

TRANSLATING QUALITATIVE REQUIREMENTS INTO DESIGN CHOICES

EVALUATING THE METHOD PROPOSED IN THE ARCHITECTURAL
REFERENCE MODEL FOR THE INTERNET OF THINGS



SIEMENS

AGENDA



Translating Qualitative Requirements into Design Choices

1. Qualitative Requirements in System Development
2. IoT-ARM Method
3. Research Question and Approach for Research
4. Conceptual Evaluation
5. Empirical Evaluation
6. Modified IoT-ARM Method
7. Conclusion and Outlook

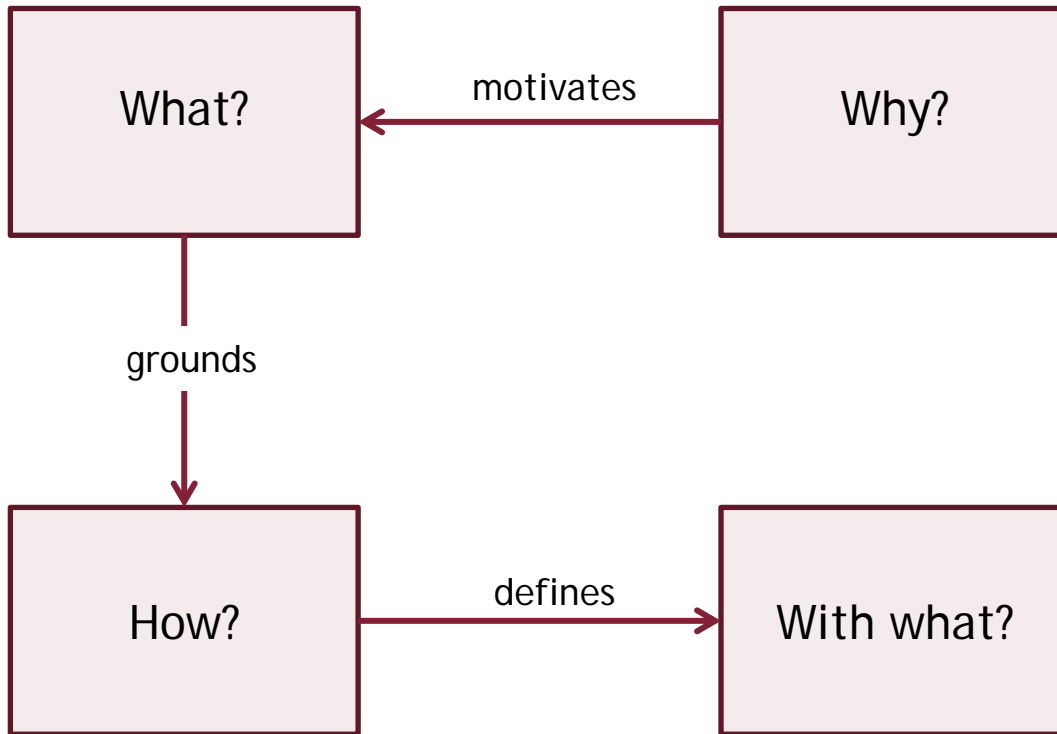
AGENDA



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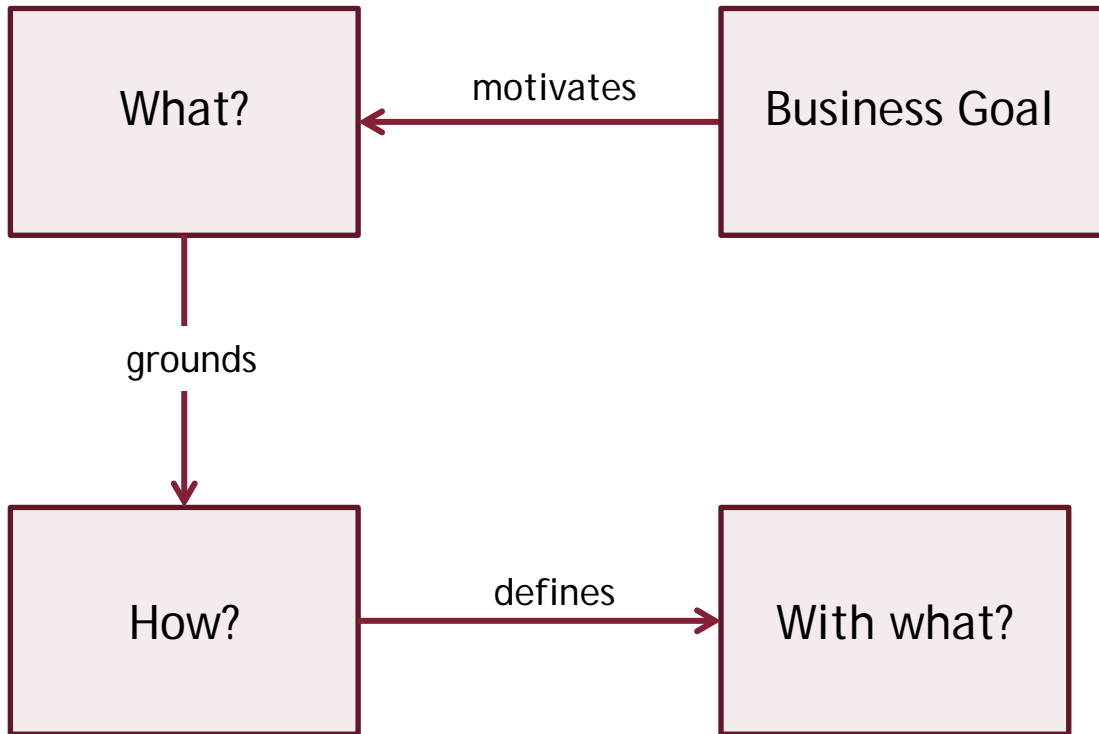
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SYSTEM DEVELOPMENT



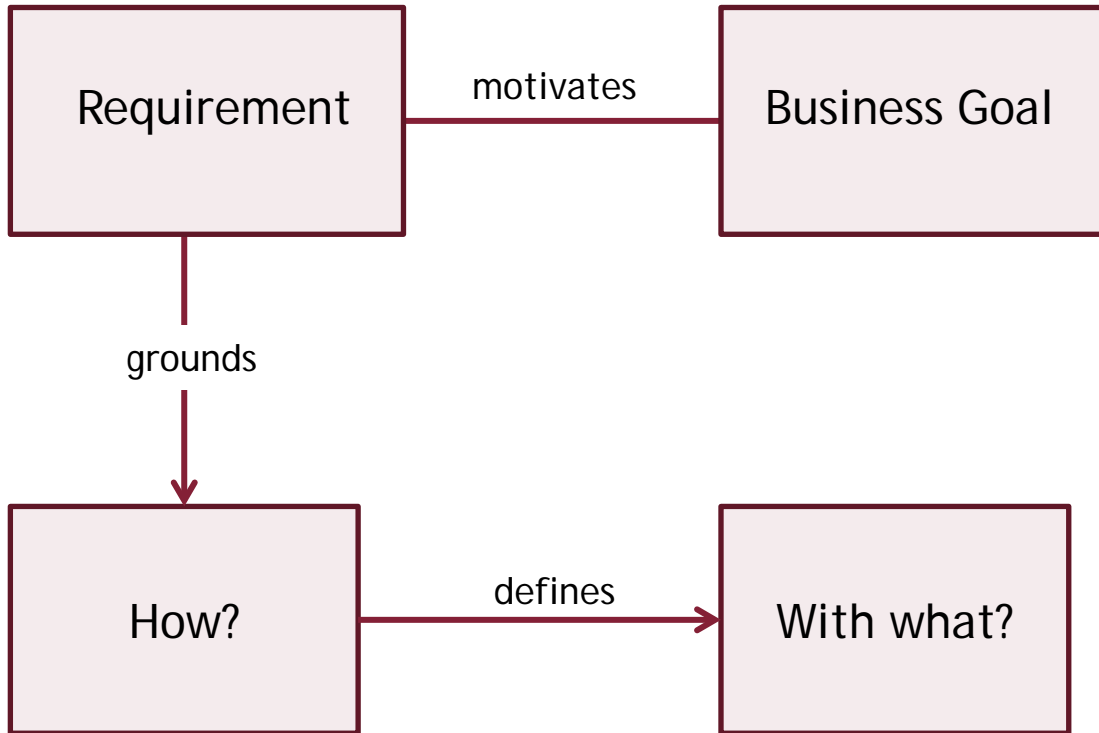
Adapted from vant'Wout al. (2010), Rozanski and Woods (2012)

SYSTEM DEVELOPMENT



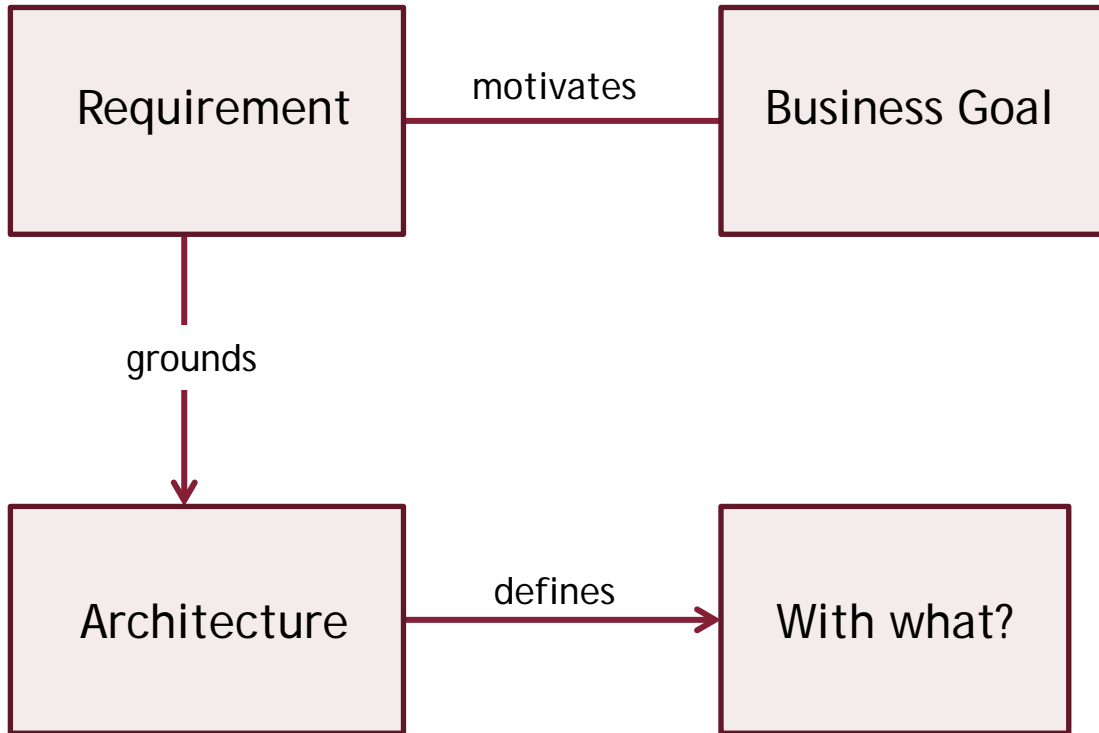
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SYSTEM DEVELOPMENT



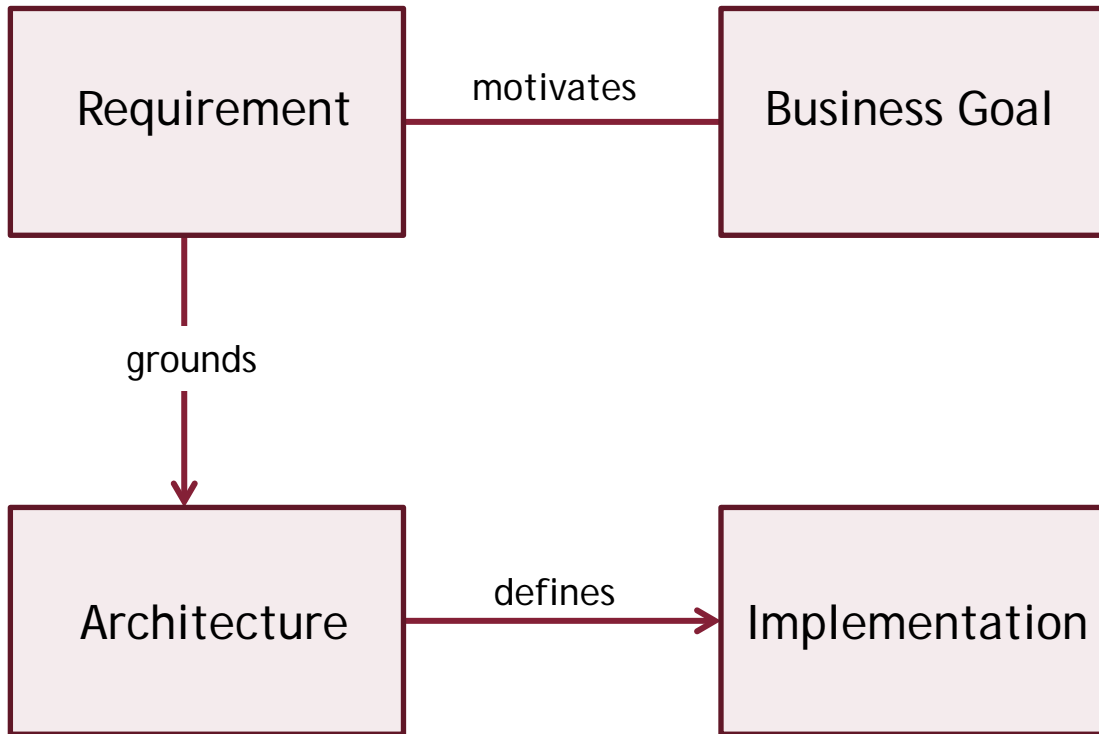
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SYSTEM DEVELOPMENT



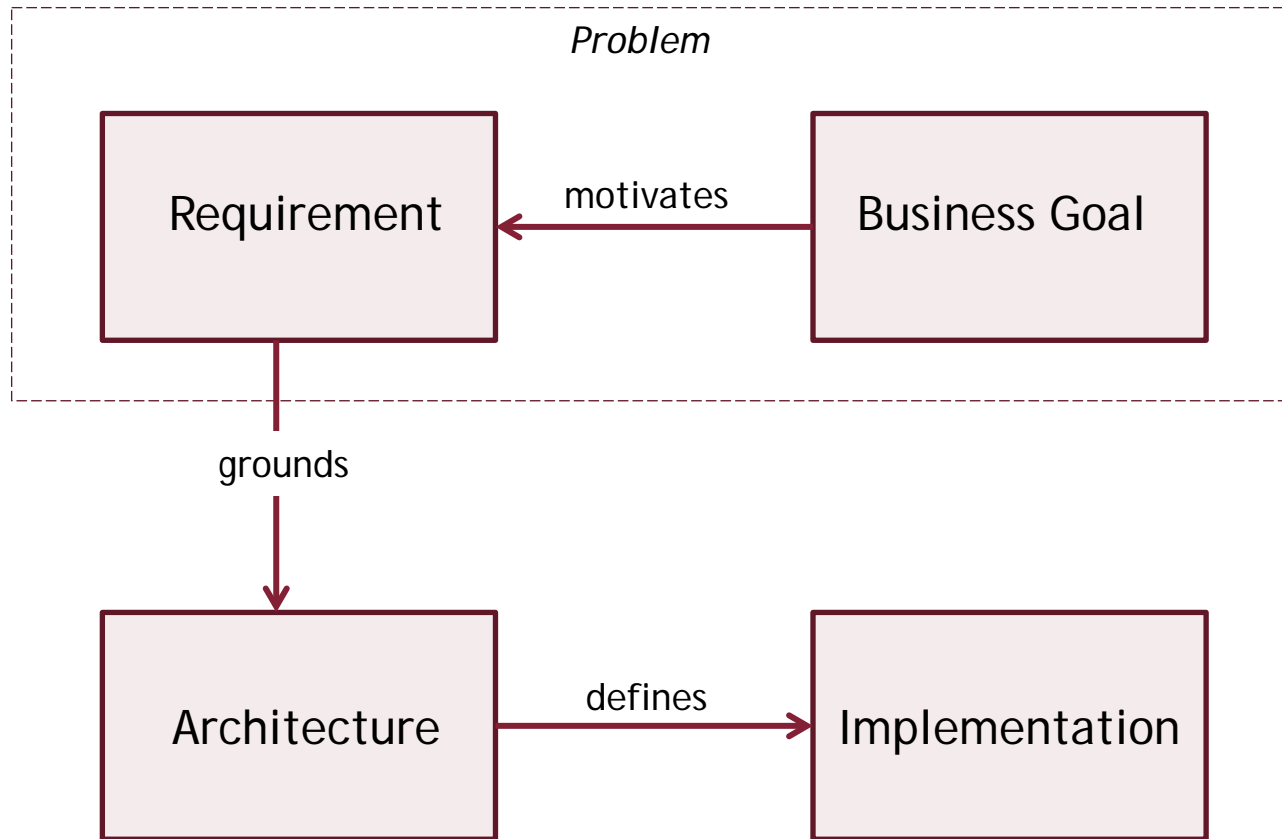
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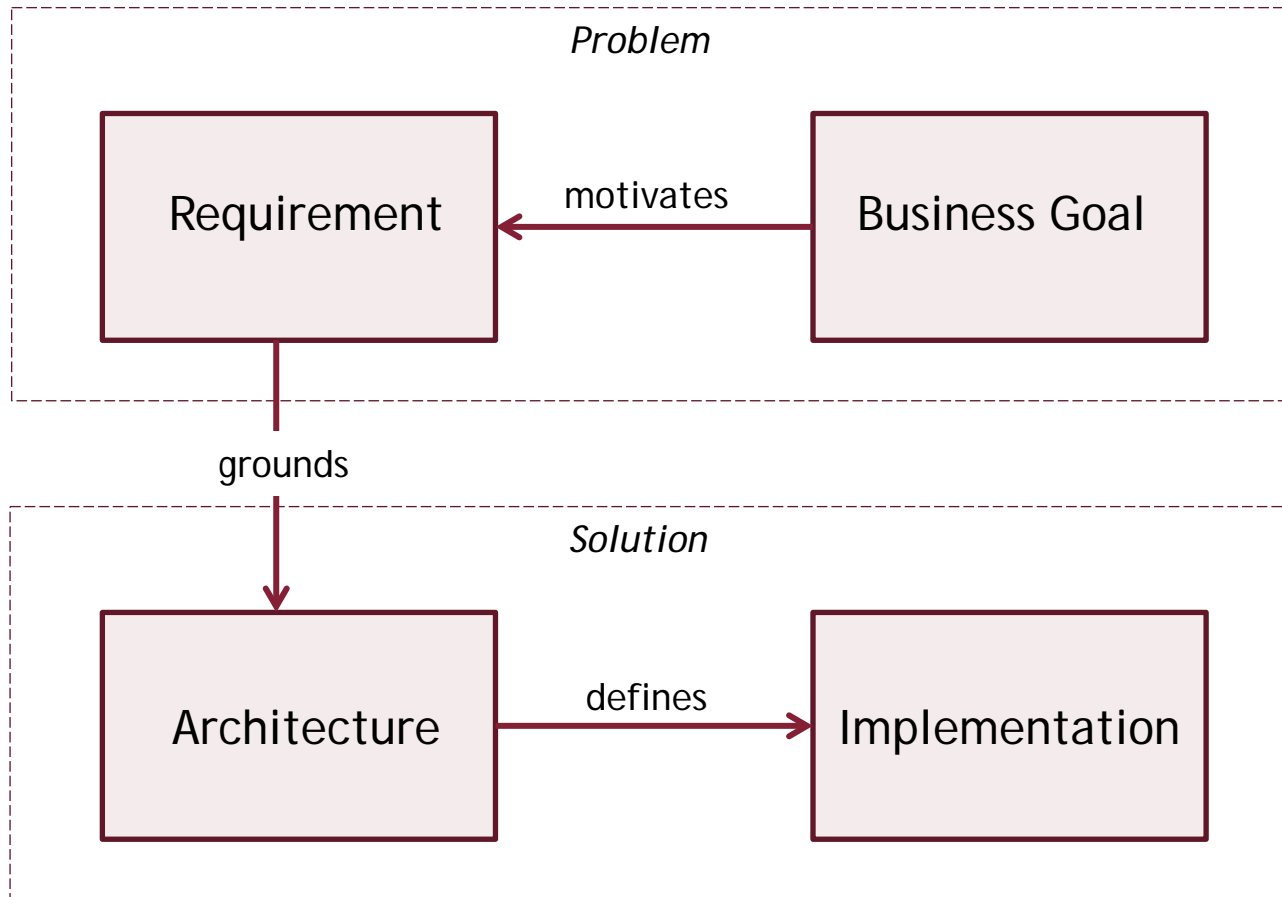
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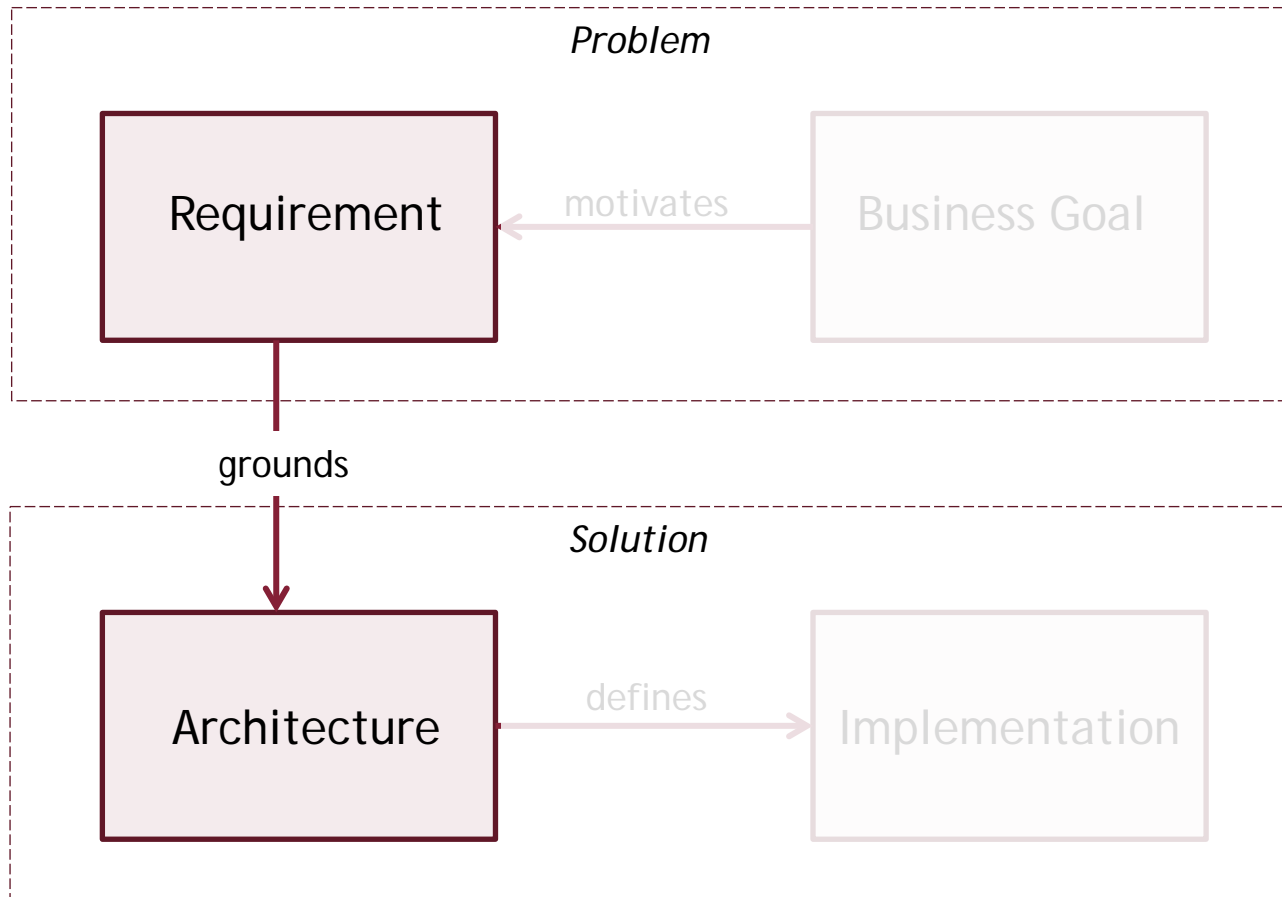
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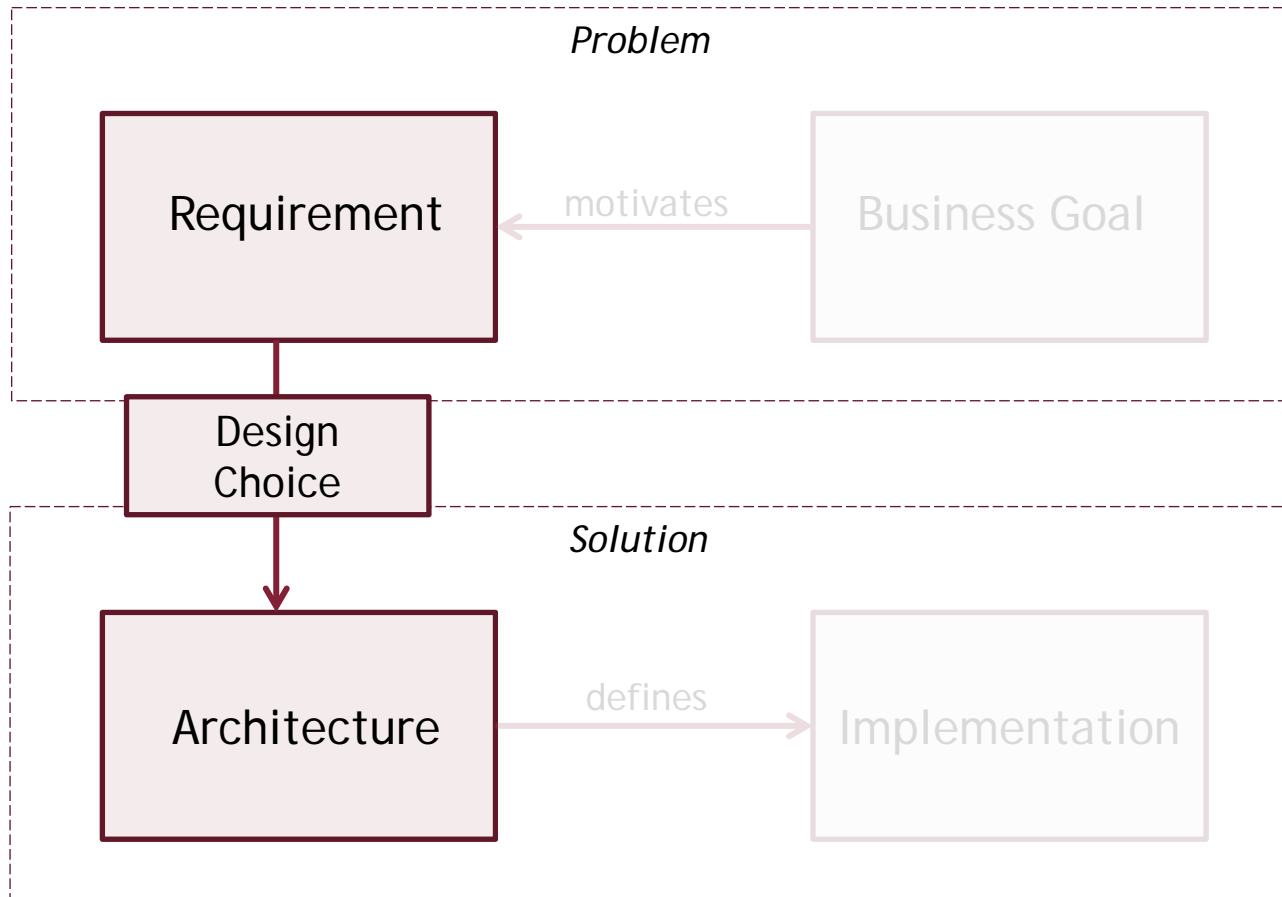
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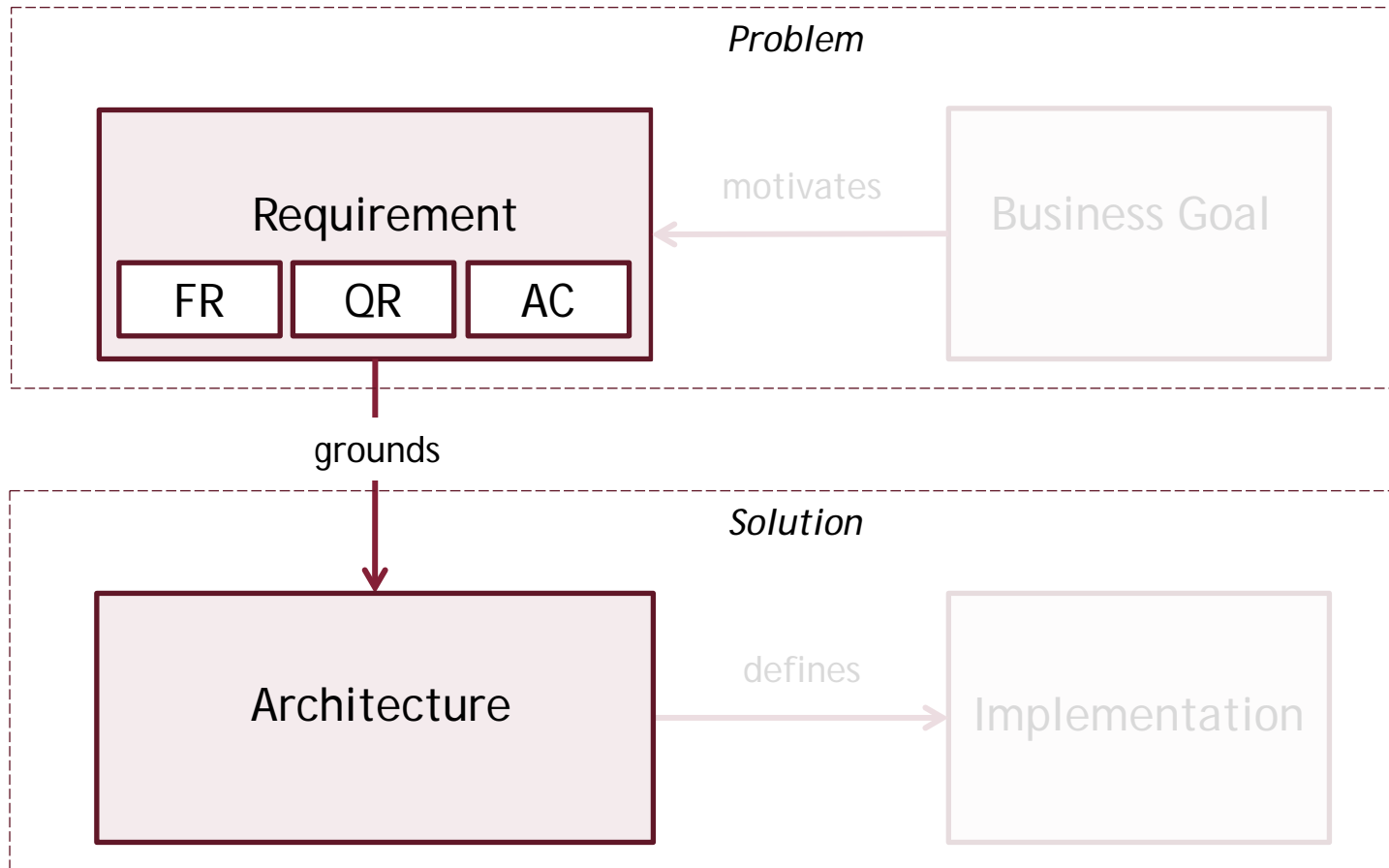
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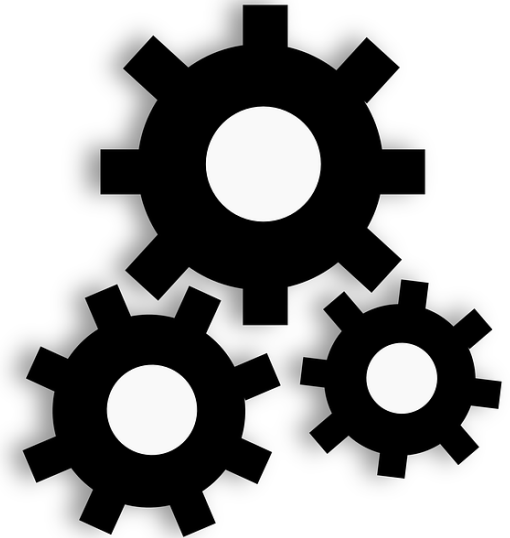
FR - Functional Requirement, QR - Qualitative Requirement, AC - Architectural Constraint

FUNCTIONAL REQUIREMENTS



- **What** system shall do
- **Actions** that makes the product **useful** to operator

The smart home system shall detect inefficient appliances to save energy



ARCHITECTURAL CONSTRAINTS



- **Limitations** to the product introduced by existing infrastructure
- **Prior** design choices

IPv4 shall be used for communication between system components



QUALITATIVE REQUIREMENTS



- Known as **Non-Functional Requirements**
- **How** system as entirety shall **behave**
- **Global traits** of the system or its components

The smart home system shall enforce security

The smart home system shall be maintainable

The smart home system shall provide high usability and a pleasing user experience



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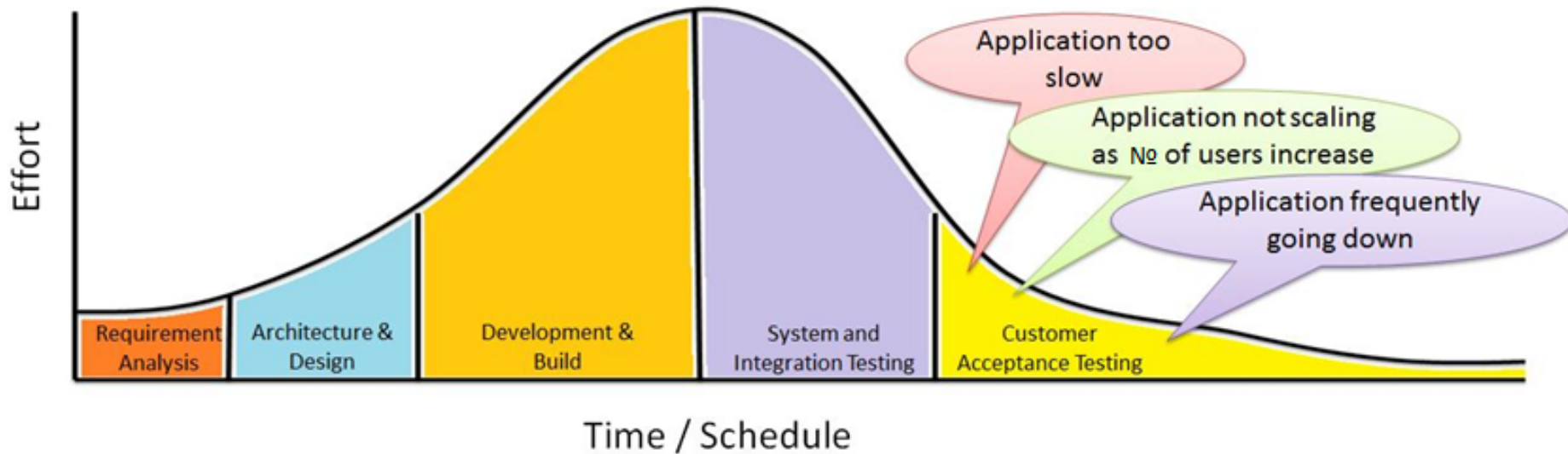


QUALITATIVE REQUIREMENTS



- Affect product acceptance

Software Development Life Cycle

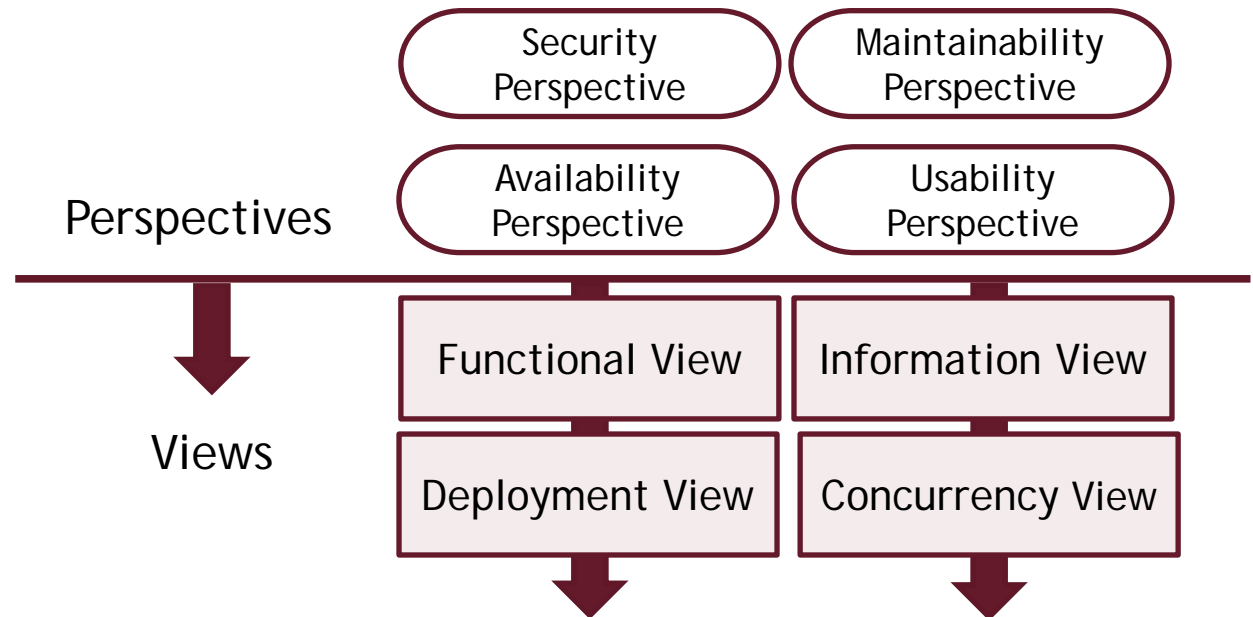


Gupta (2011)

QUALITATIVE REQUIREMENTS



- Affect product acceptance
- Global to the system

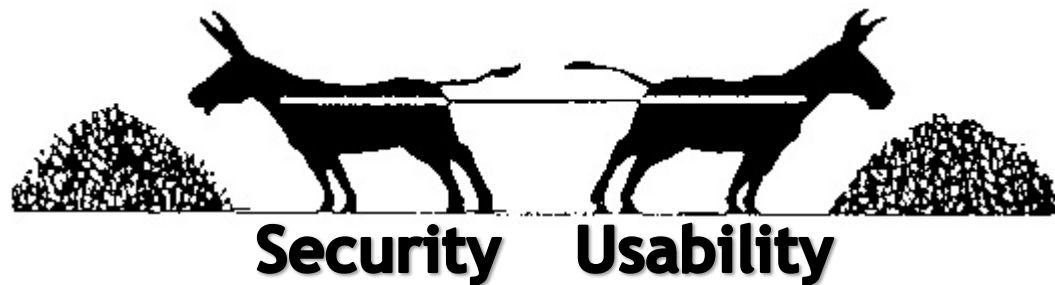


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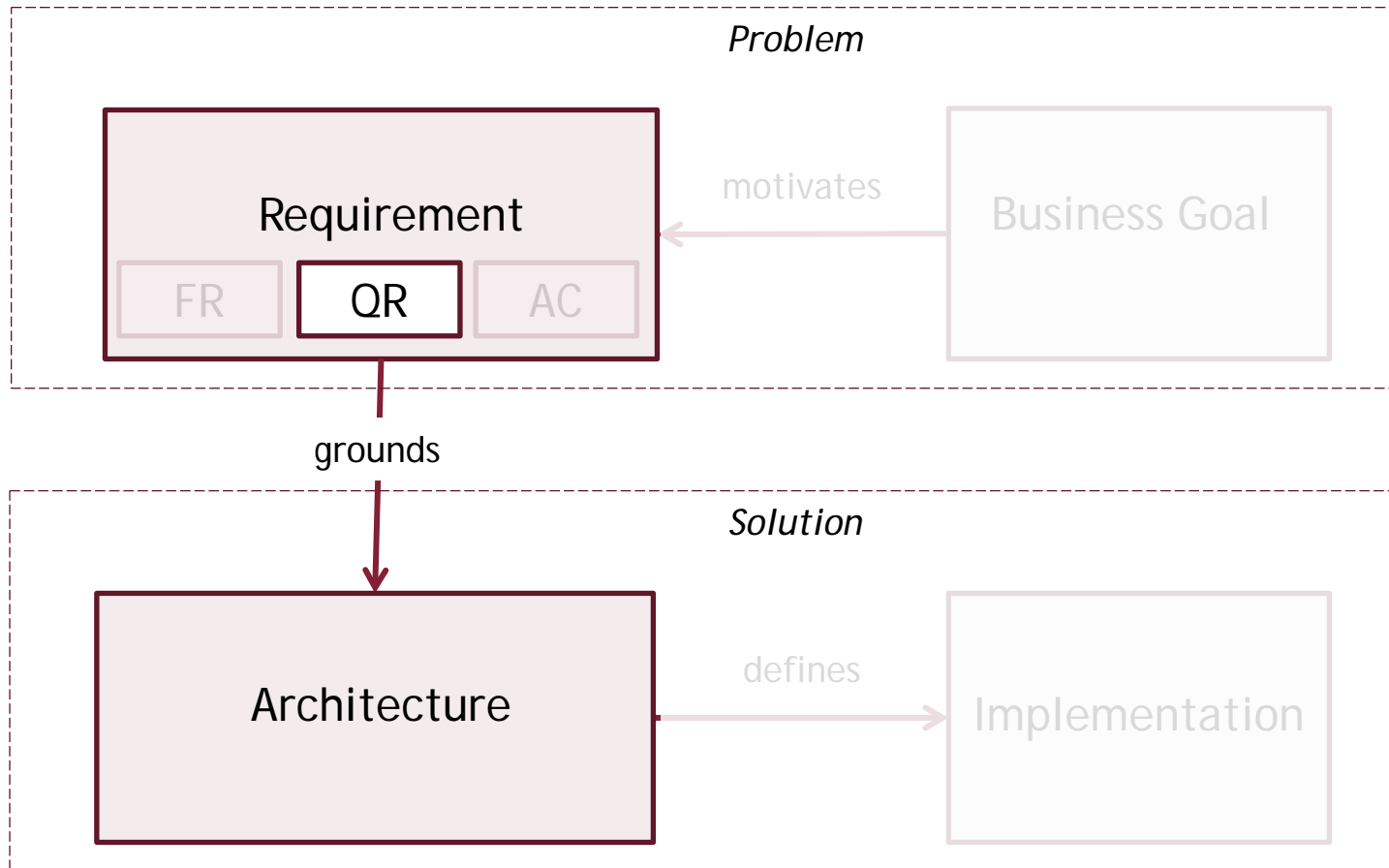
QUALITATIVE REQUIREMENTS



- Affect product acceptance
- Global to the system
- Conflicting



SYSTEM DEVELOPMENT



FR - Functional Requirement, QR - Qualitative Requirement, AC - Architectural Constraint

AGENDA



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ARCHITECTURE REFERENCE MODEL FOR THE INTERNET OF THINGS (IOT-ARM)

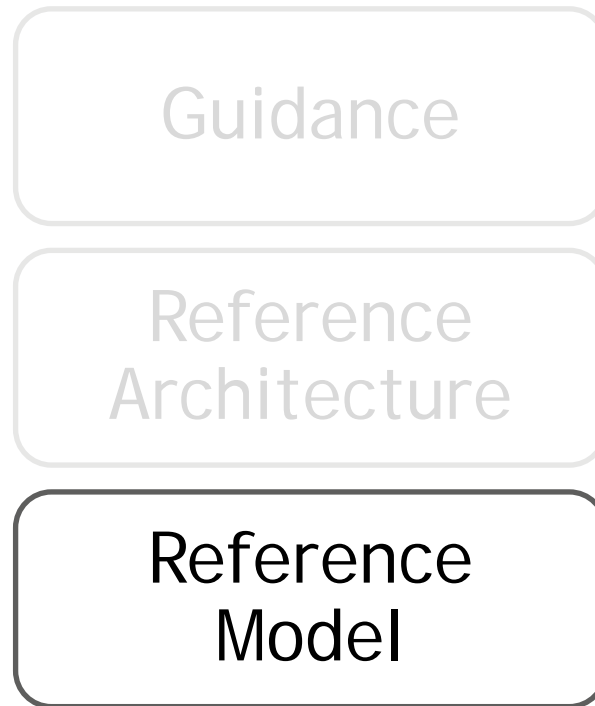


Guidance

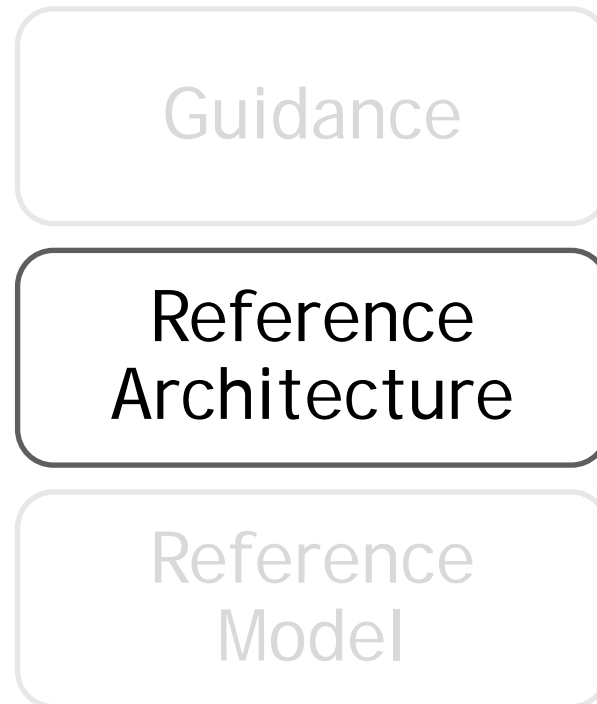
Reference
Architecture

Reference
Model

ARCHITECTURE REFERENCE MODEL FOR THE INTERNET OF THINGS (IOT-ARM)



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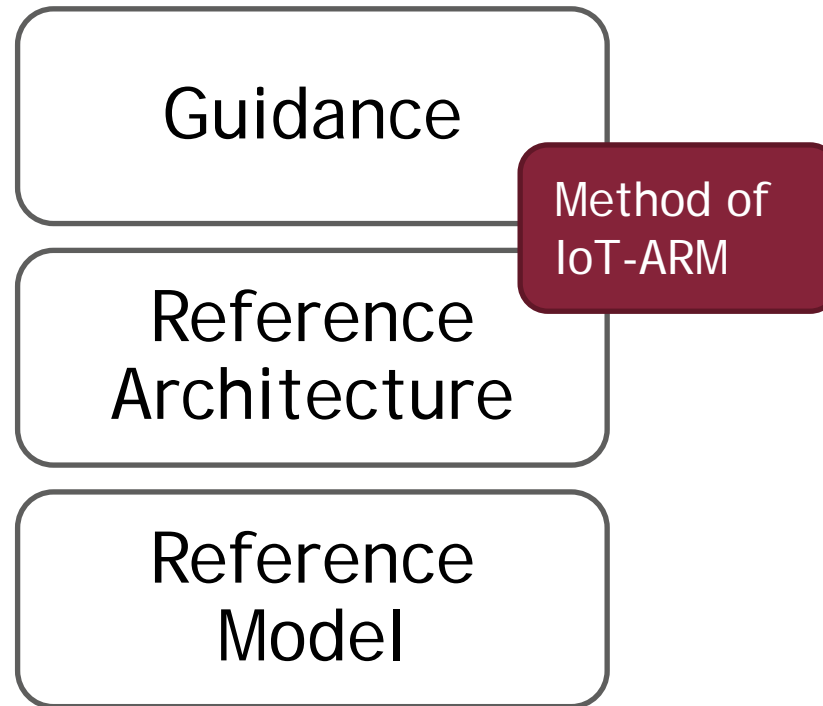


Guidance

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ARCHITECTURE REFERENCE MODEL FOR THE INTERNET OF THINGS (IOT-ARM)



METHOD OF IOT-ARM



FR - Functional Requirement, QR - Qualitative Requirement, AC - Architectural Constraint

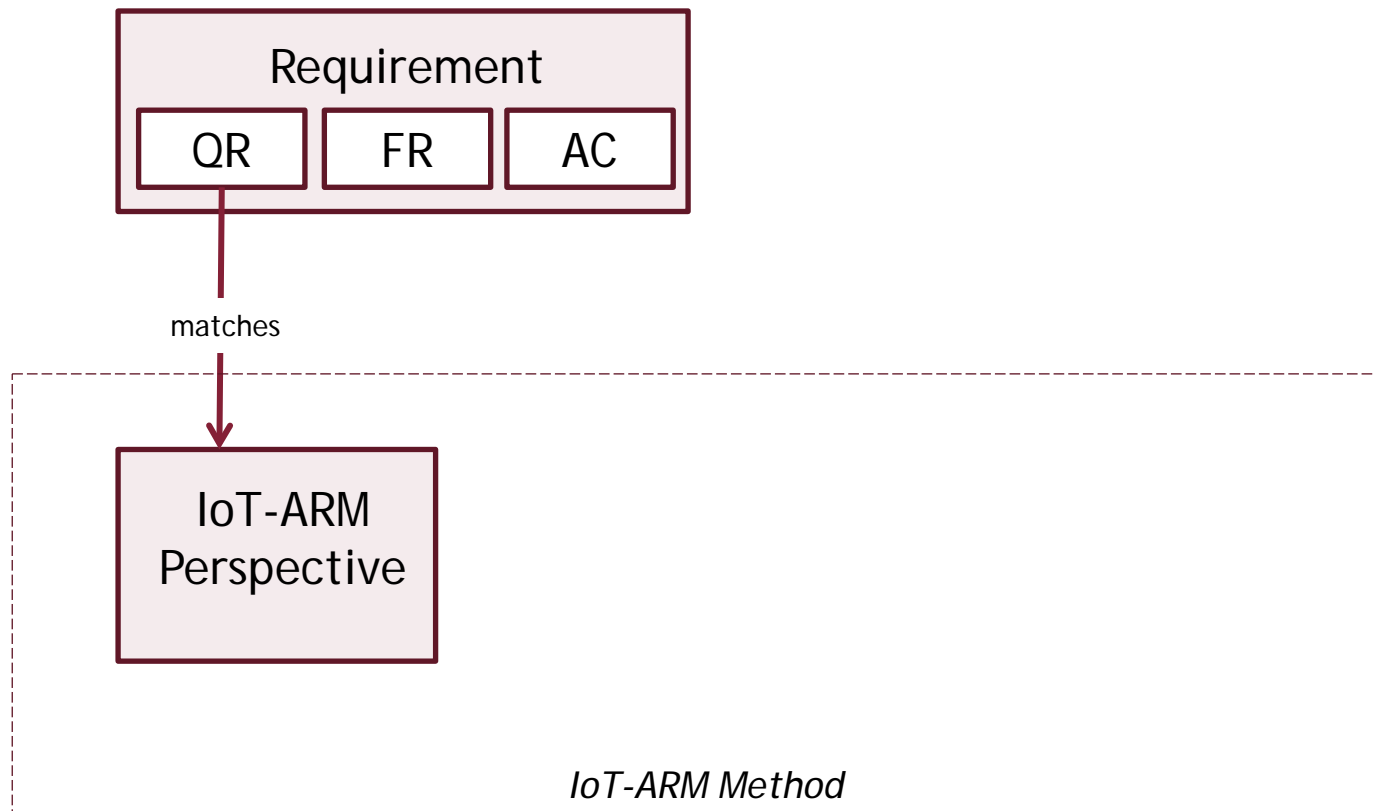
QUALITATIVE REQUIREMENT



The smart home system shall enforce security



METHOD OF IOT-ARM



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CATALOGUE OF PERSPECTIVES



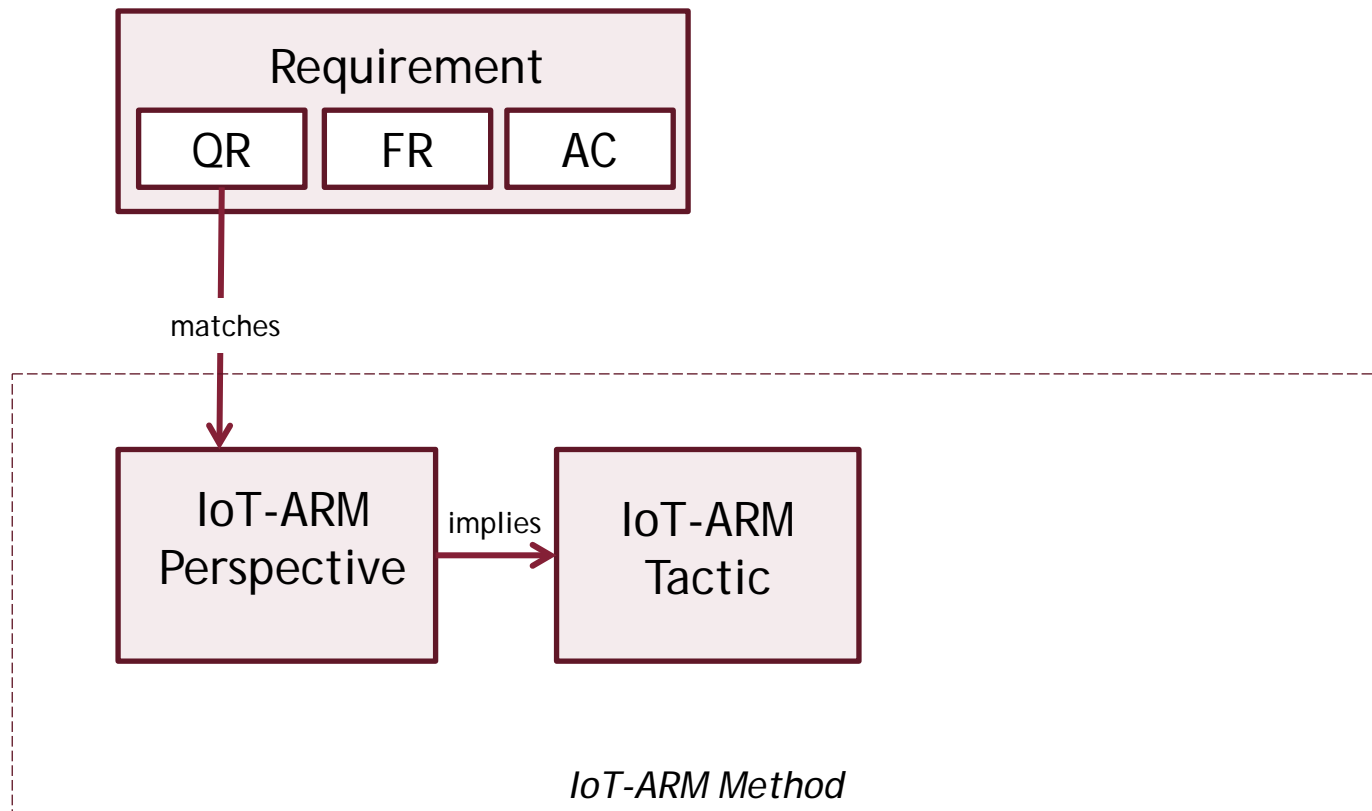
- Evolution and Interoperability
- Availability and Resilience
- Trust
- Security
- Privacy
- Performance and Scalability

CATALOGUE OF PERSPECTIVES



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METHOD OF IOT-ARM



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PERSPECTIVE OF SECURITY

TACTICS CATALOGUE



- Subject authentication
- Use access policies
- Secure communication infrastructure
- Secure peripheral networks (link layer security, secure routing)

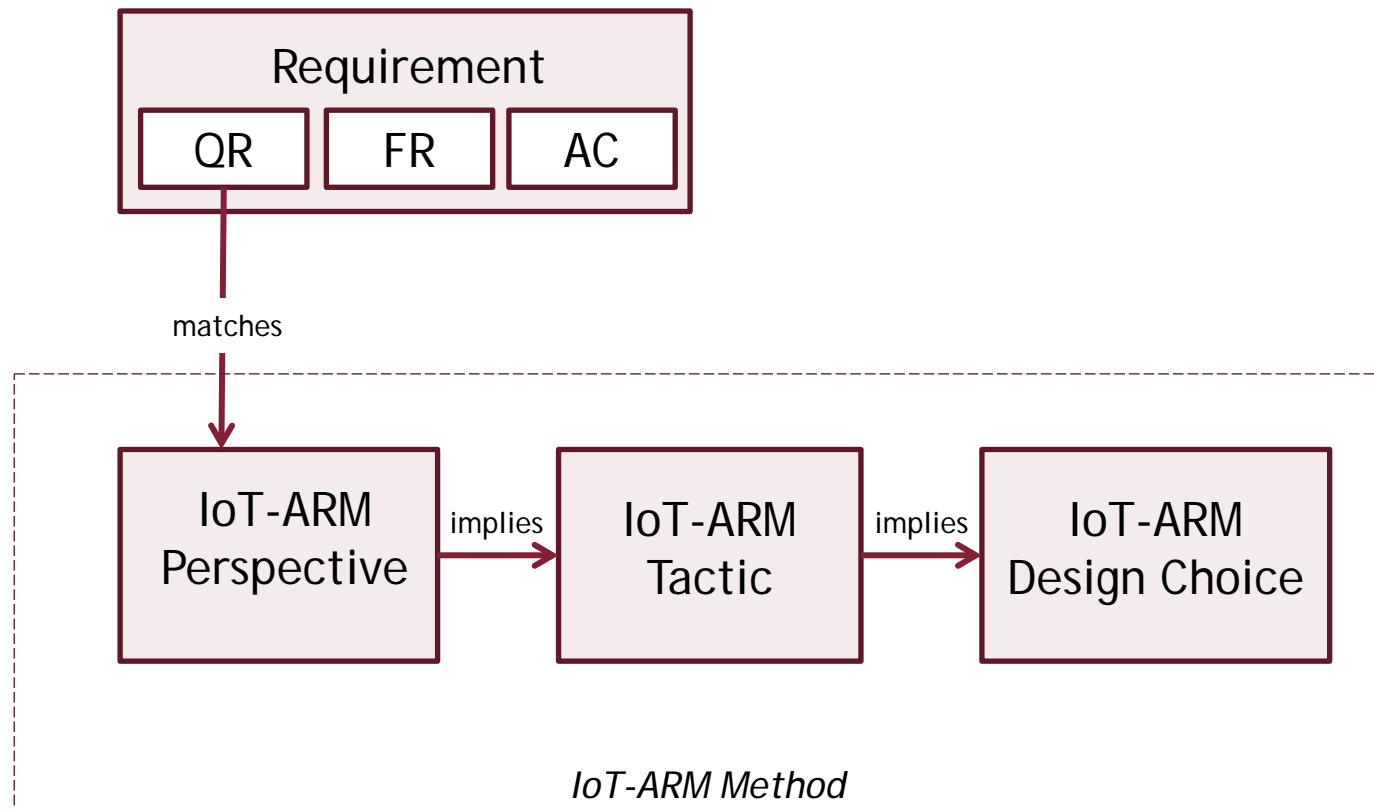
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PERSPECTIVE OF SECURITY

DESIGN CHOICES CATALOGUE



Tactic	Functional View	Information View	Deployment View
Subject authentication	Authentication over encrypted channel	No impact	Integration of authentication functional component Communication over secure channel
	Crypto-based authentication over open channel	No impact	Peer-to-peer authenticated communications over an insecure channel must be possible

Adapted from Carrez (2013)

PERSPECTIVE OF SECURITY

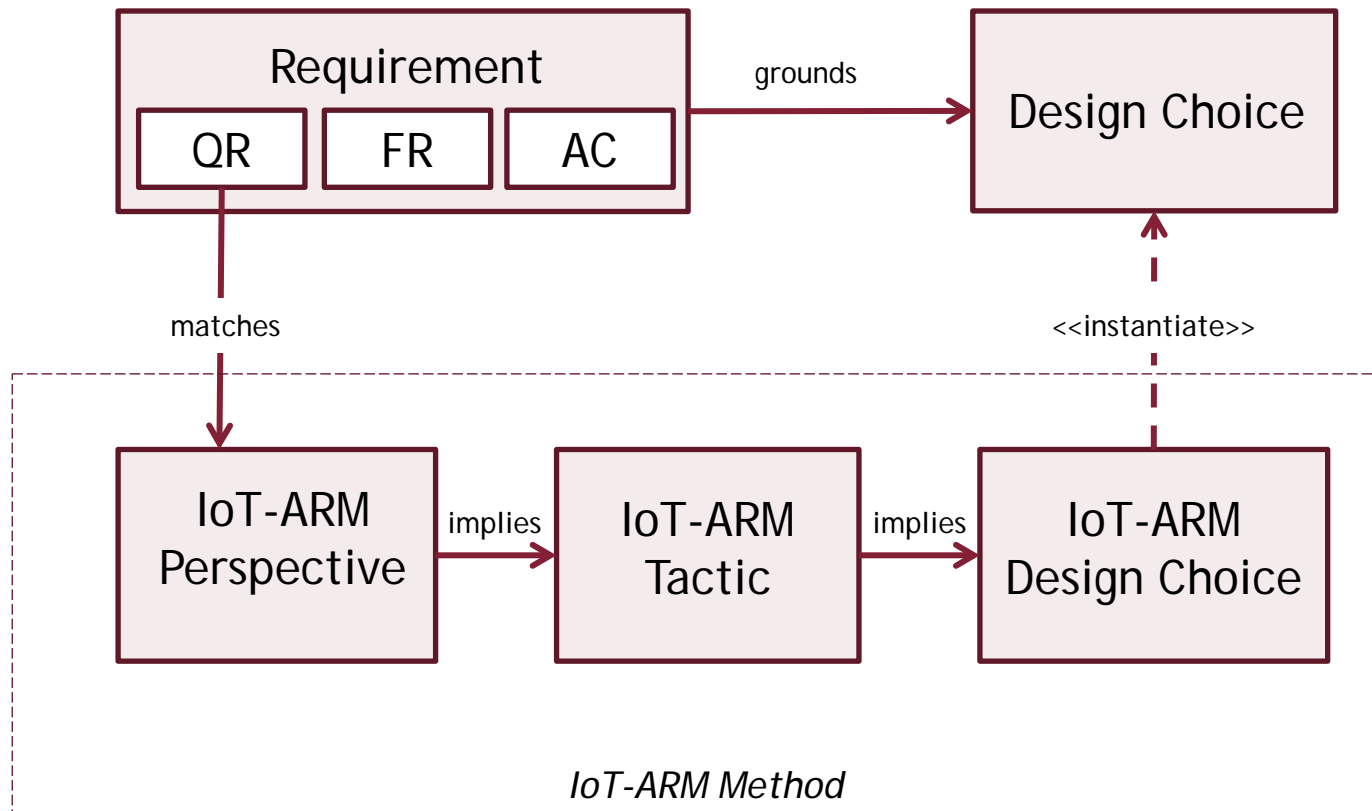
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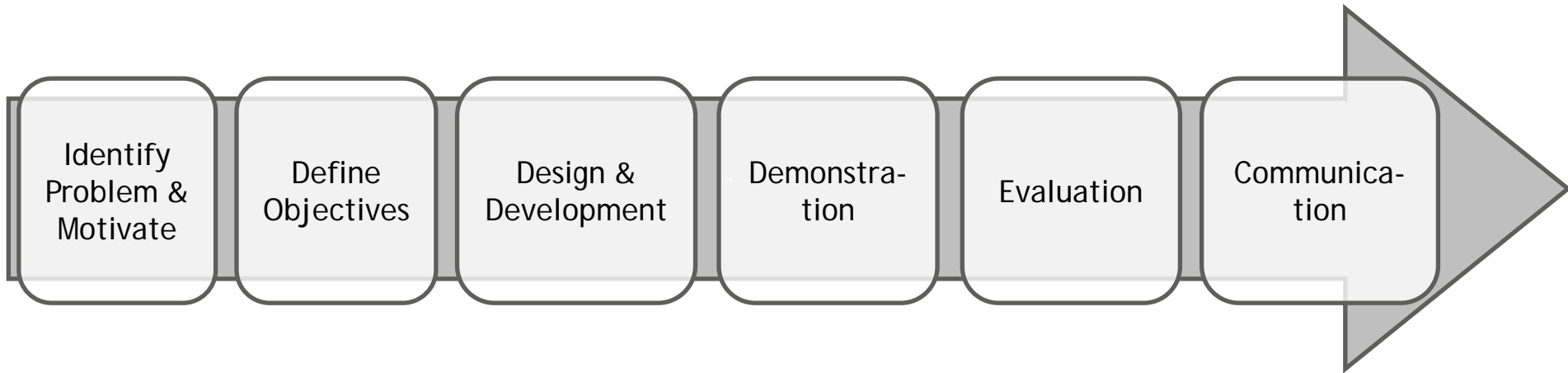
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DESIGN SCIENCE RESEARCH

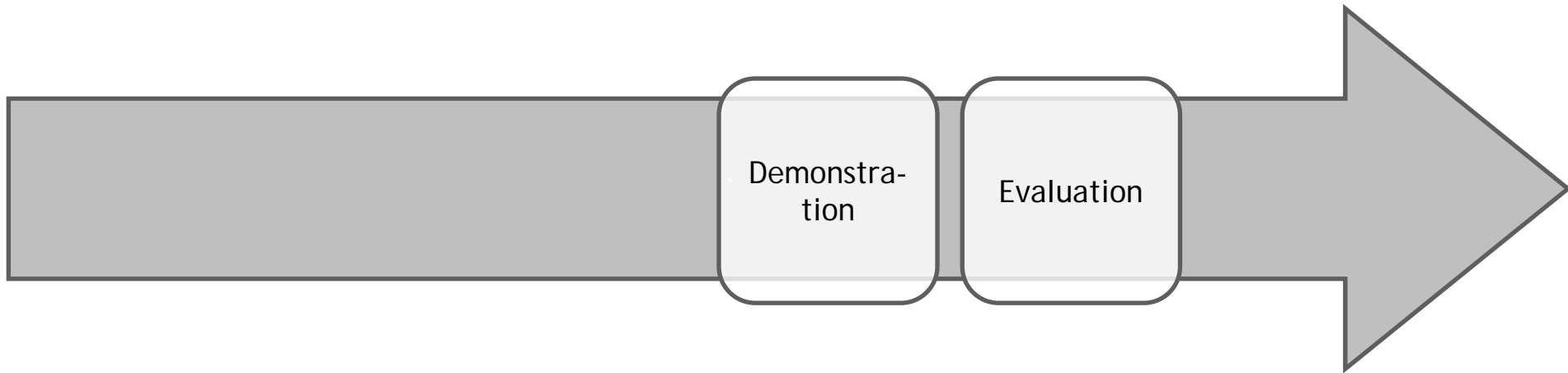


DESIGN SCIENCE RESEARCH



Adapted from Peffers et al. (2007)

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RESEARCH QUESTION



“What utility does the artifact provide?”

Hevener et al. (2004)

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In terms of research:

- Methodological completeness?

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In terms of application domain:

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Conceptual Evaluation

RESEARCH QUESTION



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Hevener et al. (2004)

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Conceptual Evaluation

In terms of application domain:

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Empirical Evaluation

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METHOD FOR CONCEPTUAL EVALUATION



Method collection

- Literature research
- Overview of connatural methods

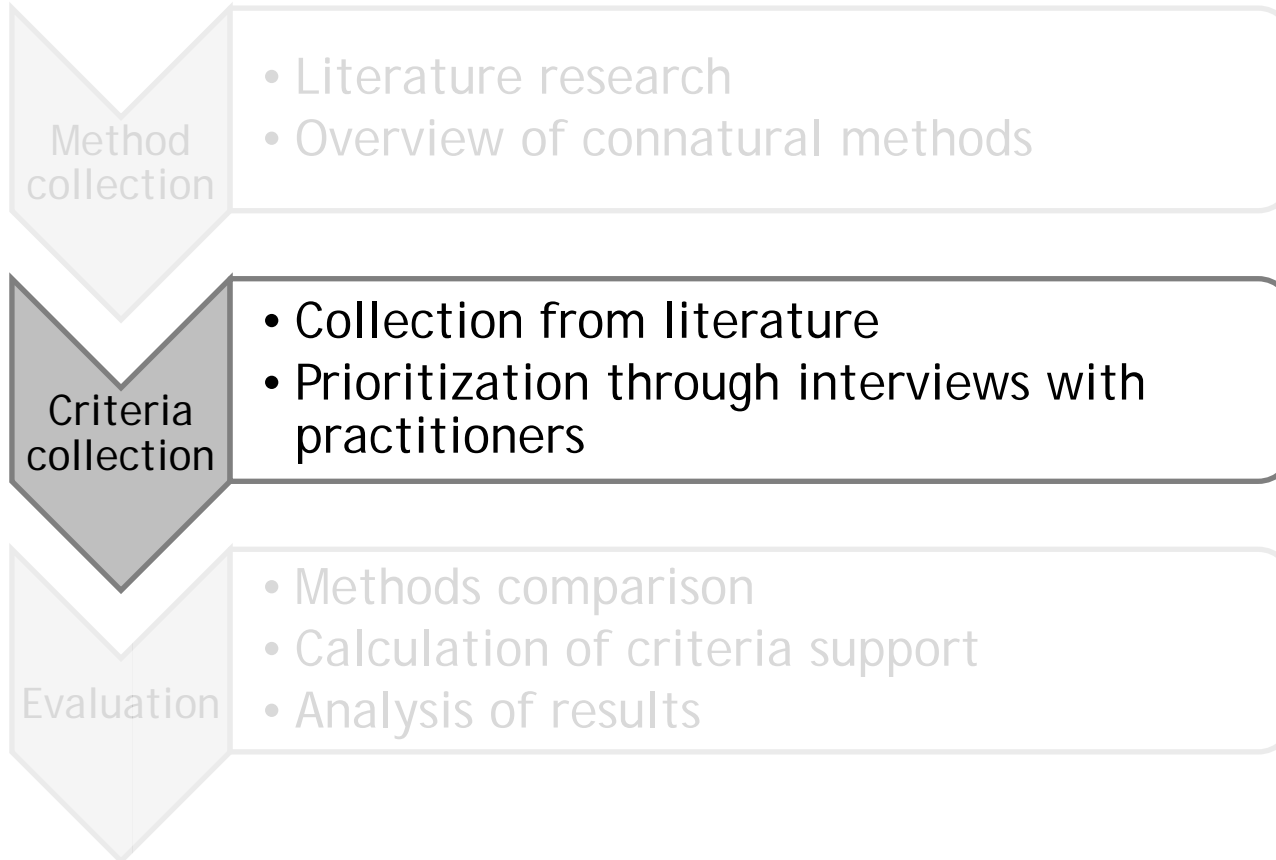
Criteria collection

- Collection from literature
- Prioritization through interviews with practitioners

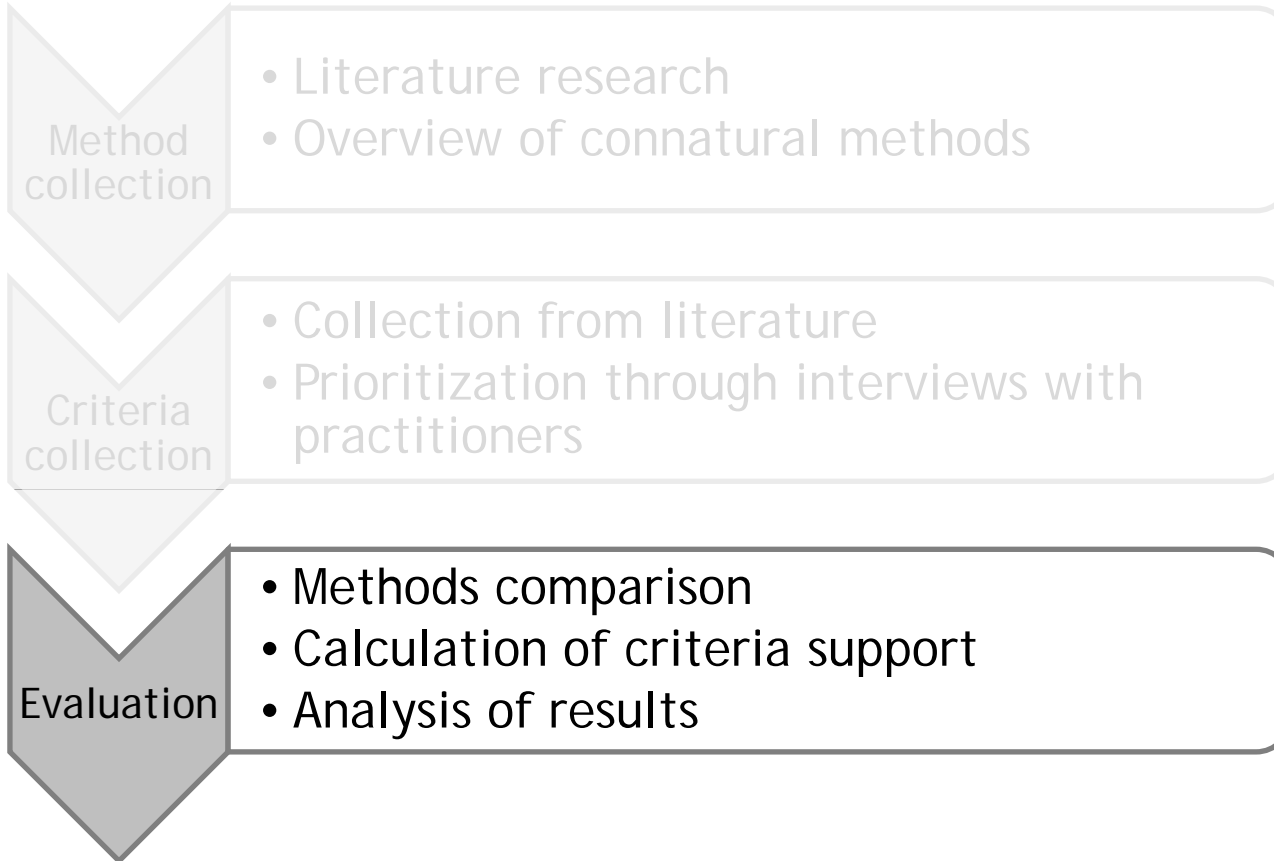
Evaluation

- Methods comparison
- Calculation of criteria support
- Analysis of results

METHOD FOR CONCEPTUAL EVALUATION



METHOD FOR CONCEPTUAL EVALUATION



CONCEPTUAL EVALUATION: IOT-ARM METHOD



RESULTS

- Three methods in total:
 - IoT-ARM Method (Carrez 2013)
 - Non-Functional Requirement Framework (Chung et al. 2000)
 - Attribute-Driven Development (Bass et al. 2003)

CONCEPTUAL EVALUATION

RESULTS

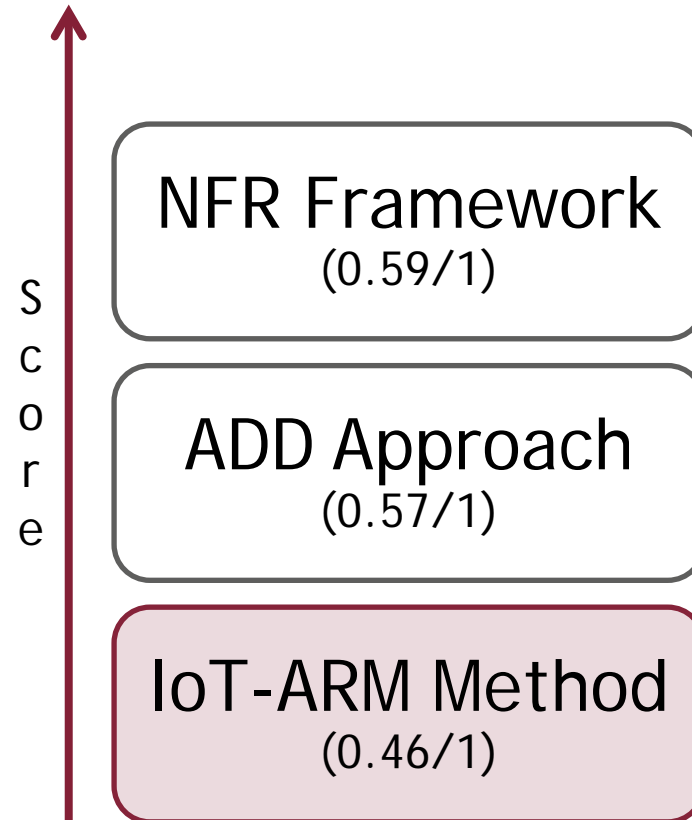


- Three methods in total:
 - IoT-ARM Method (Carrez 2013)
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- 19 criteria in four groups:
 - High-level properties
 - Method applicability
 - Requirements accountability
 - Usability

CONCEPTUAL EVALUATION

RESULTS



CONCEPTUAL EVALUATION

IDENTIFIED SHORTCOMINGS



- ✘ Notation
- ✘ Trade-off analysis
- ✘ Process support
- ✘ Method maturity
- ✘ Knowledge repository

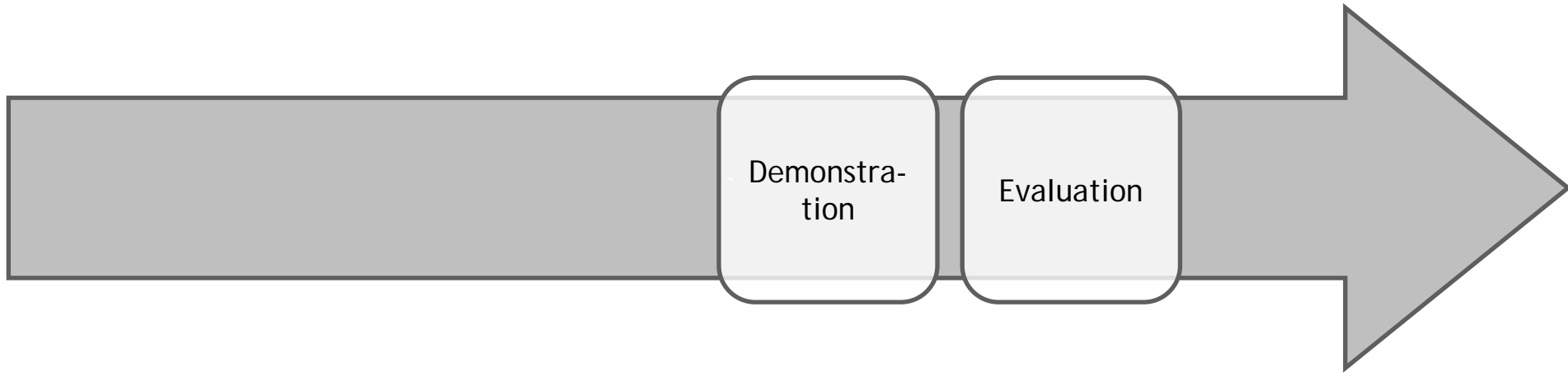
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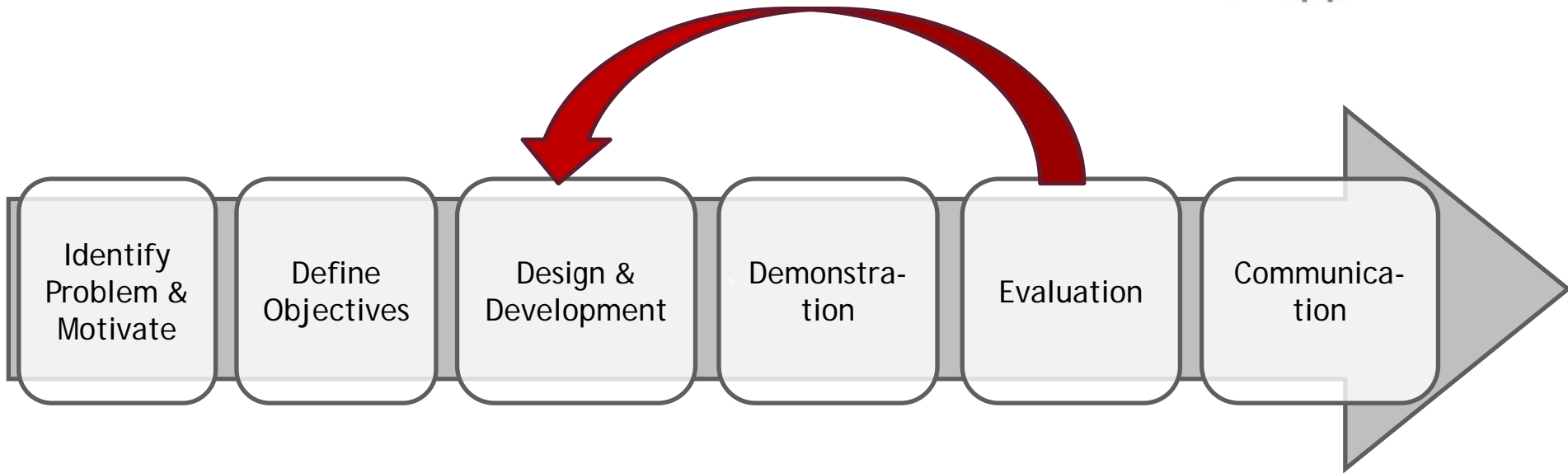
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EMPIRICAL EVALUATION



Adapted from Peffers et al. (2007)

EMPIRICAL EVALUATION



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FIND SUITABLE PROJECT



- Projects within Siemens
- European Research Cluster on the Internet of Things

Eleven IoT-related projects

PROJECTS ANALYSIS



- Incompleteness of perspectives, e.g.
 - > Maintainability
 - > Usability
 - > Regulation

PROJECTS ANALYSIS



- Incompleteness of perspectives, e.g.
 - > Maintainability
 - > Usability
 - > Regulation

- Low applicability

PROJECTS ANALYSIS



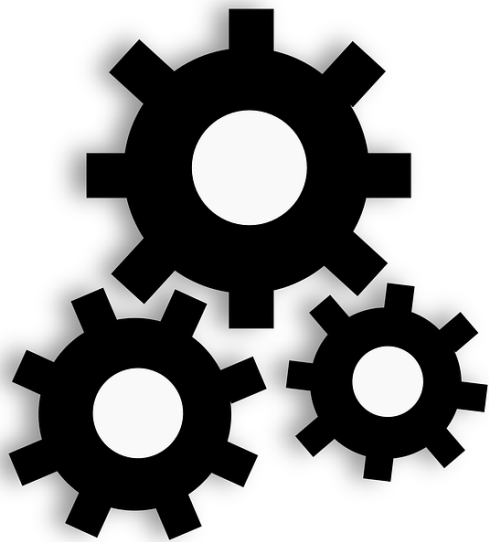
Qualitative requirements?

PROJECTS ANALYSIS



Qualitative requirements?

PROJECTS ANALYSIS



Functional requirements

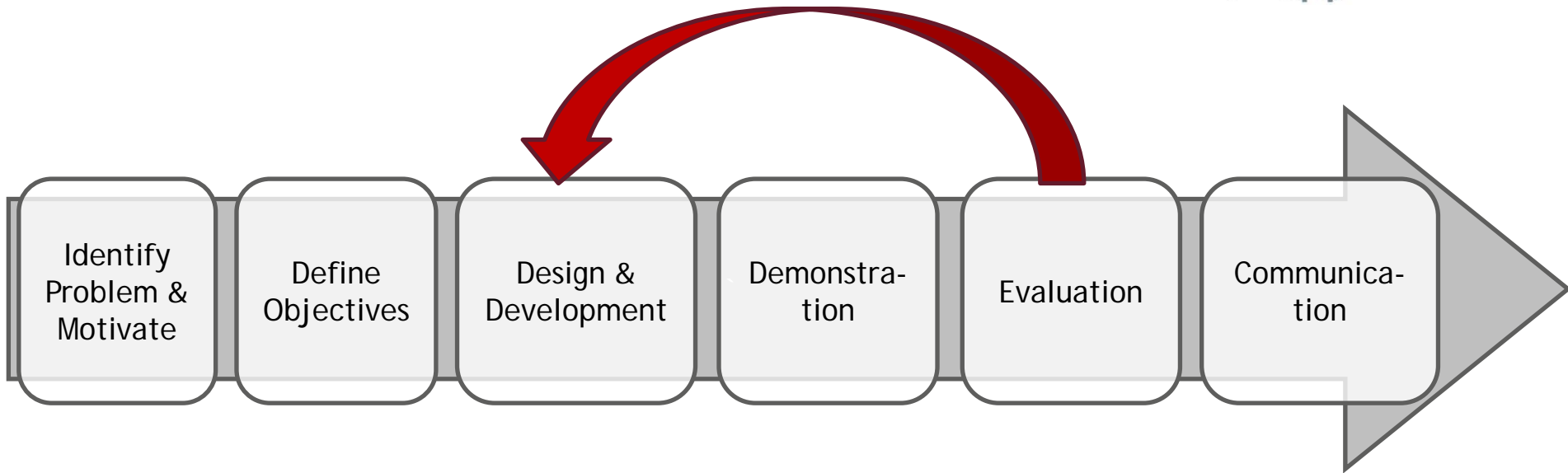


Qualitative requirements?



Architectural constraints

REDESIGN



Adapted from Peffers et al. (2007)

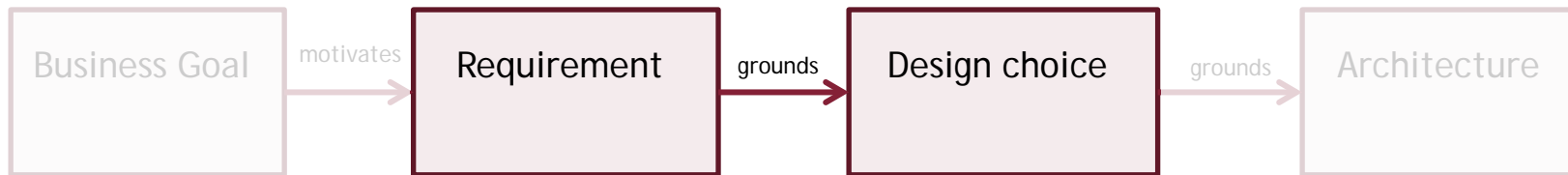
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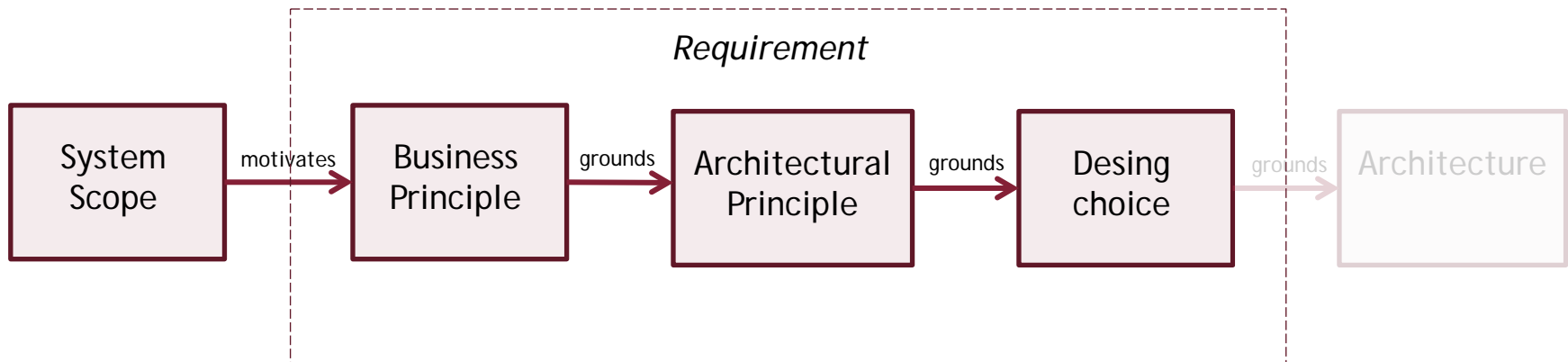
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CURRENT IOT-ARM METHOD



MODIFIED IOT-ARM METHOD

MULTILEVEL REQUIREMENT PROCEDURE



Adapted from Rozanski and Woods (2012)

MODIFIED IOT-ARM METHOD



System
Scope

BUSINESS GOAL

APPLICATION TO SMART HOME SYSTEM

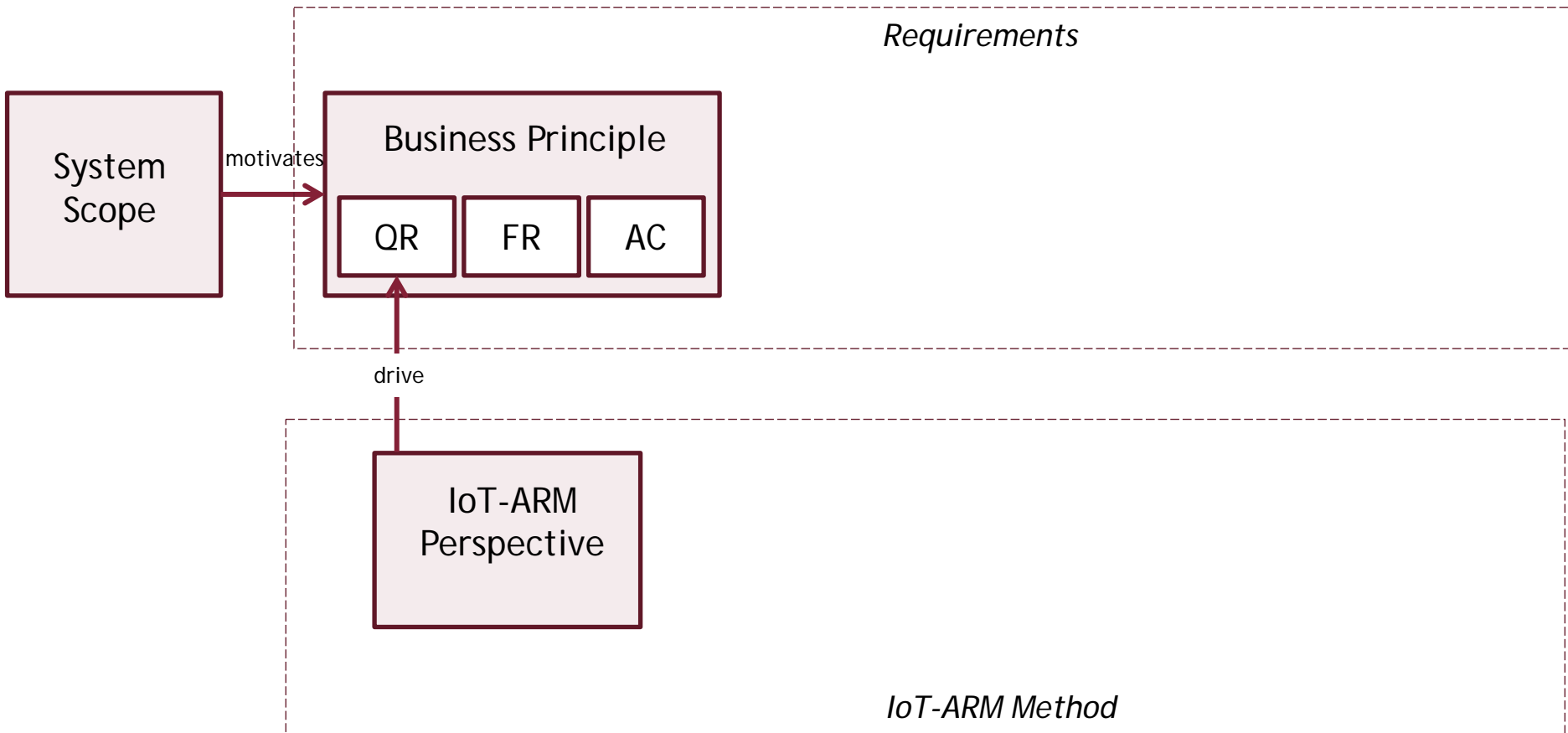


SS_1:

“According to different statistics sources, modern urban humans spend around 70-90% of their time indoors, including all possible building types. This fact, and also the variety of performed activities indoors make **privacy and security issues in buildings to be the most important** but also the most challenging task within Smart Home” system

Vuppala et al. (2012)

MODIFIED IOT-ARM METHOD



FR - Functional Requirement, QR - Qualitative Requirement, AC - Architectural Constraint

FORMULATION OF BUSINESS PRINCIPLE



Field	Description
ID	BP_1
Requirement Type	Qualitative Requirement
Description	The smart home system shall provide ways to ensure security
Rationale	Intelligent homes and buildings gather the most of data about people based on constant observation of human behavior. Hence, it is highly important to ensure the robust and secure data storage
Origin	System scope
Fit Criterion	The system prevents unauthorized access to system-related data
Priority	High
Conflicts and Dependencies	BP_2
History	Created: 18.06.2014
View	-
Perspective	Security

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Perspective	Security

FORMULATION OF BUSINESS PRINCIPLE



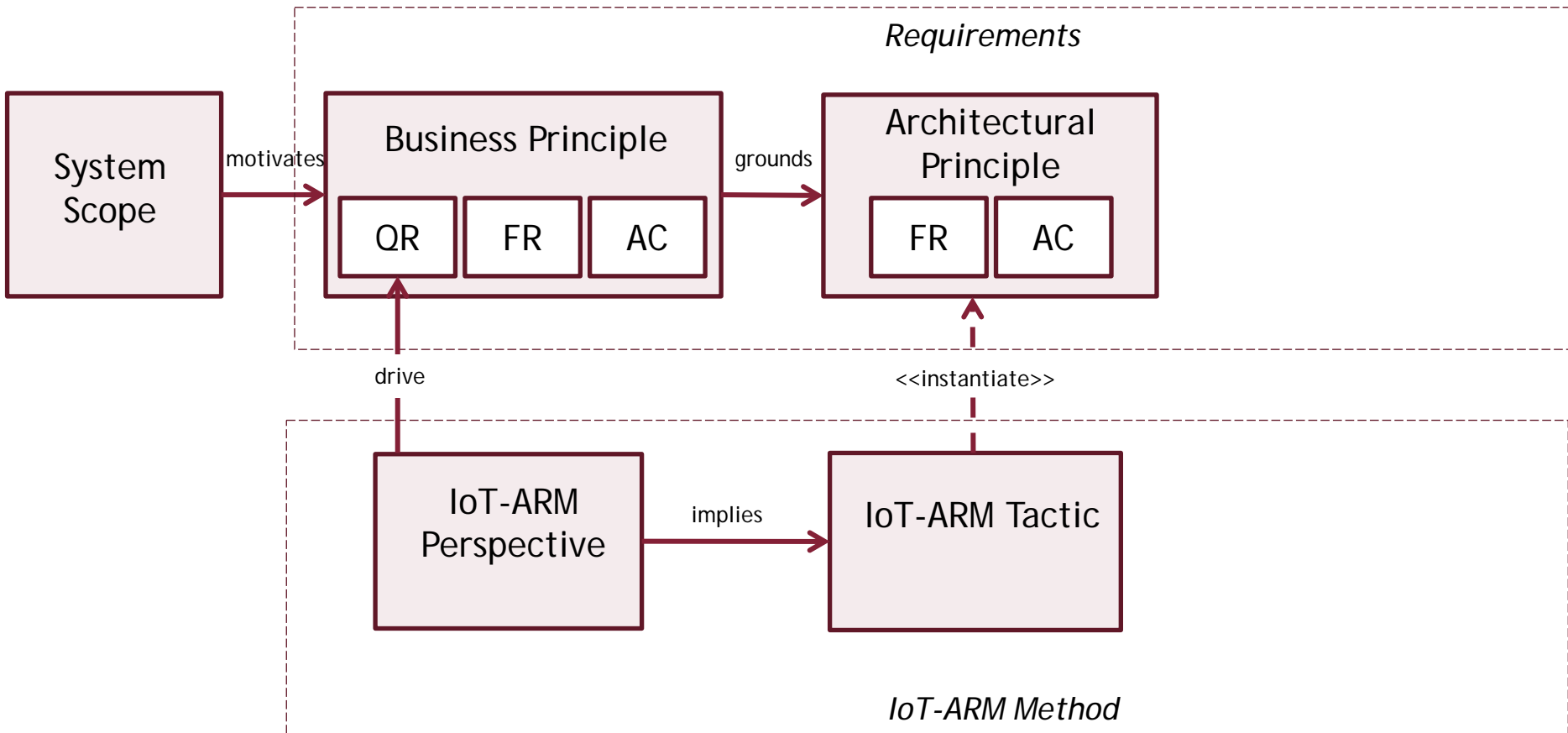
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MODIFIED IOT-ARM METHOD



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PERSPECTIVE OF SECURITY

TACTICS CATALOGUE



- Subject authentication
- Use access policies
- Secure communication infrastructure
- Secure peripheral networks (link layer security, secure routing)

FORMULATION OF ARCHITECTURAL PRINCIPLE



Field	Description
ID	AP_1
Requirement Type	Functional Requirement
Description	The smart home system shall provide authentication mechanism of family members
Rationale	Only members of the family shall be able to access information about energy consumption and other smart-home-related statistics, as well as control the home appliances. In order to provide authorization possibilities (see SH_AP_3), all users must be identified and authenticated.
Origin	BP_1, SH_1, SH_2, SH_3
Fit Criterion	The system shall distinguish and verify authenticated users
Priority	High
Conflicts and Dependencies	-
History	Created: 18.06.2014
View	-
Perspective	Security

FORMULATION OF ARCHITECTURAL PRINCIPLE



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Rationale	Only members of the family shall be able to access information about energy consumption and other smart-home-related statistics, as well as control the home appliances. In order to provide authorization possibilities (see SH_AP_3), all users must be identified and authenticated.
Origin	BP_1, SH_1, SH_2, SH_3
Fit Criterion	The system shall distinguish and verify authenticated users
Priority	High
Conflicts	and -
Dependencies	
History	Created: 18.06.2014
View	-
Perspective	Security

FORMULATION OF ARCHITECTURAL PRINCIPLE



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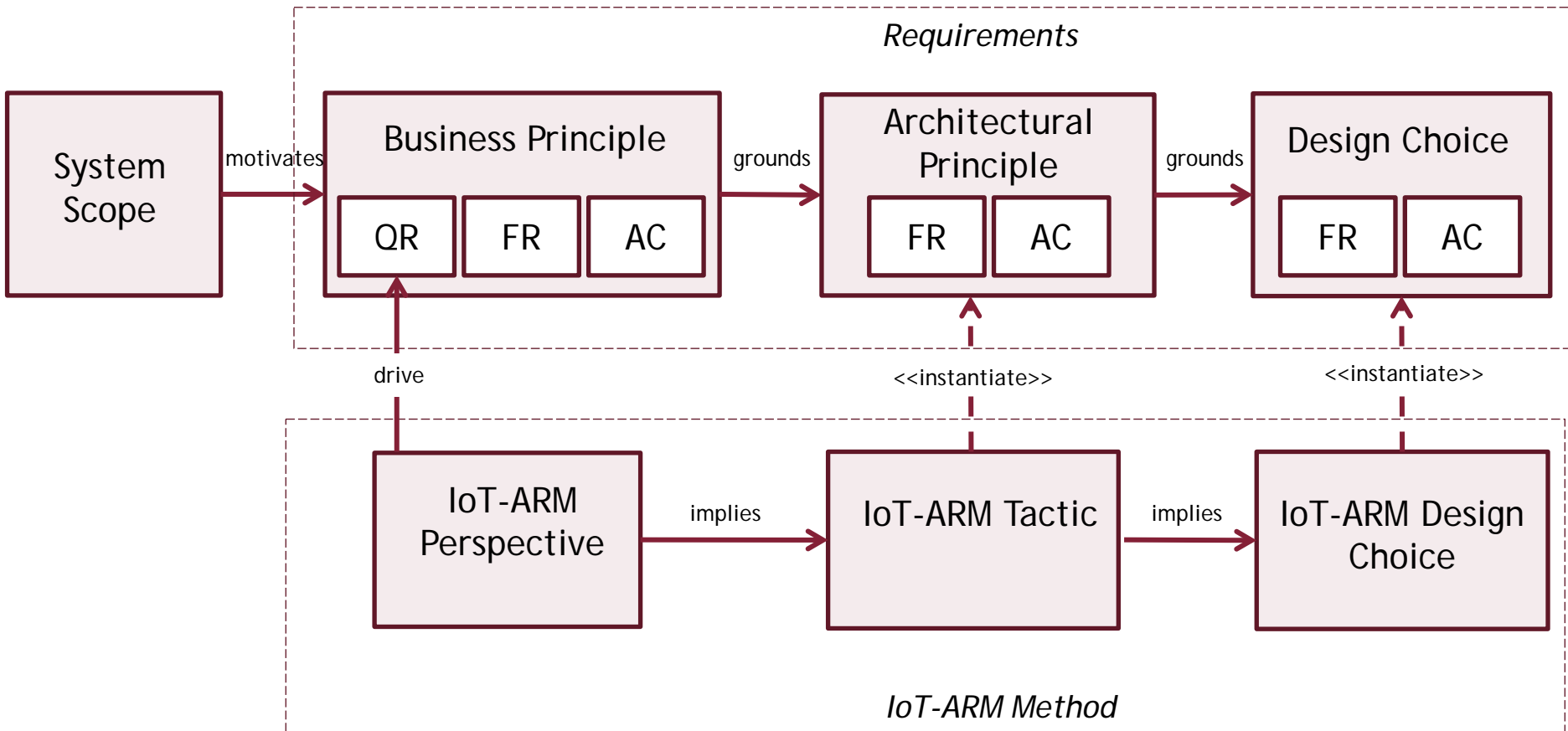
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MODIFIED IOT-ARM METHOD



FR - Functional Requirement, QR - Qualitative Requirement, AC - Architectural Constraint

PERSPECTIVE OF SECURITY

DESIGN CHOICES CATALOGUE



Tactic	Functional View	Information View	Deployment View
Subject authentication	Authentication over encrypted channel	No impact	Integration of authentication functional component Communication over secure channel
	Crypto-based authentication over open channel	No impact	Peer-to-peer authenticated communications over an insecure channel must be possible

Adapted from Carrez (2013)

PERSPECTIVE OF SECURITY

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FORMULATION OF DESIGN CHOICES



Field	Description
ID	DC_1
Requirement Type	Architectural constraint
Description	The system shall support authentication using login/password of users over the Internet
Rationale	Need authentication possibilities for remote control and monitoring of the house appliances over the Internet requires, combined with need for easy access to the system, drives selection of login/password authentication
Origin	AP_1
Fit Criterion	Login-password pair allow uniquely authenticate the user
Priority	High
Conflicts and Dependencies	DC_2, DC_3
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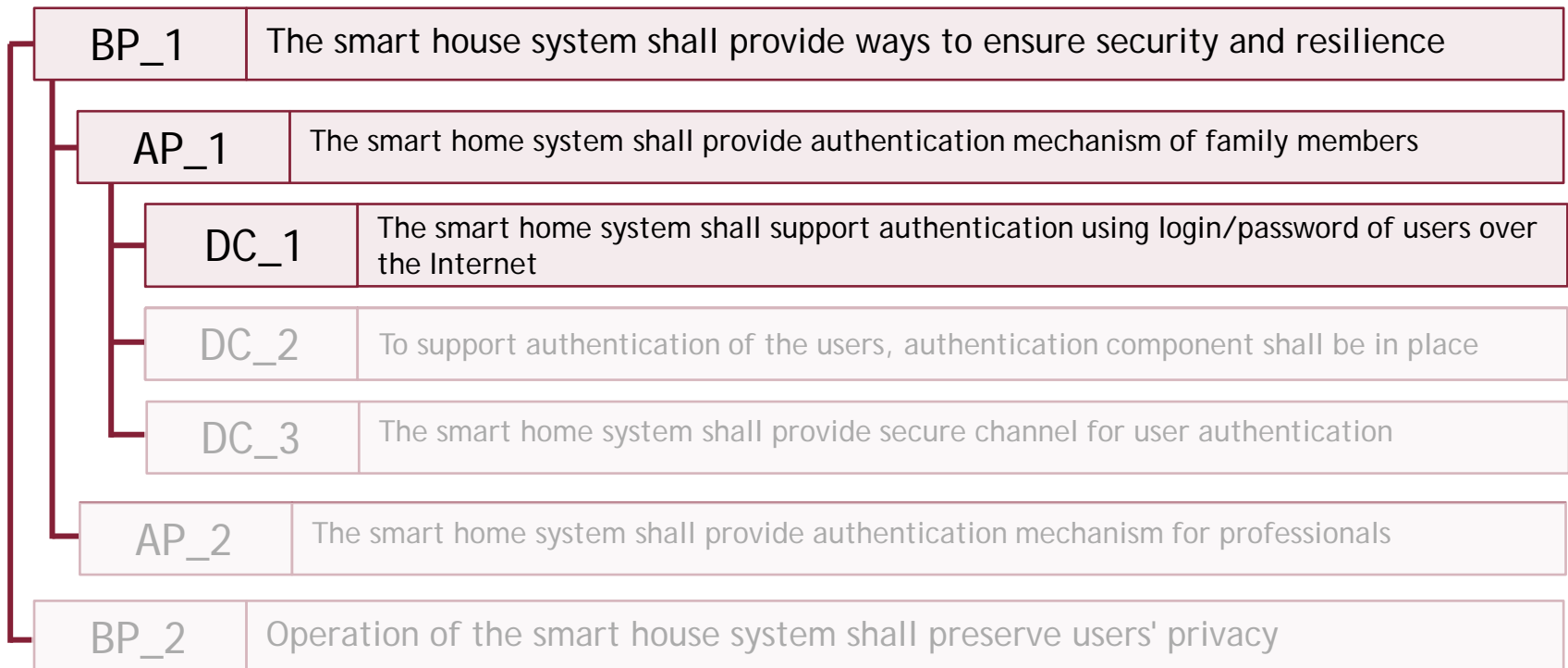
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REQUIREMENT HIERARCHY



EVALUATION OF MODIFIED IOT-ARM METHOD



Benefits:

- > Traceability
- > Structured thinking in a problem oriented-way
- > Completeness

EVALUATION OF MODIFIED IOT-ARM METHOD



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Shortcomings:

- > Guidelines
- > Knowledge base
- > Tool support

AGENDA



Translating Qualitative Requirements into Design Choices

1. Qualitative Requirements in System Development
2. IoT-ARM Method
3. Research Question and Approach for Research
4. Conceptual Evaluation
5. Empirical Evaluation
6. Modified IoT-ARM Method
7. Conclusion and Outlook

RESEARCH QUESTION



“What utility does the artifact provide?”

Hevener et al. (2004)

Brings attention to consideration of qualitative requirements



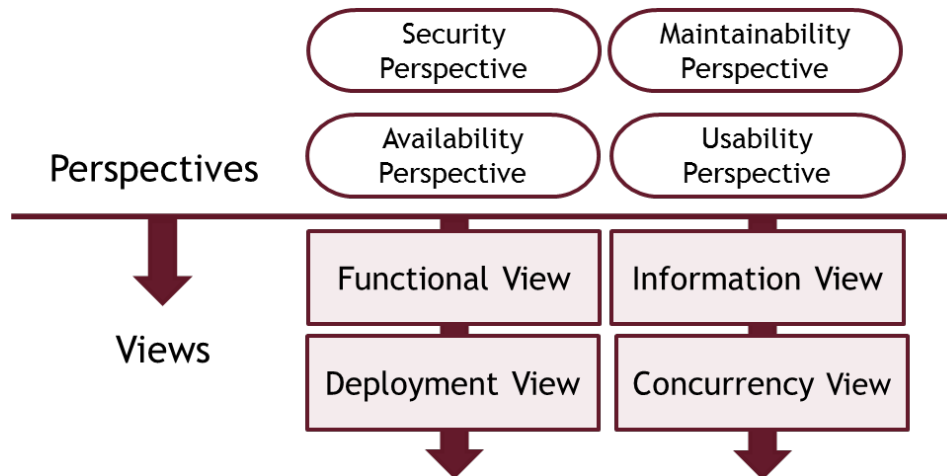
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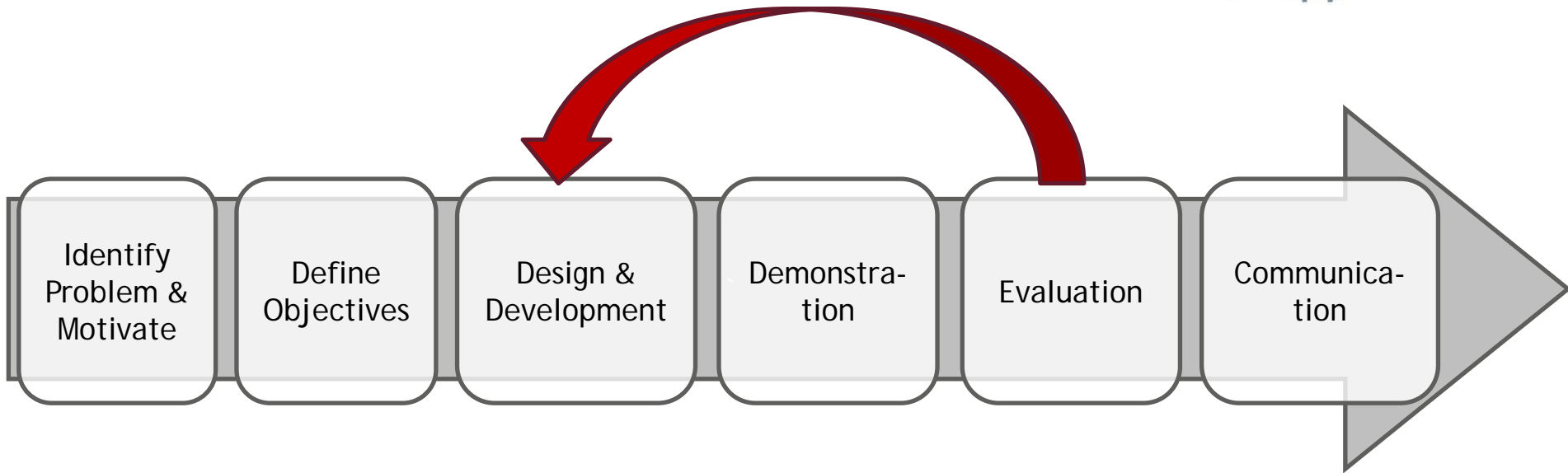
Hevener et al. (2004)

Assists in completeness of their consideration and implementation



Adapted from Rozanski and Woods (2012)

DESIGN SCIENCE RESEARCH



Adapted from Peffers et al. (2007)

OUTLOOK



- Extension of knowledge base
- Introduction of proposed changes
- Evaluation in industrial case study

QUESTIONS & ANSWERS



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