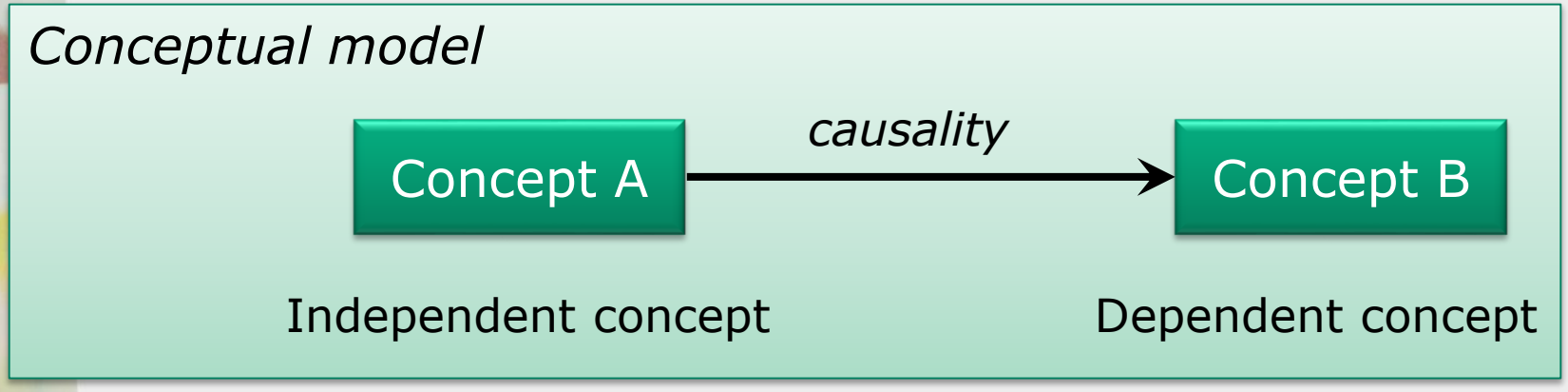
A full elaboration of theory building and theory testing can be found in the book: Dul, J., & Hak, T. (2007). Case study methodology in business research. Routledge.

A PhD: Your contribution to the sciences



- A Phd work builds upon all the work done in a particular domain.
- In Computer Science we design innovative technology, and we forget our theoretical contributions.
- Poor habit, so our colleagues in other sciences are looking down on us

Your hypothesis



Examples:

- Executing systems development in sprints improves stakeholder satisfaction
- Establishing linguistic relationships simplify requirements engineering in high volume requirements management

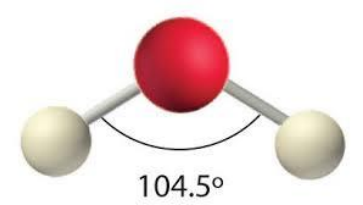
What is a theory?

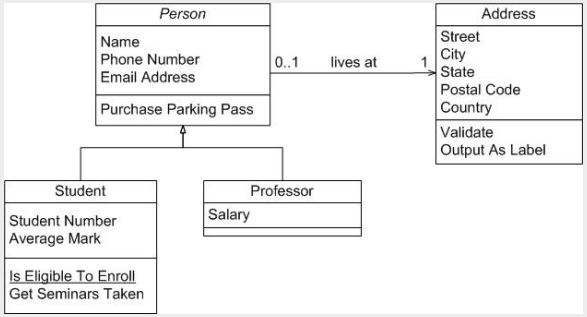
- A theory is a set of propositions about an object of study.

- A proposition consists of concepts and specifications of relations between concepts.
- The relations are assumed to be true for the object of study.
- The set of instances to which the relations apply is called the domain, i.e. the field in which the proposition can be generalized.

Four essential characteristics of a theory:

1. Object of study
2. Concepts
3. Propositions
4. Domain





Discussion: what is your theory?

- Name the four essential theory characteristics of your project:
  1. Object of study
  2. Concepts
  3. Propositions
  4. Domain

  What are the Dependent and Independent Concepts?

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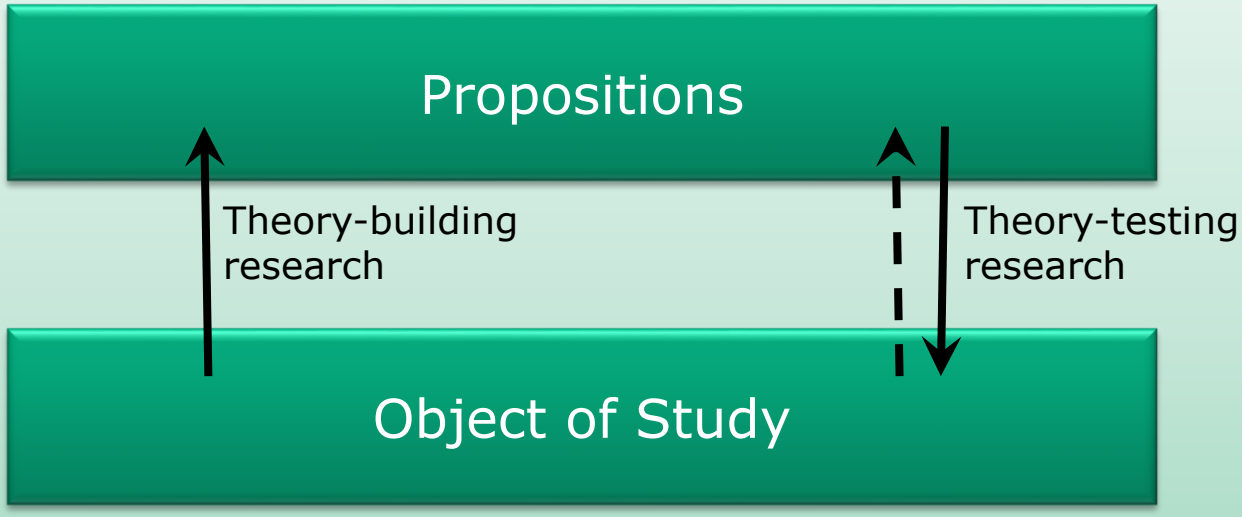
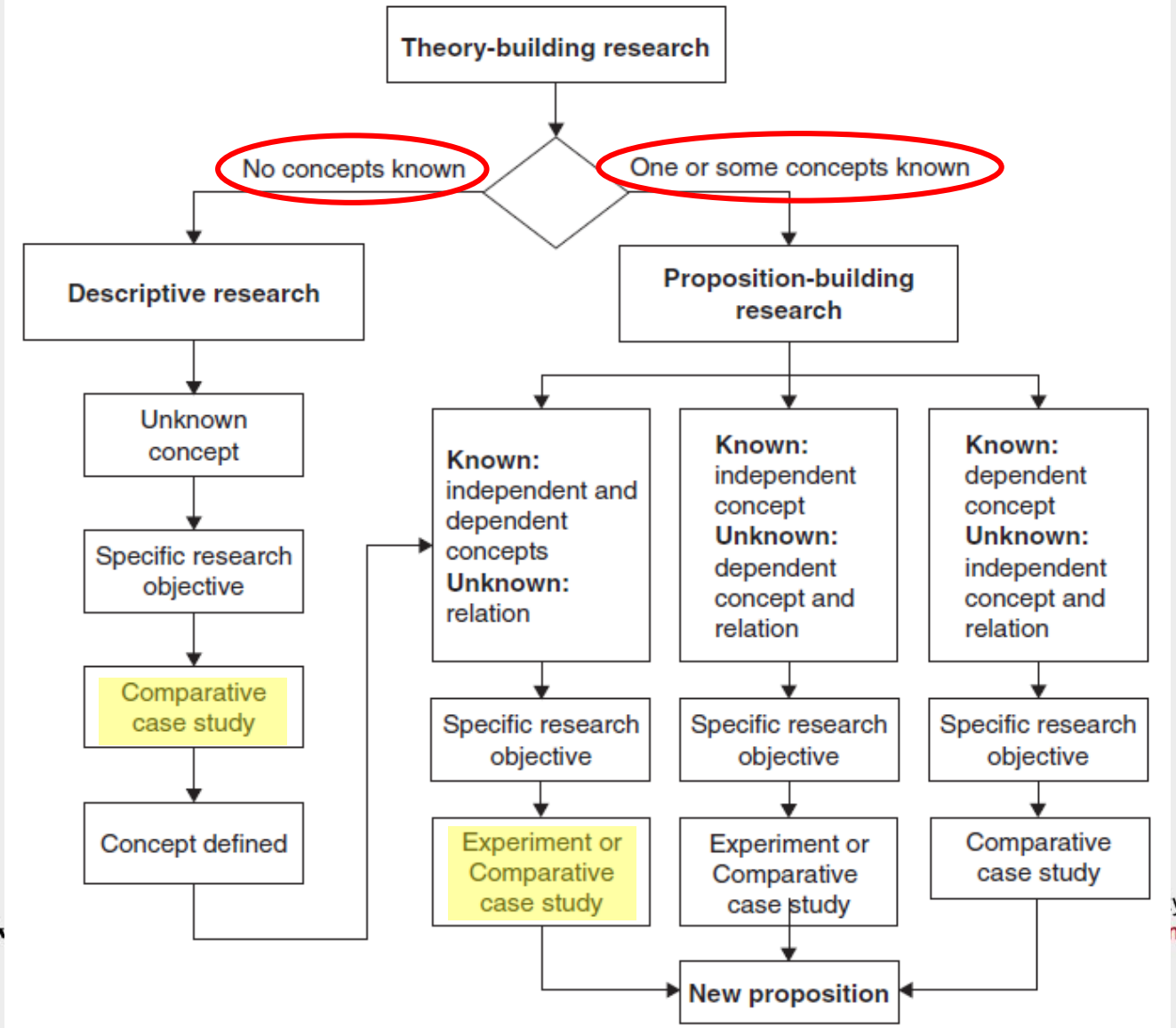
Theory Development

Empirical cycle



- Theory building research is research with the objective of formulating new propositions based on the empirical evidence drawn from observation of instances of the object of study.
- Theory testing research is research with the objective of testing propositions

Research strategies for Theory building



Types of causal propositions

1. Sufficient: If there is A, then there will be B
2. Necessary: B exists only if A is present
3. Deterministic: If A is higher, then B is higher
4. Probabilistic: If A is higher, then it is likely that B is higher

Discussion: what are good examples of these causalities in our field?

What applies for RE research?

Contributions with new techniques and tools are usually focusing on Deterministic and Probabilistic causality of the efficiency or effectiveness of RE work.

Research strategies for theory testing

Proposition	Preferred	Case study	Survey
Sufficient condition	Experiment	Single-case study	Third-best
Necessary condition	Experiment	Single-case study	Third-best
Deterministic relation	Experiment	Longitudinal single-case study or comparative case study	Third-best
Probabilistic relation	Experiment	Third-best: comparative case study	Second-best

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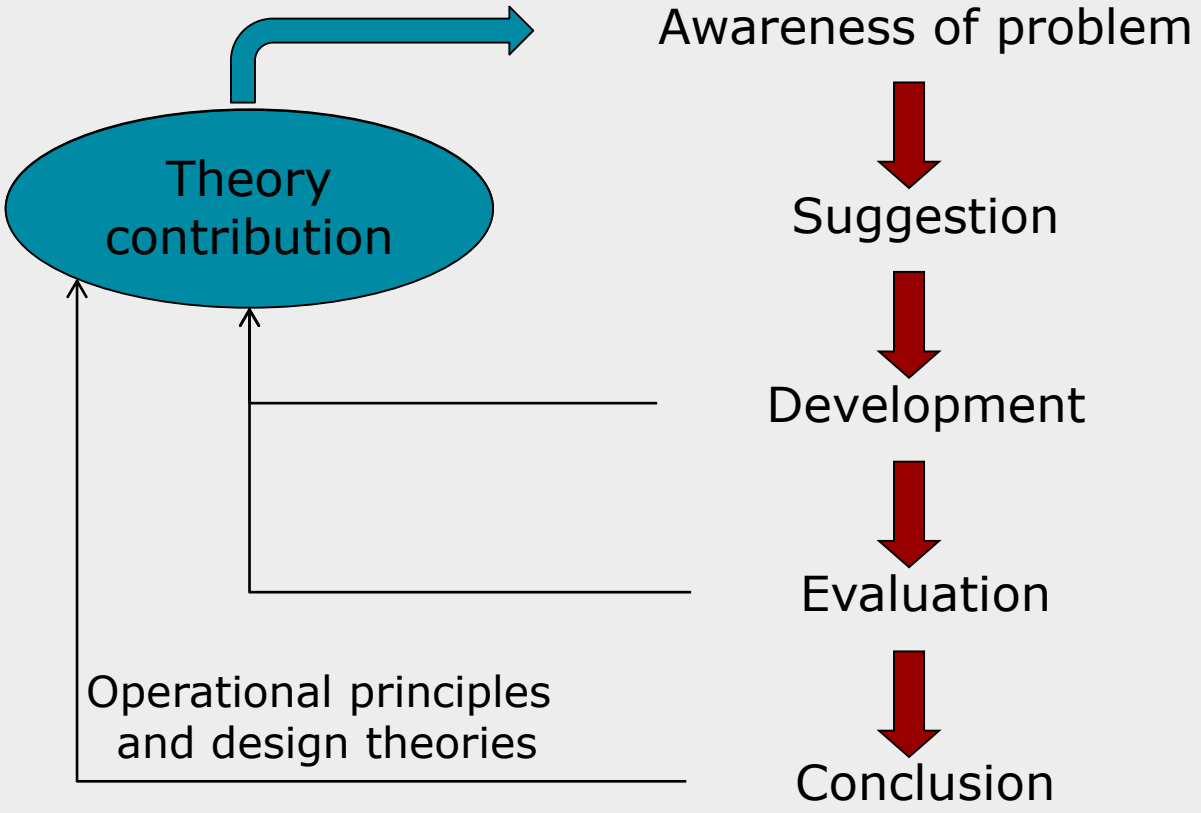
Theory in design science?

- Theories of the usage and performance of newly designed artifacts to understand, explain or enhance aspects of information technology in general

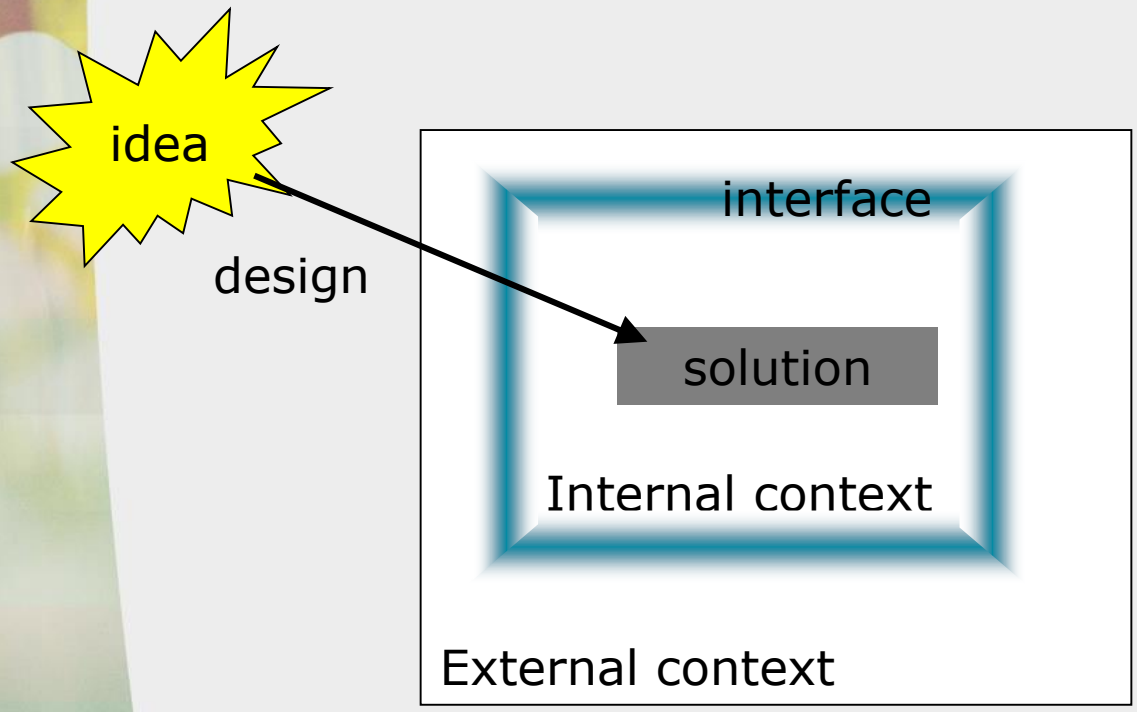
- Usage: changes for the users, e.g. their way of working
- Performance: change of properties, e.g. speed, integration
- Artifact: Interface, method, tool, specification language, ...

- Measure improvements, gain insight in the way work is performed
- Application in medical and technological sciences, including information and computing science

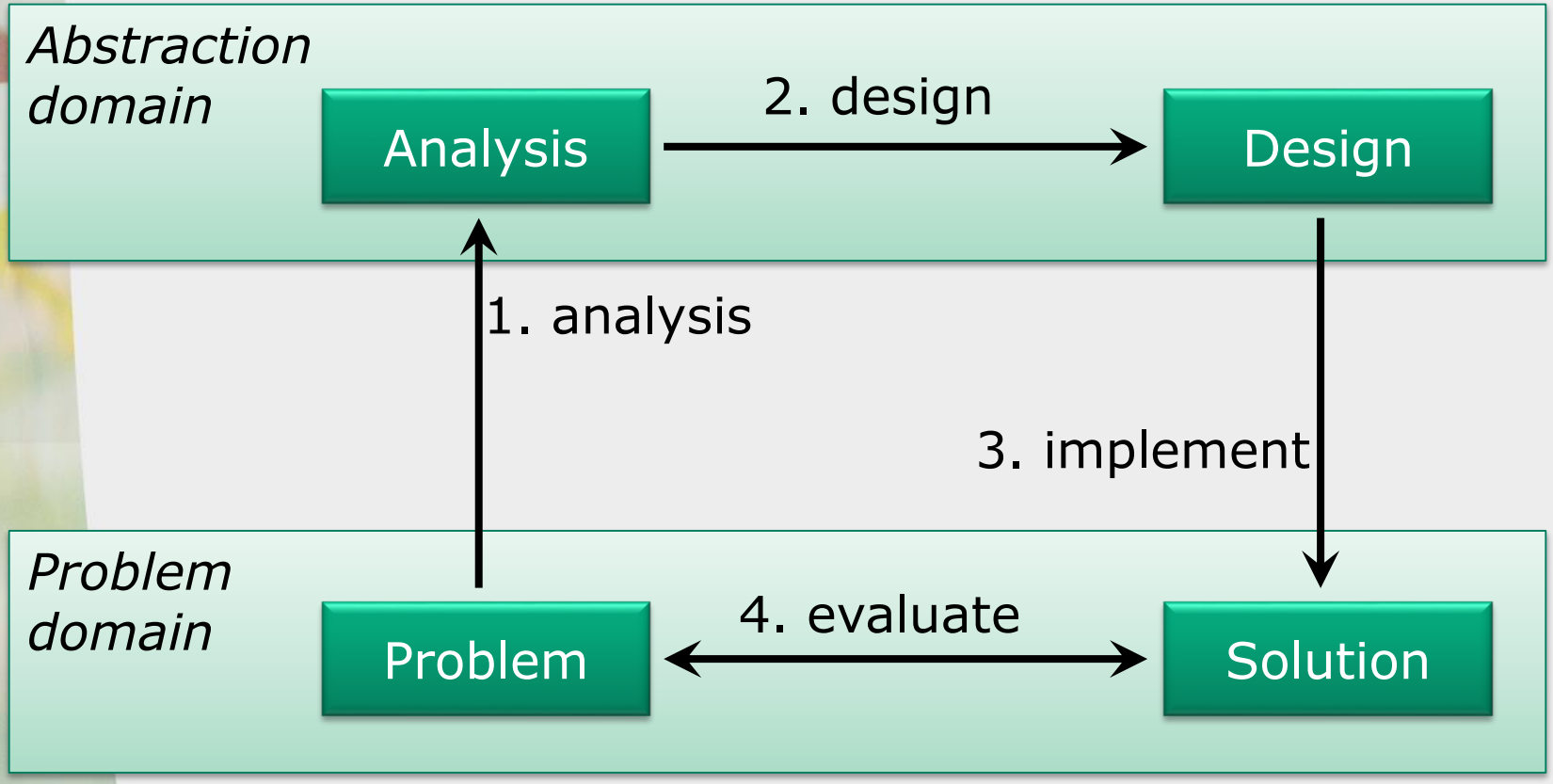
Design cycle



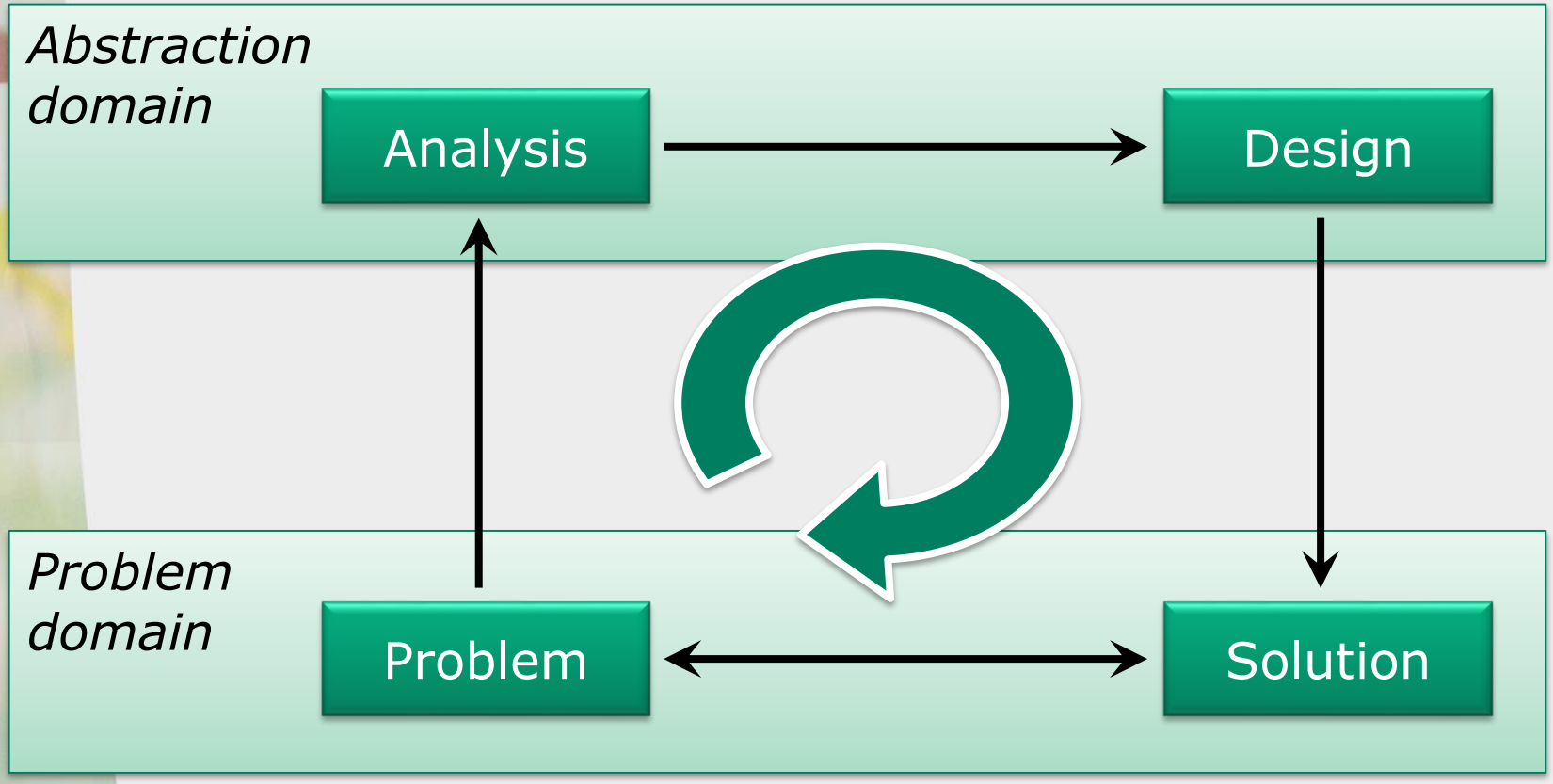
Design and its context



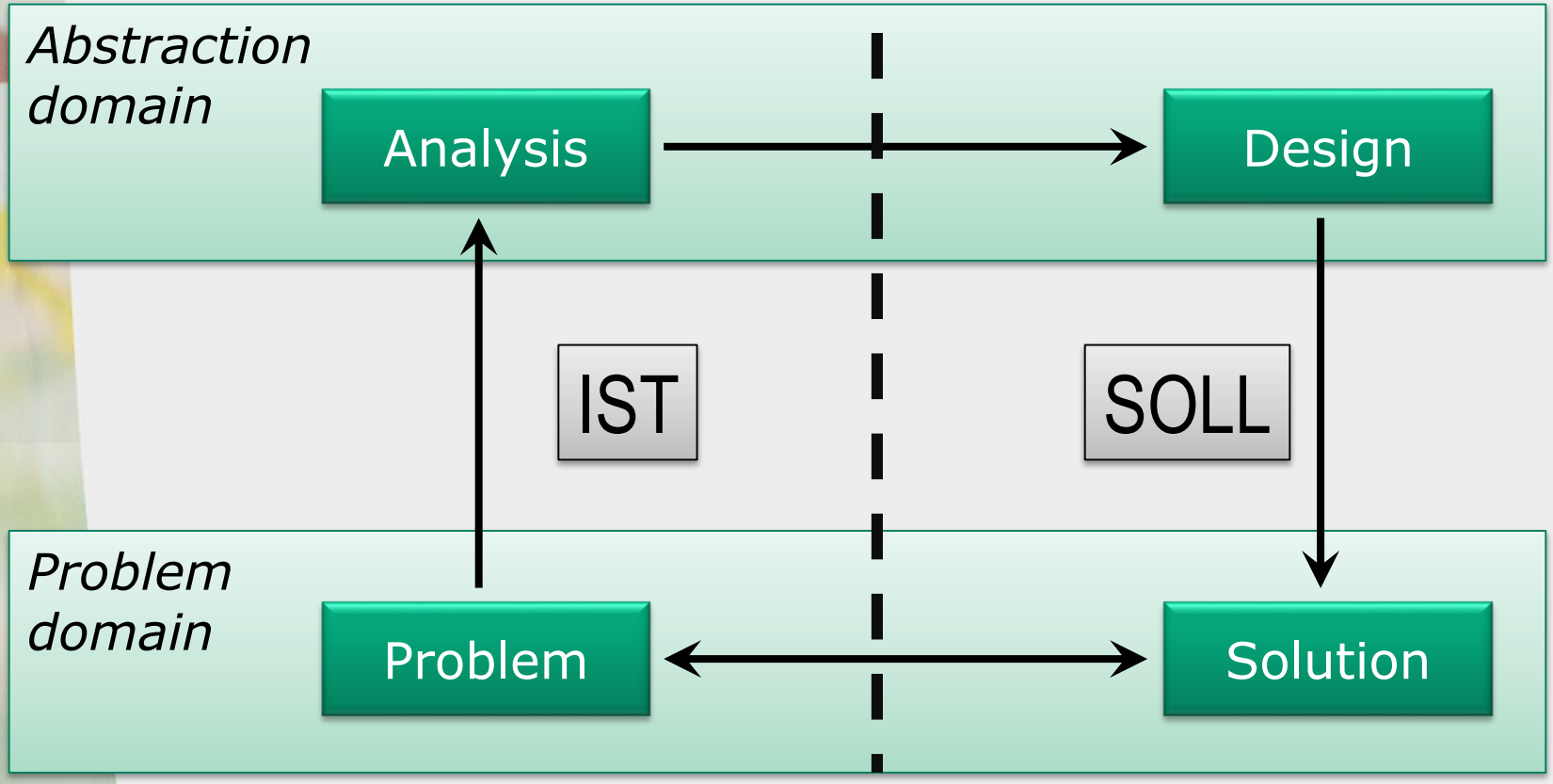
Approach


Abstraction domain
Analysis
2. design
Design
1. analysis
3. implement
Problem domain
Problem
4. evaluate
Solution

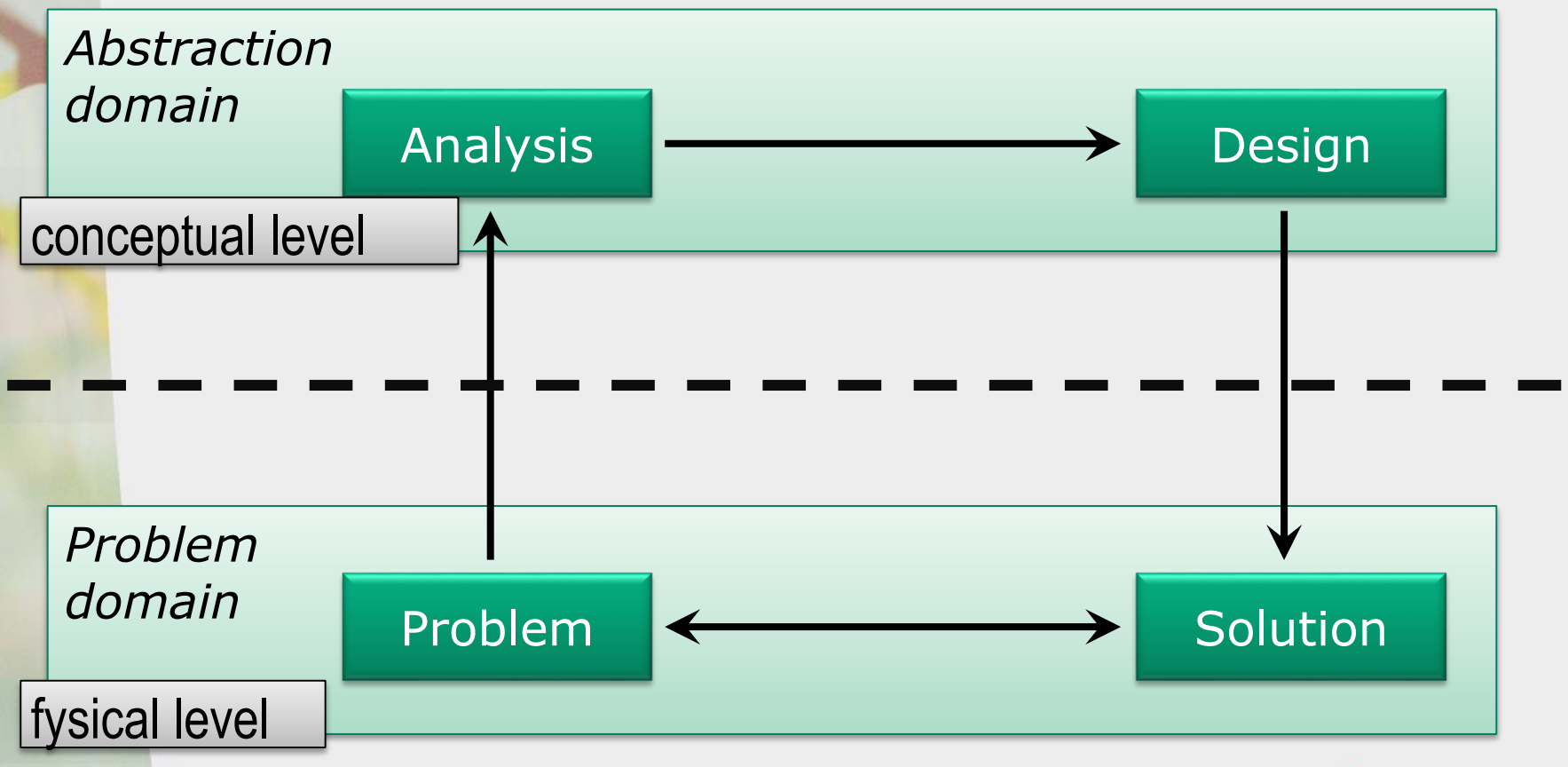
Design Research Cycle



IST and SOLL


Abstraction domain
Analysis
Design
IST
SOLL
Problem domain
Problem
Solution

Design levels



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Theory building: Speeding up Requirements Management in a Product Software Company

- External Context: Baan with 8000 customers and 15.000 product installations
- Internal Context: 60 Product managers responsible for the requirements management processes
- Problem: linking of customer wishes to product components is too cumbersome
- Idea: Use linguistic engineering techniques to link customer wishes to product requirements

- Joint work of:
  - Björn Regnell and Johan Natt och Dag, Lund Institute of Technology, Sweden
  - Vincenzo Gervasi, Pisa University, Italy
  - Sjaak Brinkkemper, Utrecht University, The Netherlands

Approach: what is the problem?

Problem domain

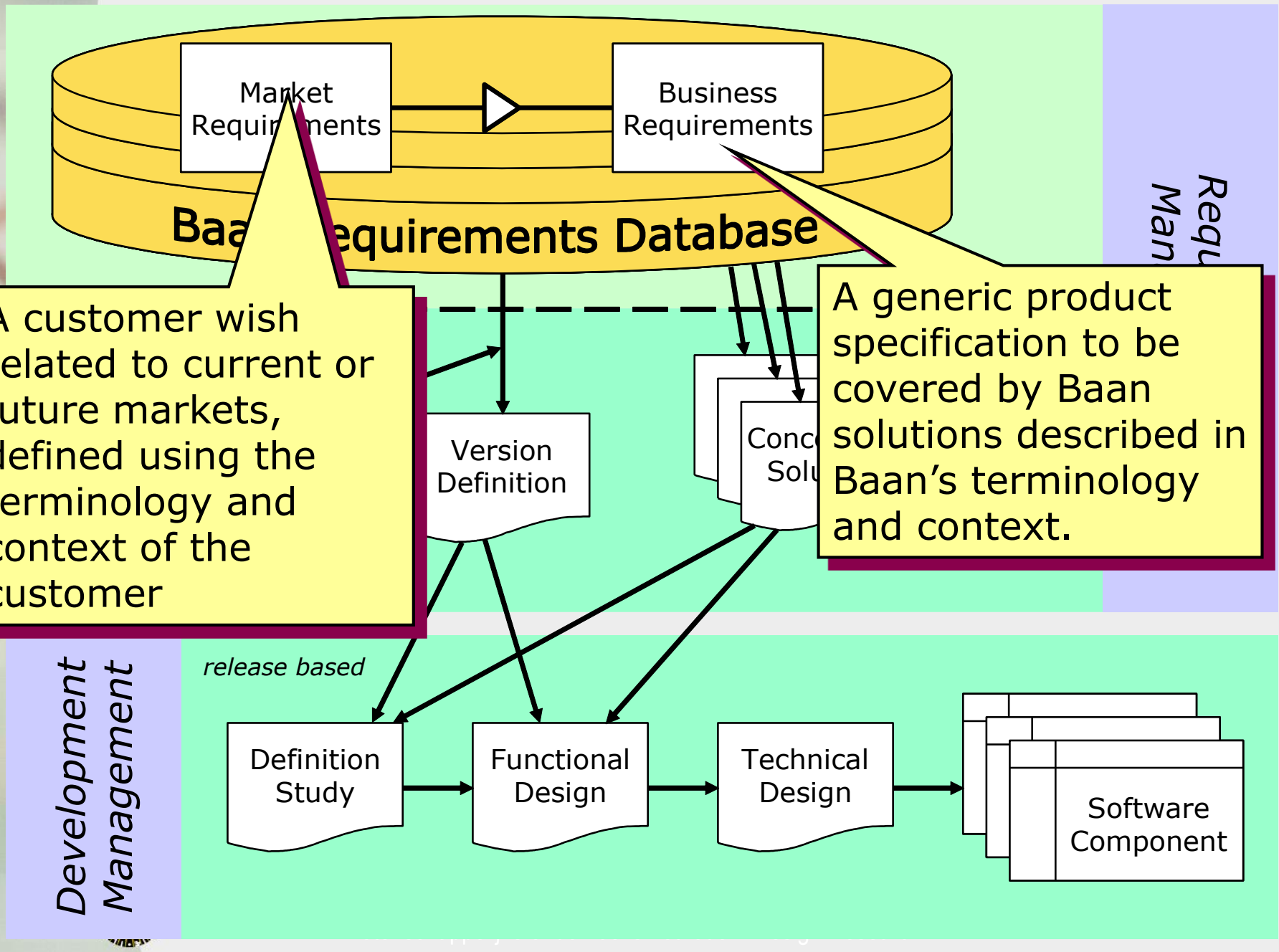
Problem

Context: organisation “Baan”

- Founded in 1978 in the Netherlands
  - 15,000+ customer sites worldwide
  - 1000+ employees
  - 1,000.000+ users
- Markets
  - Manufacturing industry
  - Engineering industry
- Headquartered in Barneveld, The Netherlands
  - Offices and partners worldwide
  - 400 employees Development
  - 200 employees Customer Service & Support
- Now part of Infor

Complexity of large scale product software

- Several thousands of whishes, needs, and requirements stored in a database
- Market- and technology-driven software development
- Large, complex software systems
- Several different product lines
- Distributed development
- Uncertainty, frequent change, and time pressure
- Requirements written in plain text

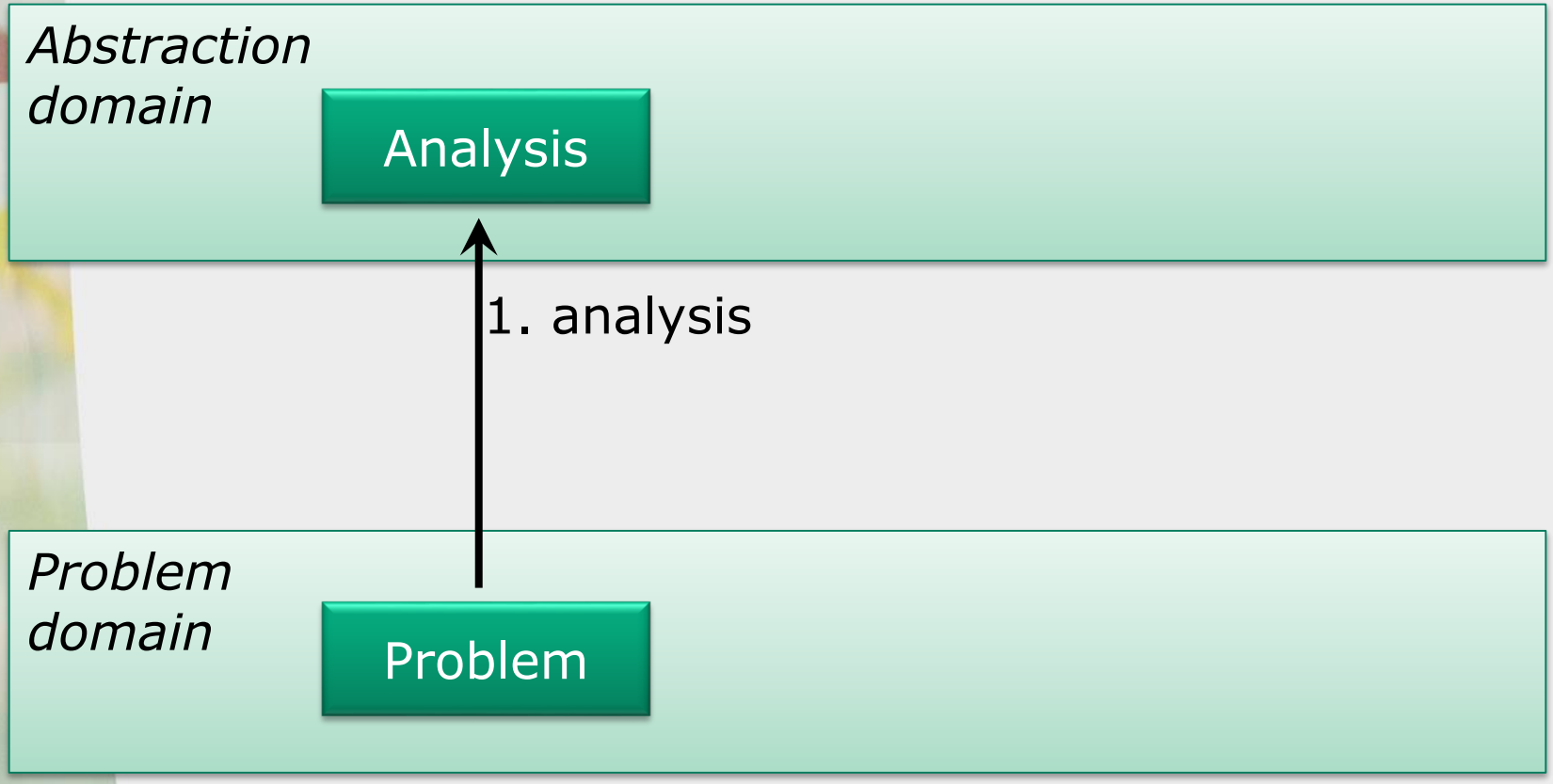

Market Requirements
Business Requirements
Baan Requirements Database
A customer wish related to current or future markets, defined using the terminology and context of the customer
A generic product specification to be covered by Baan solutions described in Baan's terminology and context.
Version Definition
Requirements Management
release based
Development Management
Definition Study
Functional Design
Technical Design
Software Component

Example requirements

Field	Example *[Description]*
Id	MR10739
Example	*[Request raiser's company]*
Request Person	*[Request raiser]*
Date	1996-05-29
Label	Pricing and Containerization
Description	Specifically what I am interested in is containerization and pricing. For a prospect I am working with (pretty much a distributor of electonic components) I need pricng by type of package by cusotmer type (wholesale or retail). I think pricing by container solves this problem, but I understand to use this feature the item must be a process item and I don't know if this is good or bad. If I must use process what do I gain or lose, like do I have to run a seperate MRP etc. Do I have to have one process company and one non-process company. They have mainly an assembly operation with no process involved. If process would be to cumbersome how difficut a mod would it be to disconnect containerzation from process.
Keywords	Pricing, order planning
Priority	Medium
Type	Functionality
Status	Closed/Completed
User name	*[Requirement submitter]*
Comments	020699: functionality is available in BaanERP in the Pricing module
Agreement	None

Field	Example *[Description]*
Id	BR10025
Date	1998-01-27
Label	Statistics and containers
Description	1. Container (end item) in statistics Purchase and sales statistics used to be maintained only at main item level. But now it has also become possible to build statistics at container level. There are two aspects: printing statistics in the number of containers for a main item selecting and/or printing statistics at container level 2. Displays in statistics Displays are compositions of end items (for example, an attractive display of different types of cake). The statistics will be updated at both the levels of display item and container (which is part of the display). Prevention of duplicate counting, and correct pricing must be arranged in a procedural manner.
Keywords	Process industries
Type	Usability
Status	Assigned
User name	*[Requirement submitter]*
Comments	Warehousing only

Approach – step 1: analysis



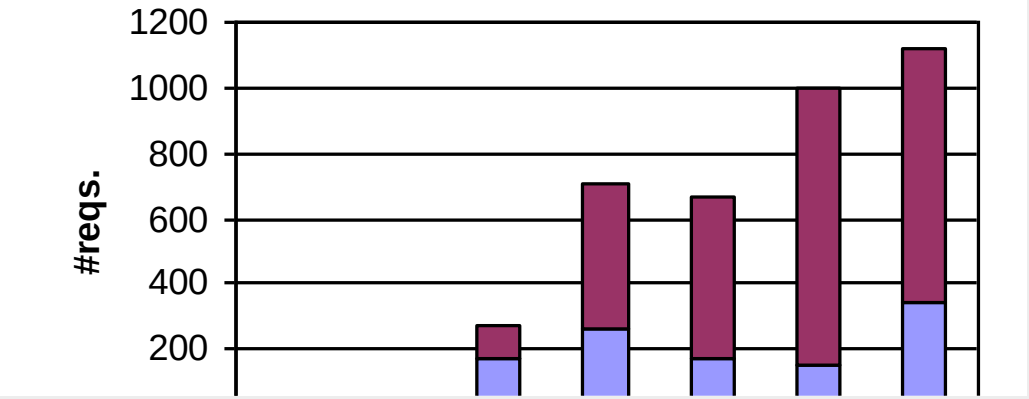
The Baan RDB

Year	# Business Requirements	# Linked	# Market Requirements	# Linked
1996	0	0	183	113
1997	5	4	683	262
1998	275	169	1,579	388
1999	709	261	2,028	502
2000	669	167	1,270	397
2001	1,000	153	864	224
2002	1,121	340	1,695	514
Total	**3,779**	**1,094**	**8,302**	**2,400**

Linking statistics

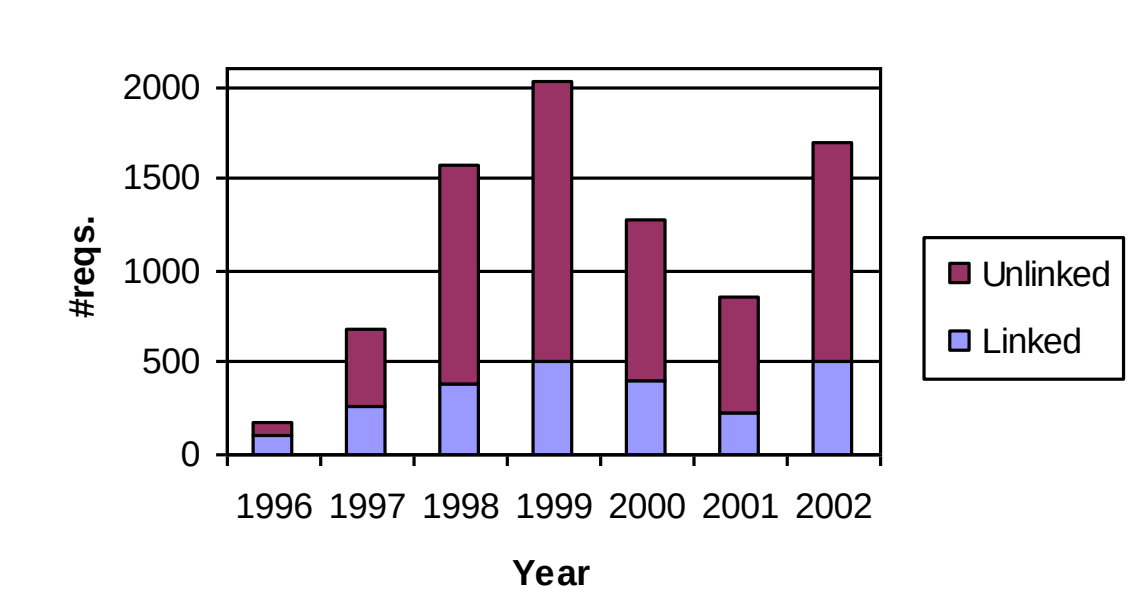
3,779 Business Requirements

1,094 linked

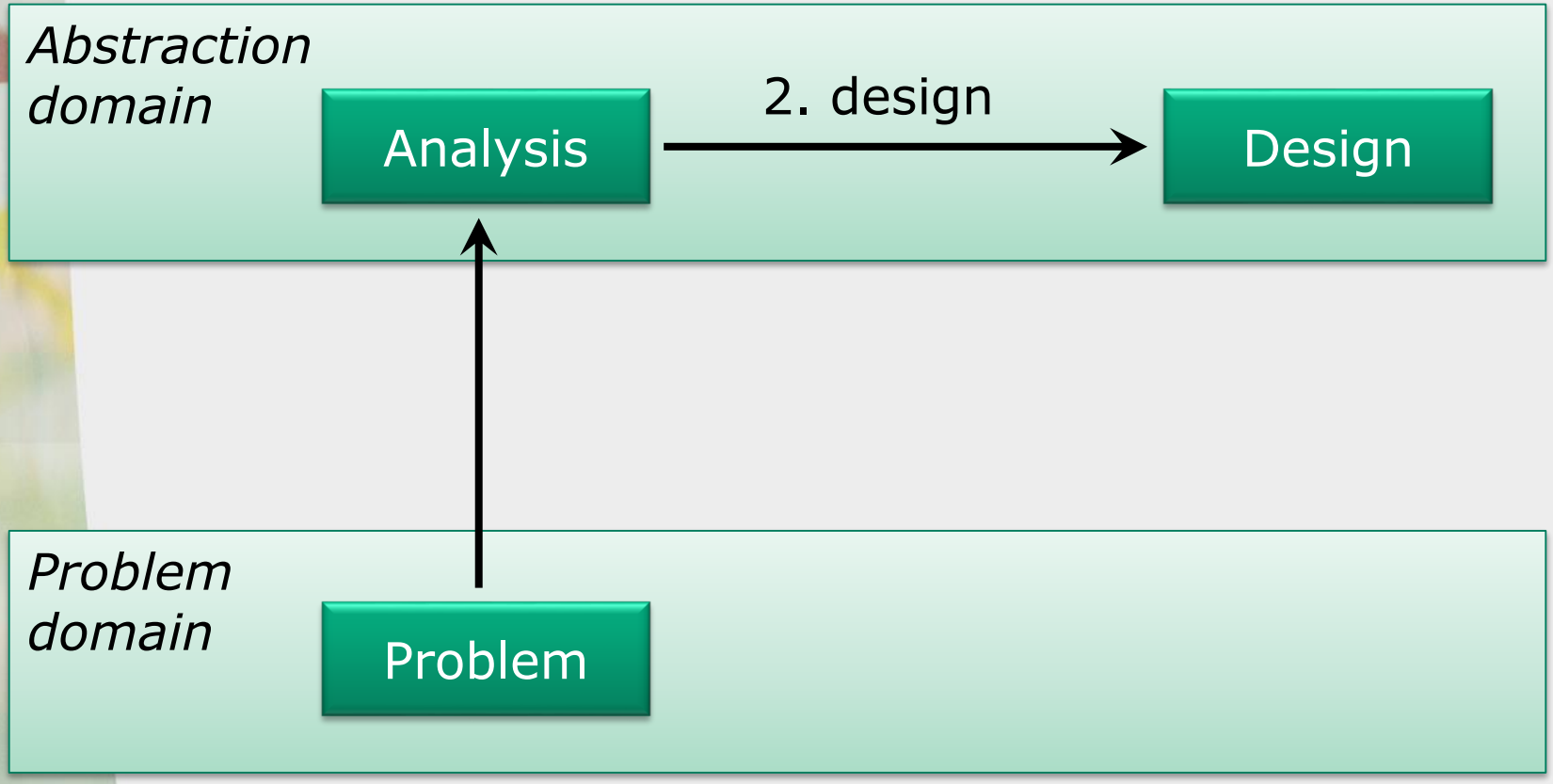


8,302 Market Requirements

2,400 linked



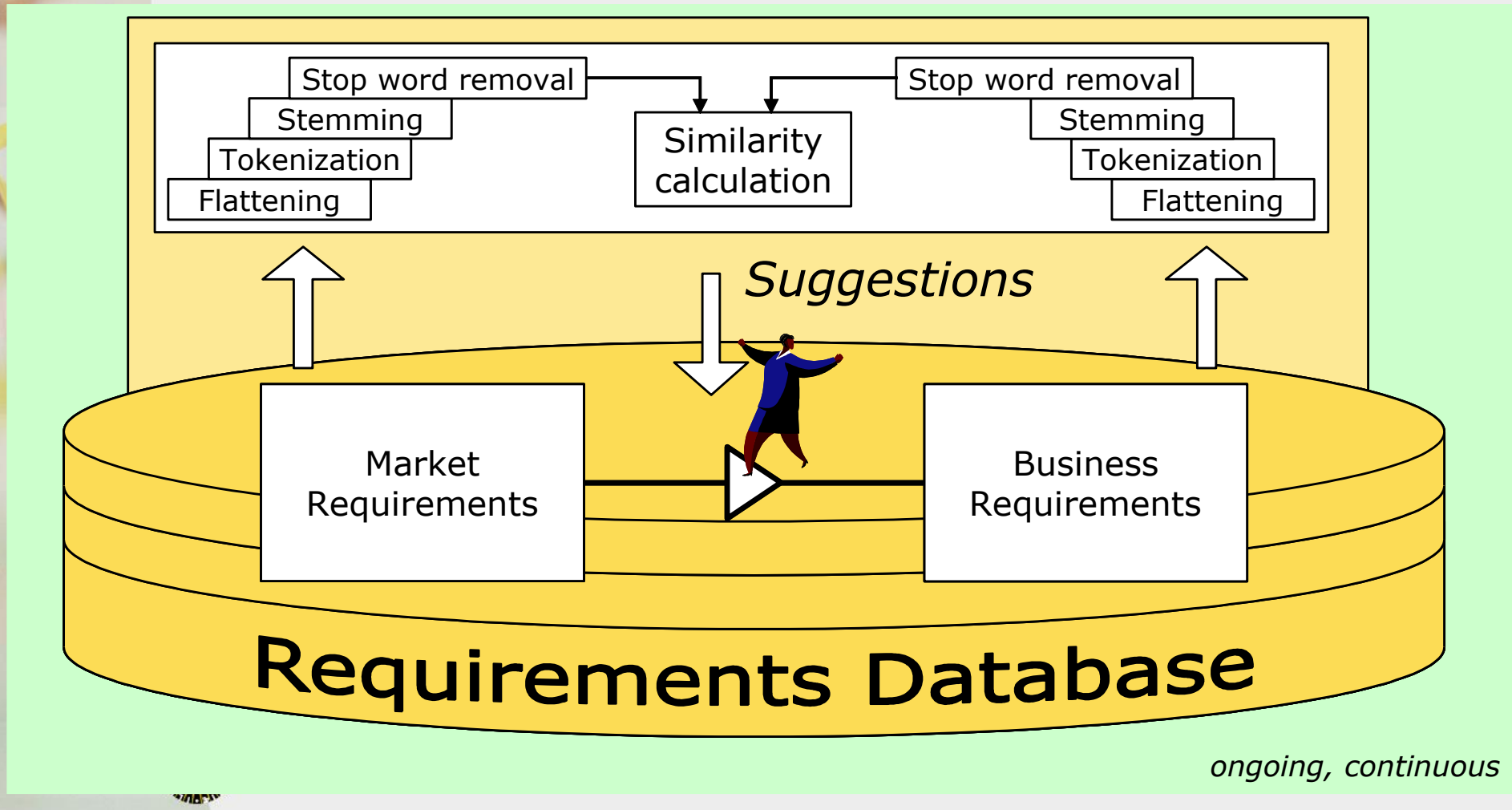
Approach – step 2: design



Tactics: possible solutions

- Add more resources
  - Too costly!
- Reduce the amount of incoming requirements
  - Not a good idea for customer relationship!
- Let customers do the linking
  - Plans of new releases may not be shown externally!
- …

Idea: use linguistic techniques to find similar requirements



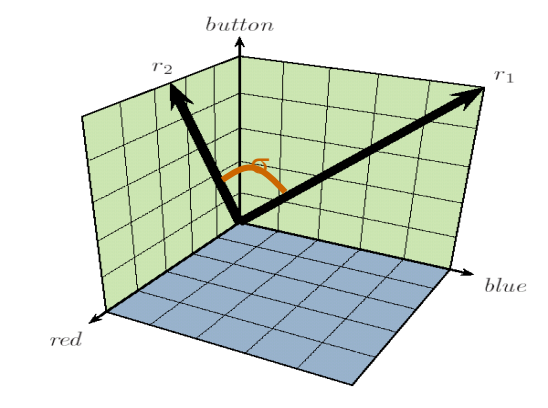
Linguistic Engineering approach

Flattening	Tokenization	Lemmatisation	Stop word removal
Storing multiple charts in one file.	storing multiple charts in one file	store multiple chart in one file	store multiple chart file

market requirement

business requirement

The user should be able to store charts in a single (.SOV) file	the user should be able to store several charts in a single sov file	the user should be able to store several chart in a single sov file	user store several chart sov file



$$\sigma(r_m, r_b) = \frac{\sum_i [1+\log_2 r_m(i)] \cdot [1+\log_2 r_b(i)]}{\sqrt{\sum_i 1+\log_2 r_m(i)} \cdot \sqrt{\sum_i 1+\log_2 r_b(i)}}$$

Suggestion list

MR10013		
Pos	**Requirement**	**Similarity**
1	BR10012	0.45
2	BR10156	0.43
3	BR10006	0.42
4	BR10536	0.38
5	BR10987	0.36
6	BR10273	0.36
7	BR10740	0.34
8	BR10419	0.33
9	BR10622	0.24
10	BR10082	

Design issue:
What is the optimal top list size?

MR10013		
Pos	**Requirement**	**Similarity**
1	BR10012	0.45
2	BR10156	0.43
3	BR10006	0.42
9	BR10622	0.24
10	[illegible]	[illegible]

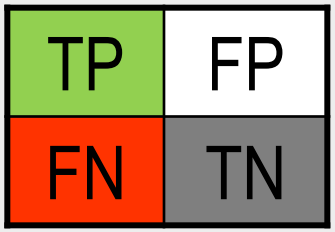
Suppose we restrict the suggestions to the top list

-*How many candidate requirements are in the top list?*

-*How many candidate requirements are missed?*

-*How long is an optimal top list?*

Theory testing in text retrieval: Found and correct? – Confusion matrix



TP: True Positives	Found and correct
FP: False Positives	Found but incorrect
FN: False Negatives	Not found but correct
TN: True Negatives	Not found and incorrect

Recall = Found correct / All Correct = TP / (TP + FN)

Manual related to automated

MR10013		
Pos	Requirement	Similarity
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2	BR10156	0.43
3	BR10006	0.42
4	BR10536	0.38
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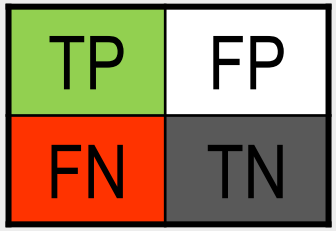

Manually linked and presumed correct

Recall related to top list size

MR10013		
Pos	Requirement	Similarity
1	BR10012	0.45
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8	BR10419	0.33
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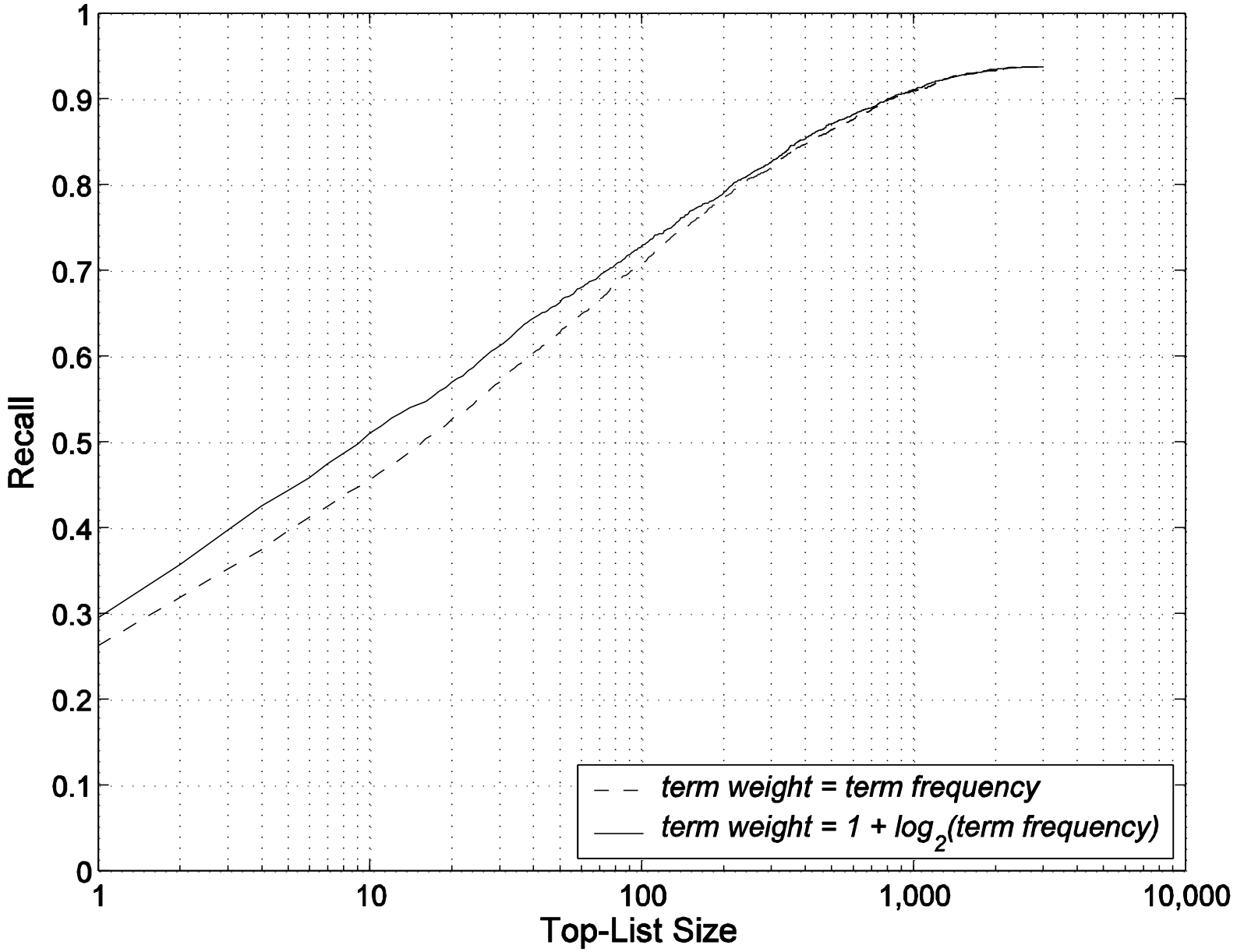
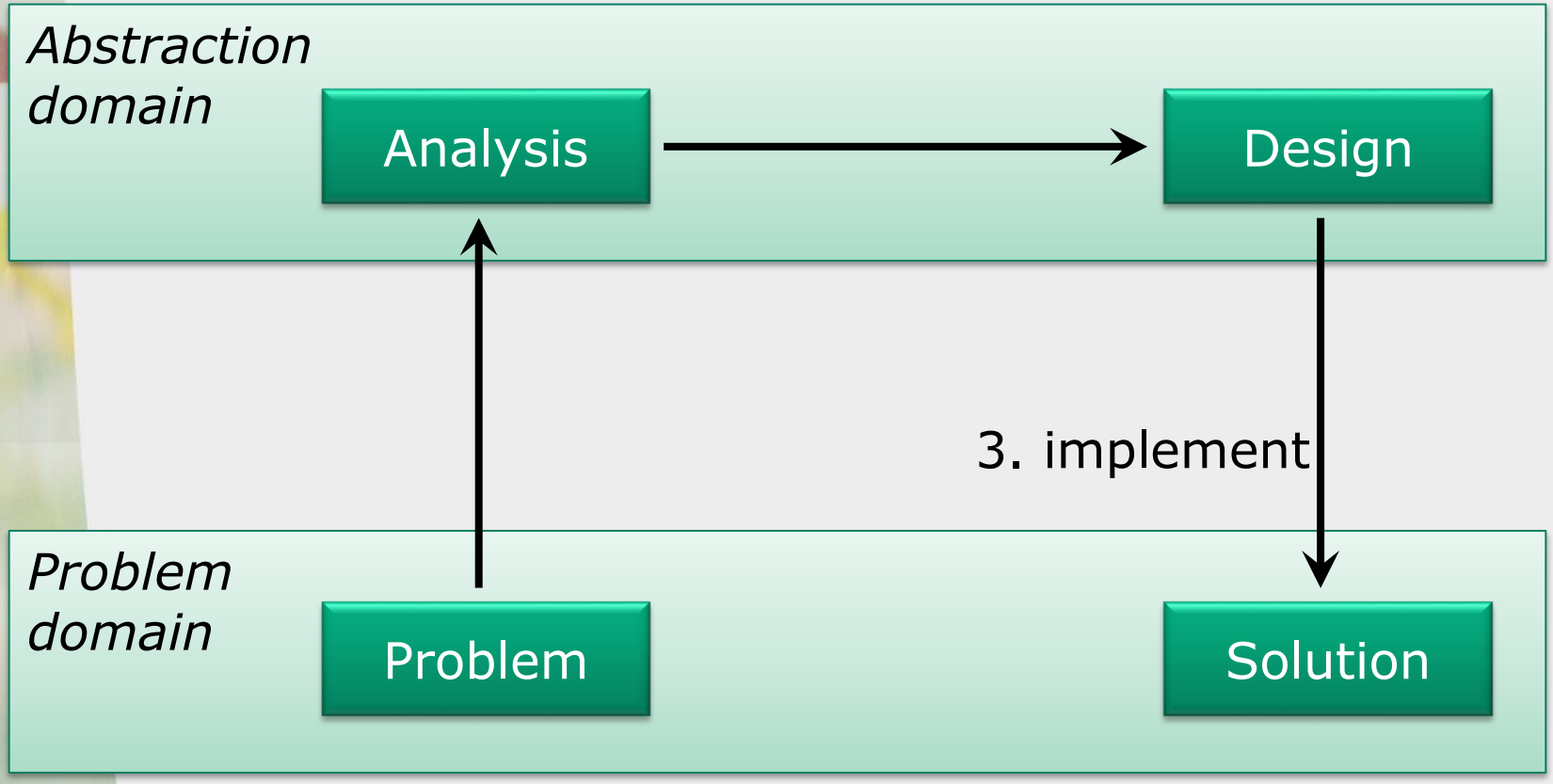
Recall(**7**) =

= 2 / 3 =

= **67%**


Recall
Top-List Size
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
1
10
100
1,000
10,000
term weight = term frequency
term weight = 1 + log2(term frequency)

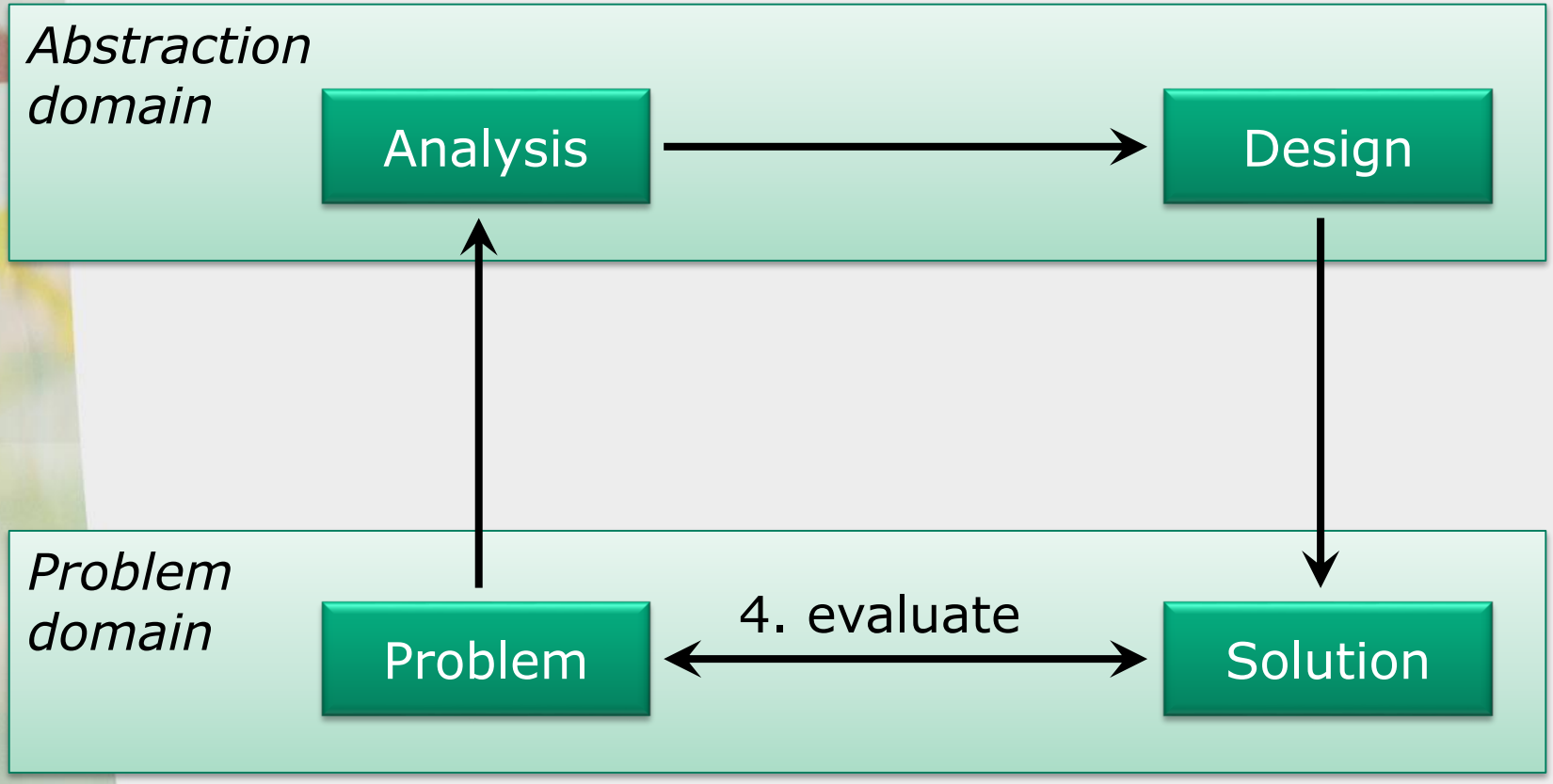
Approach – step 3: implement



Implementation

- Linguistic functionality was coded and inserted into the Baan RDB
- A pilot was run first to check whether extension was according quality standards
- Product managers were trained to use the functionality

Approach – step 4: evaluate



A comparative cost-benefit evaluation

Subset providing 100% recall using a top-10 list	
BRs	**690**
The MRs linked by product managers	**1,249**

Manual search ▪ **Assume 1 search term is enough**	**~30 hits**
Automatically supported	**10 hits**

Savings:
~66%
or
~115 hours

Potential next steps

- Aggregate similarity measures using other techniques
- Reuse information in already linked requirements
- Incorporate semantics from names of software modules
- Expert validation in concept similarities

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Conclusion

- Theory building or theory testing is an overlooked issue in PhD project design
- Most RE research work is theory building, where the design is the theory
- Design science research requires a variety of research methods for validating the design

- In 2014 the discussed paper (Dag, J. N., Regnell, B., Gervasi, V., & Brinkkemper, S. (2005). A linguistic-engineering approach to large-scale requirements management. Software, IEEE, 22(1), 32-39.) was awarded the Most influential Paper award of the Requirements Engineering Conference community

Discussion