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DESIGNING SMART CITY MOBILE APPLICATIONS: A GROUNDED THEORY

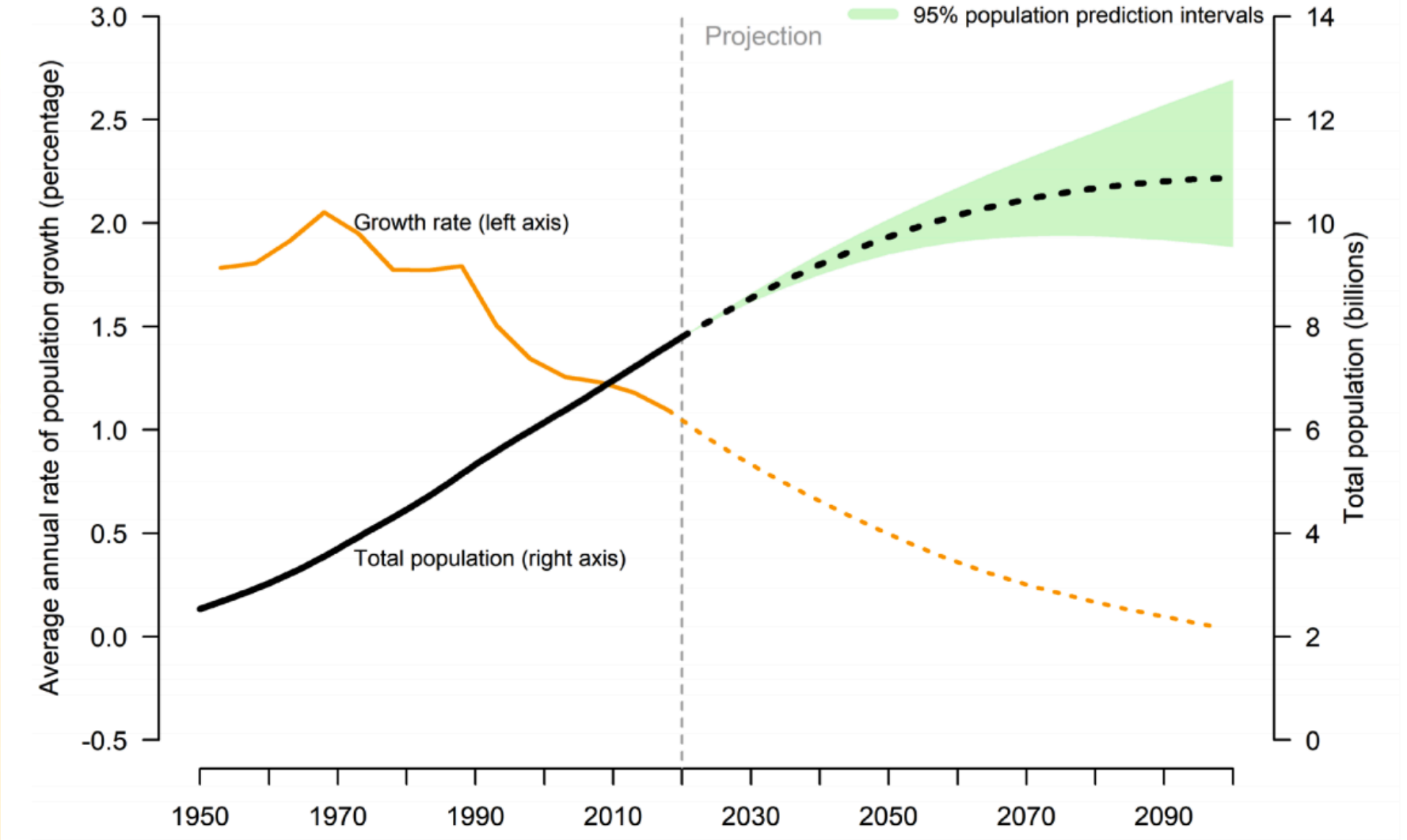
Roselane Santana Silva
Eduardo Santana de Almeida

About us

Agenda

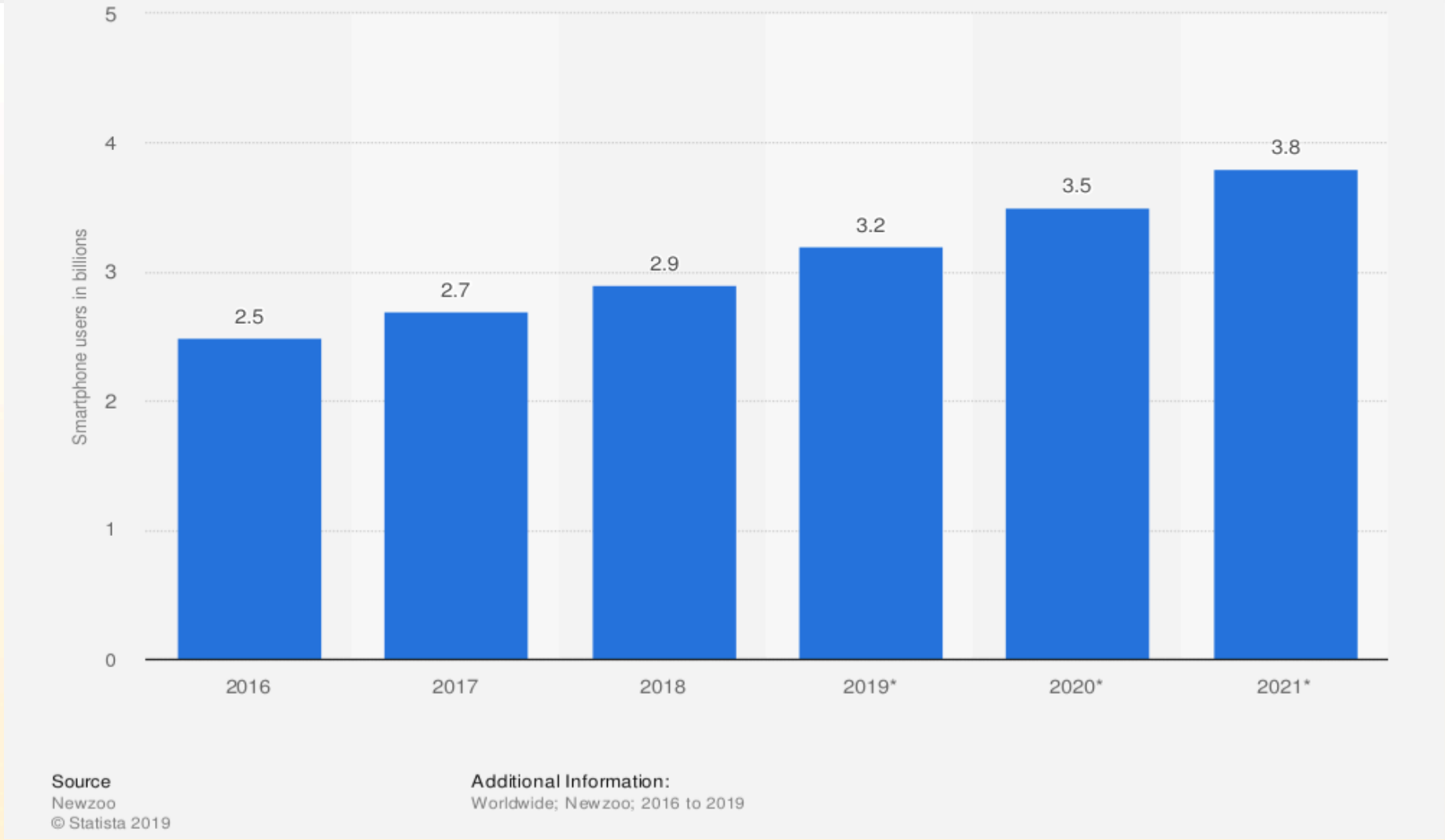
- Introduction
- Research Design
- A Grounded Theory about the Development of SCMA
- Insights from the Theory
- The evaluation of the Initial Grounded Theory
- Conclusion and Future Work

Population size and annual growth rate for the world



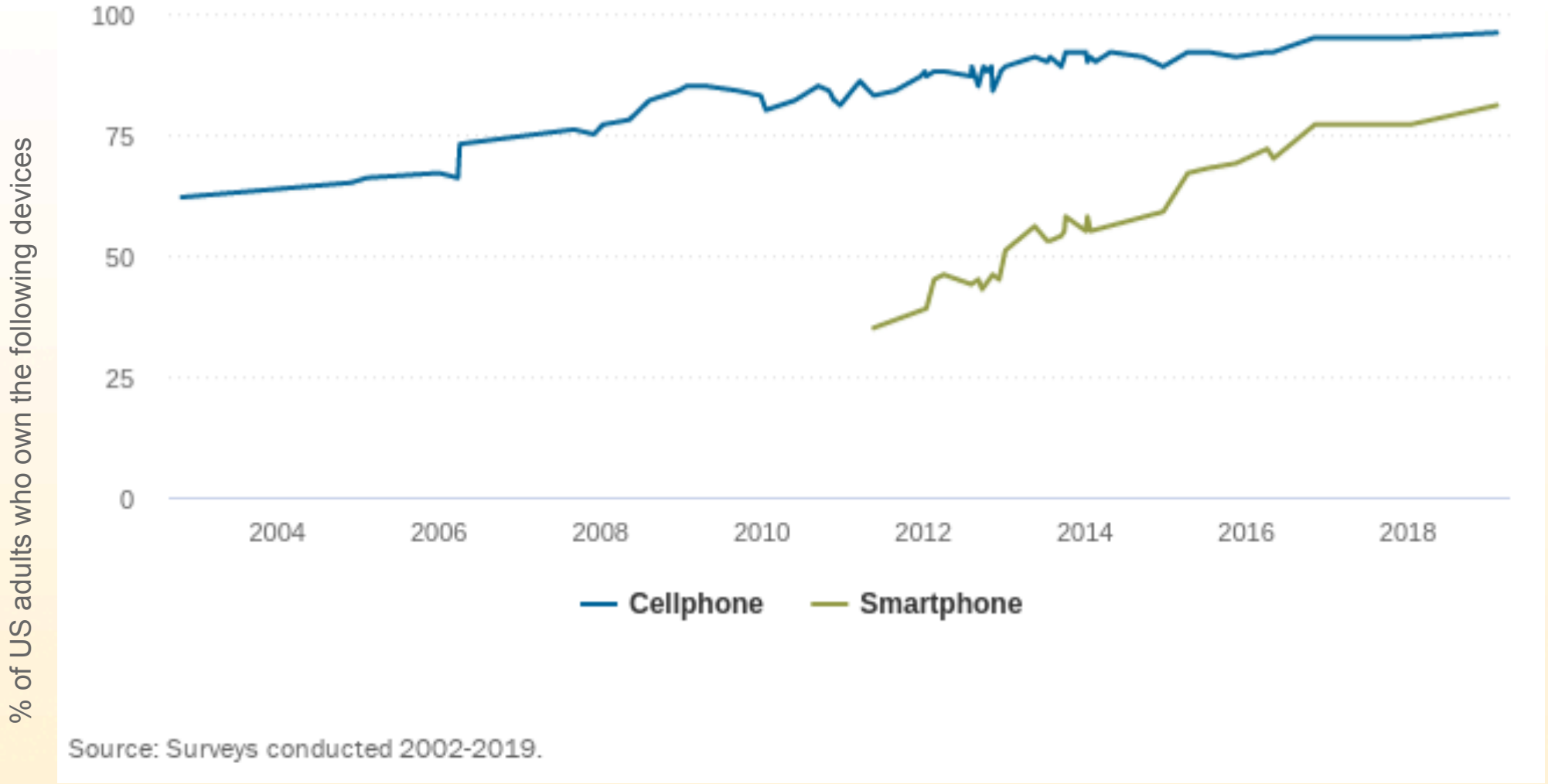
Data source: World Population Prospects 2019. (UNITED NATIONS, 2019)

Number of smartphone users worldwide



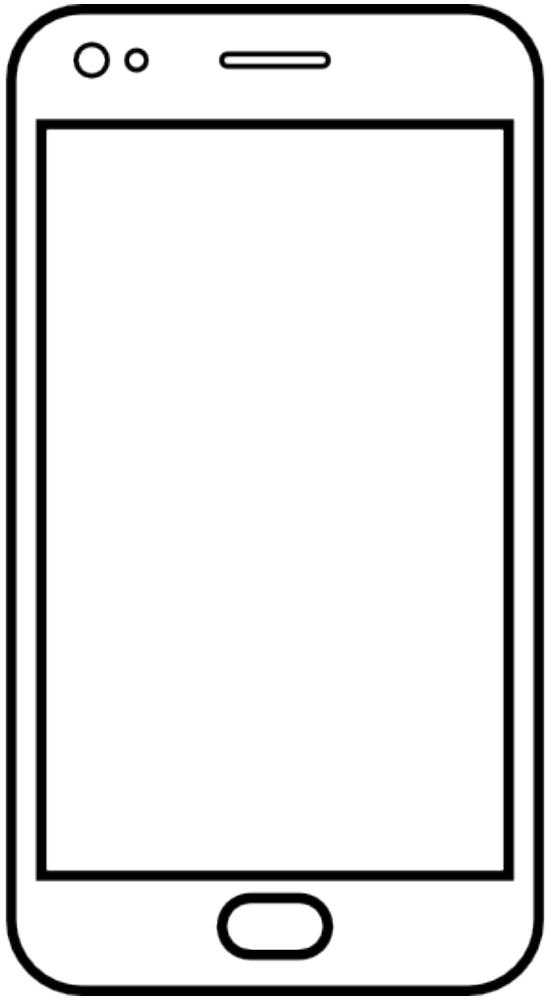
Data Source: Statista. Number of smartphones users worldwide from 2016 to 2021 (STATISTA, 2019)

Mobile phone ownership in the US

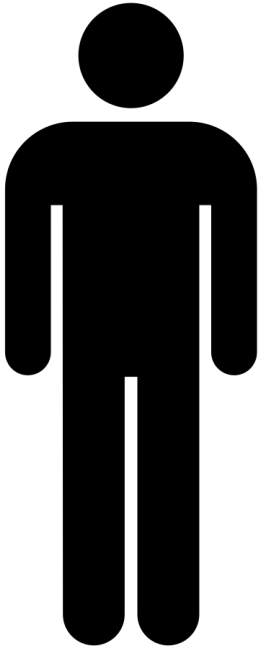


Data source: Pew Research Center's, 2019 (TAYLOR, K.; SILVER, L, 2019)


ORDEM E PROGRESSO



+230 milhões



211.8 milhões

Motivation

- The **world's population** had reached nearly 7.7 billion in June of 2019 (UNITED NATIONS, 2019)

- As **cities** become increasingly **crowded**, **several urban issues** are exacerbated (NEWCOMBE, 2014)

- **Mobile computing** offers opportunities to **aid citizens** in providing a wide variety of services (NEWCOMBE, 2014)


SHOPPING
CENTER


THE Jetsons

Brief Background: The Smart City Concept

A city which has certain smart ability to **deal with a city's problems** and **provides citizens with a better living environment** (WENGE et al., 2014)

An ultra-modern urban area that **addresses** the **needs** of businesses, institutions, and **especially citizens** (KHATOUN; ZEADALLY, 2016)

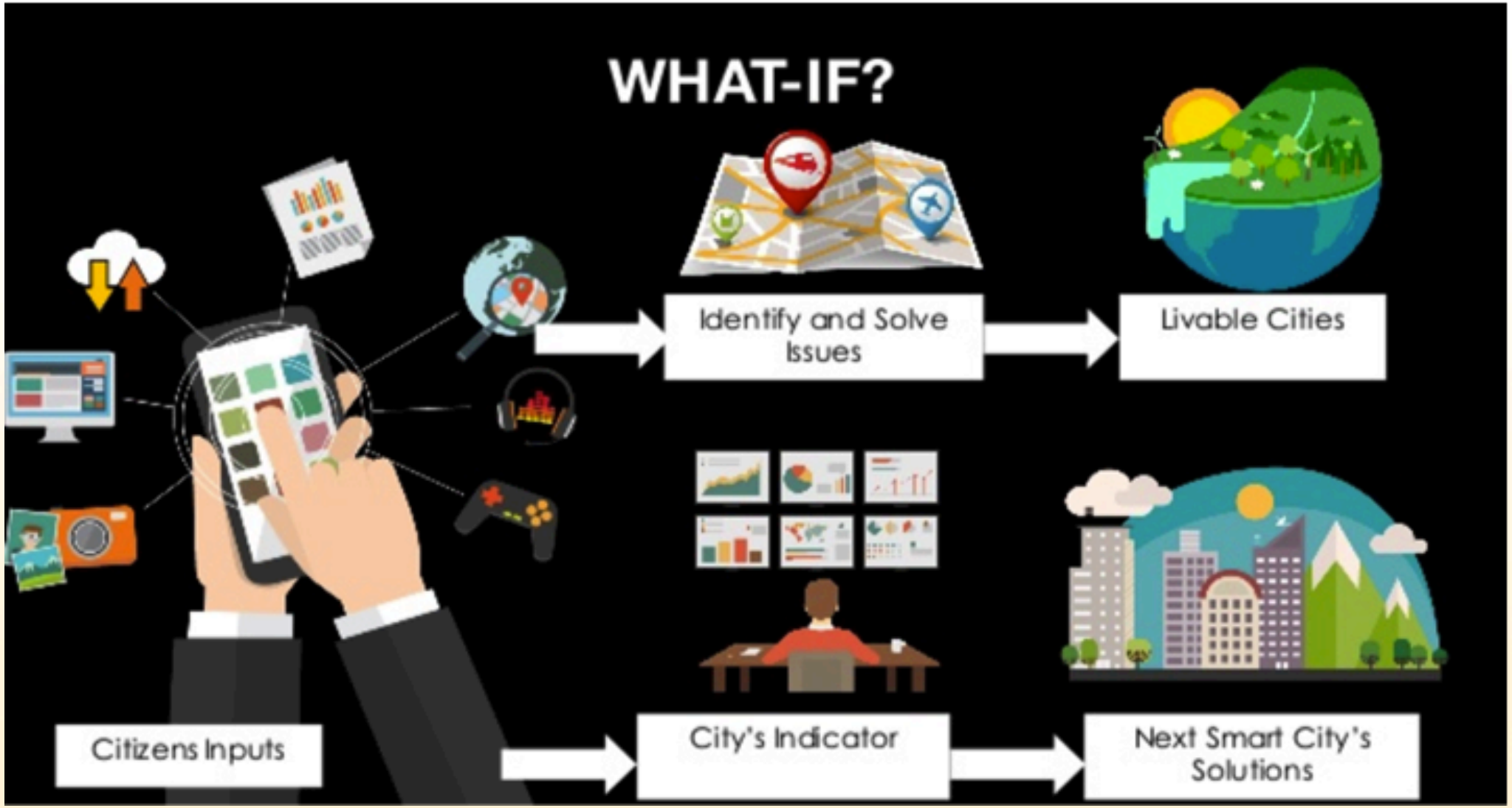
The characterization of Smart City Mobile Applications

- Enables solutions to **improve citizens' quality of life** (DAMERI, 2013)

- Promises multiple **benefits** for the citizen (KHATOUN; ZEADALLY, 2016)

- Facilitates citizens' interaction to **solve urban problems**, often on the fly (ESPOSTE et al., 2019)

Why Smart City Mobile Applications (SCMA)?



Data Source: https://www.slideshare.net/mazlan1/building-the-next-smart-city-with-mobile-cyberphysical-systems-61086396

Metrópole lança 0800 gratuito para facilitar a vida de ouvinte; confira

Nesta semana, a Rádio Metrópole passou a contar com mais um meio de interação. Além do 3505-5000 e do WhatsApp 98155-3258, ouvintes do interior e da capital voltaram a poder ligar gratuitamente no 0800 201 5000, para participar dos programas, concorrer a prêmios e fazer suas reclamações [Leia mais...]

Foto : Tácio Moreira/Metropress

Por **Bárbara Silveira** no dia 23 de Março de 2017 · 09:07

Motivation

- SCMA must constantly **monitor** all incoming information and **make smart decisions** (MEDVIDOVIC et al., 2003)

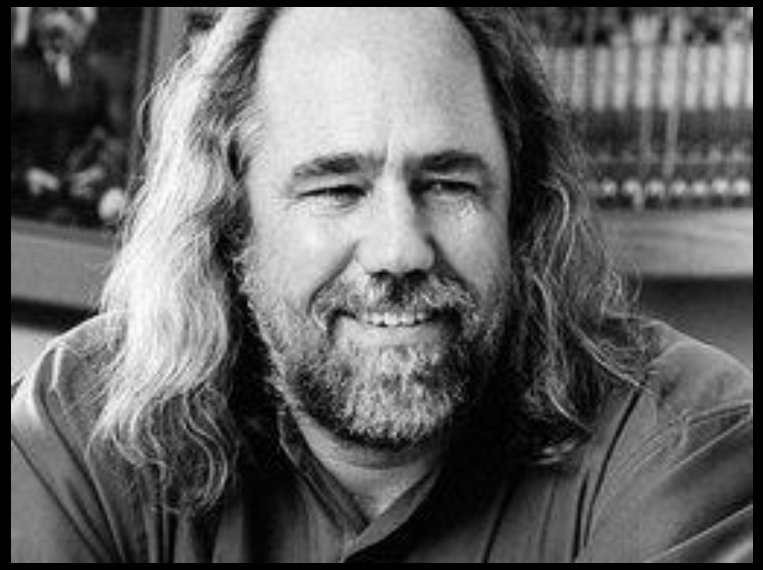
- Mobile apps require **addressing a number of limitations** (NAGAPPAN; SHIHAB, 2016)

There is a need for **more empirical studies** on how those specialized mobile device are designed to address these challenges (DINIZ et al., 2016).

Software Architecture as a bridge

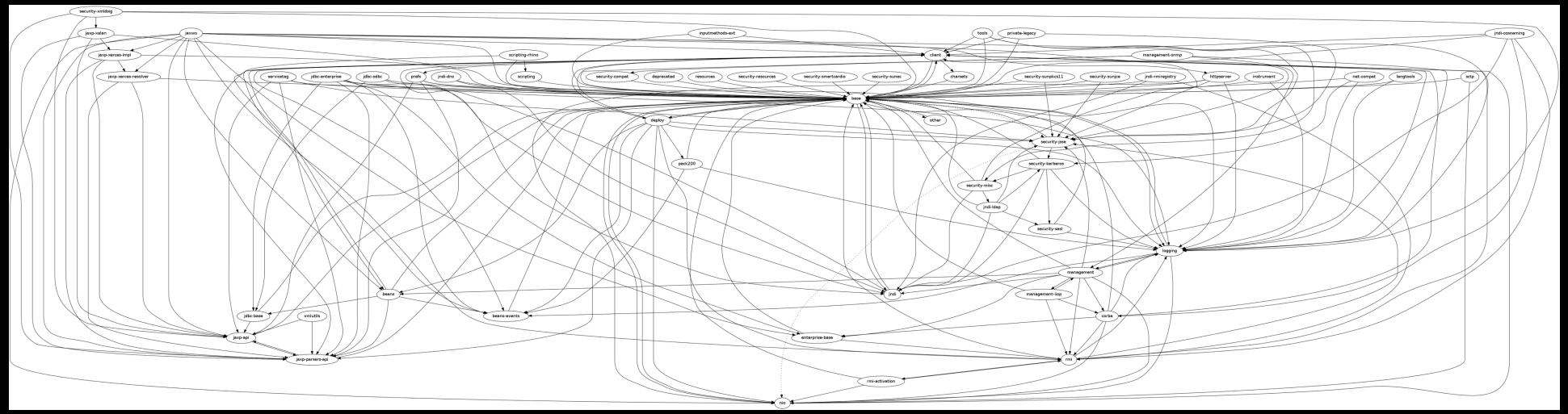
Many of the ideas used in the design of mobile systems came from **traditional software architecture** and those ideas have **contributed to mobile computing** becoming ubiquitous (BAGHERI, 2016).

Software Architecture as a bridge (GARLAN, 2000)



Grady Booch

“Every system has an architecture; some architectures are made manifest and visible, Many others are not.”



module graph for JDK 7

http://openjdk.java.net/projects/jigsaw/doc/jdk-modularization.html

Objective

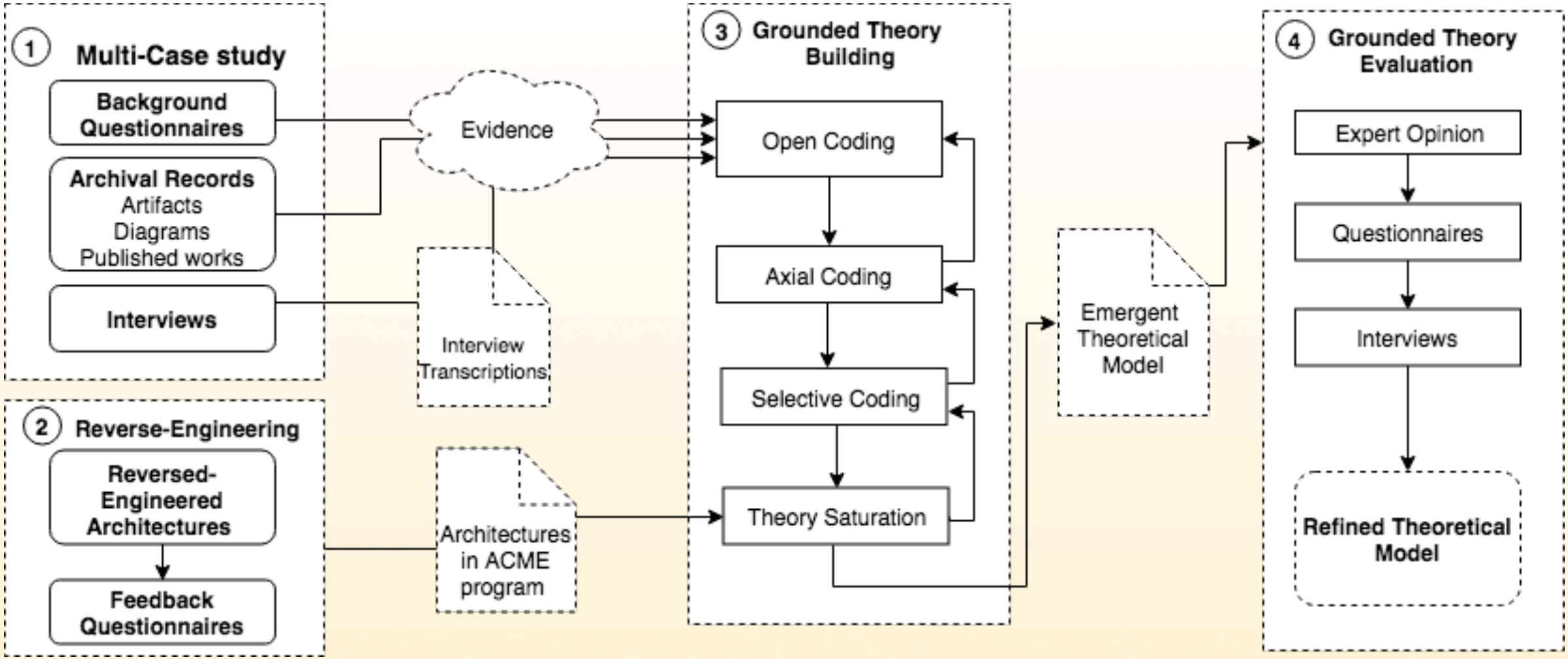
This study aims to investigate what **characteristics influence the design of the architecture of mobile software in the smart city domain through a multi-method research approach**.

Based on the results, we provide a theoretical model

and a set of recommendations in order to help improve the design of smart city mobile applications.

Research Design

Research Analysis Process



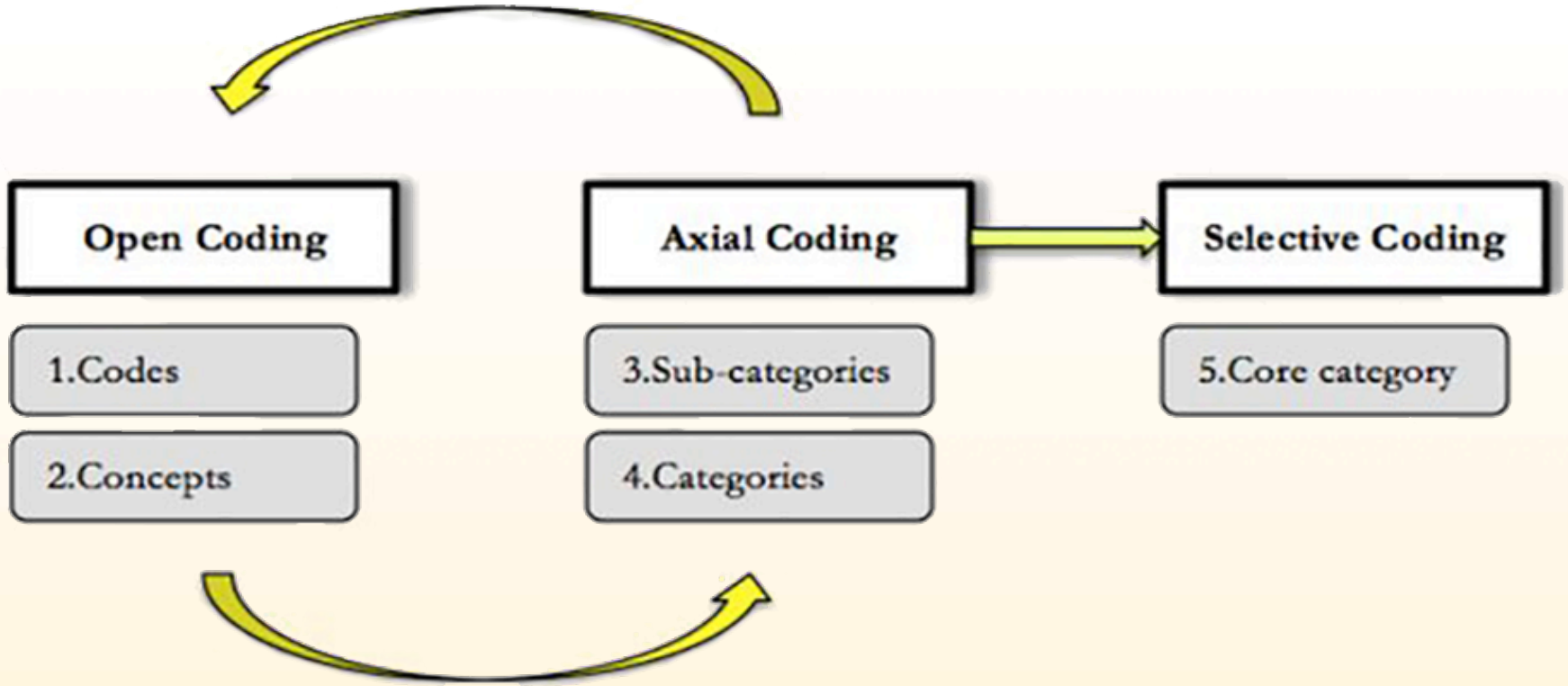
Brief Background: Grounded Theory

It is a method for qualitative research, proposed by sociologists to **understand and explain a phenomenon** under investigation (GLASER; STRAUSS, 1967)

Juliet Corbin and Anselm Strauss (1990) defined **systematic methods** and procedures for grounded theory research

The expected end result of applying GT methods is **a set of propositions** that describes the phenomenon under investigation

Constant Comparison Method

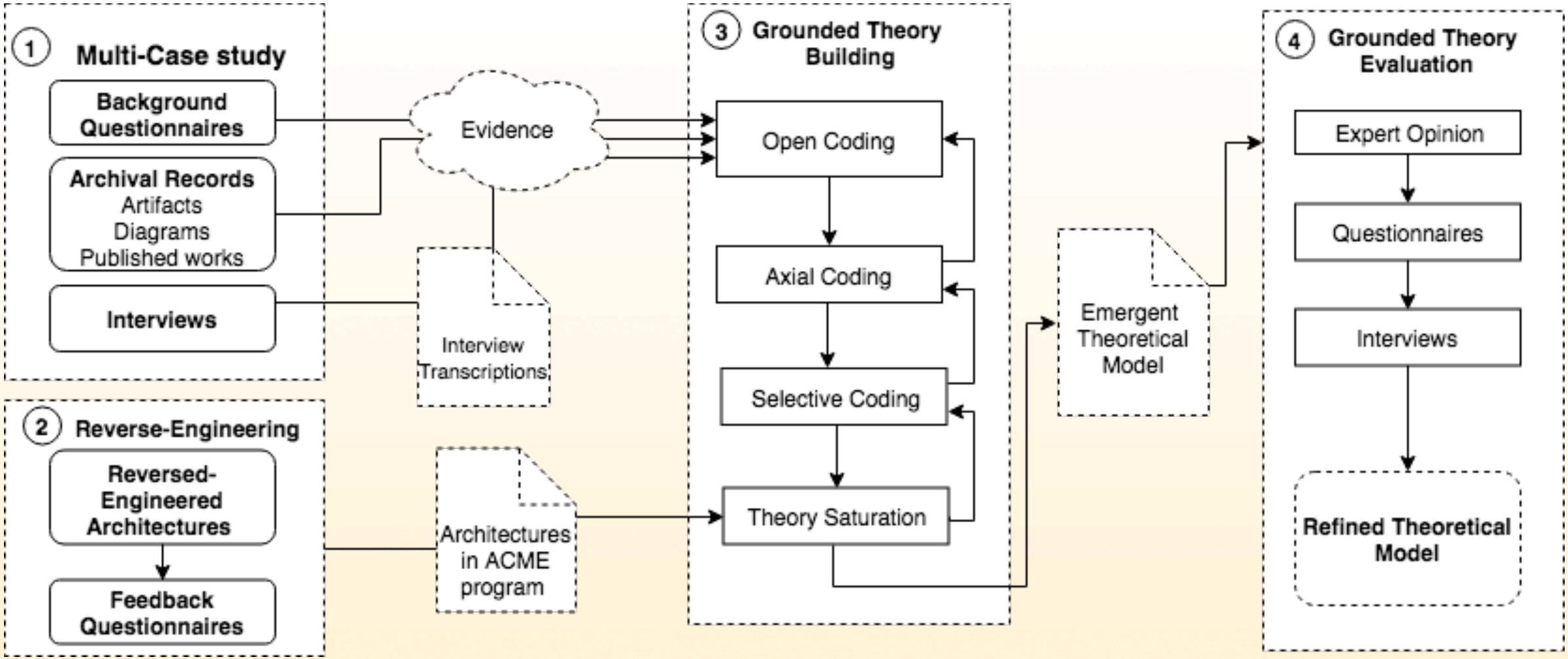


Participant: the architecture is divided into layers of components, actually it is even more complex than that (...) for example, data analysis layer is a component that contain a subcomponent called image analysis (...) there is a part in our software architecture document that shows for each component who was responsible for it

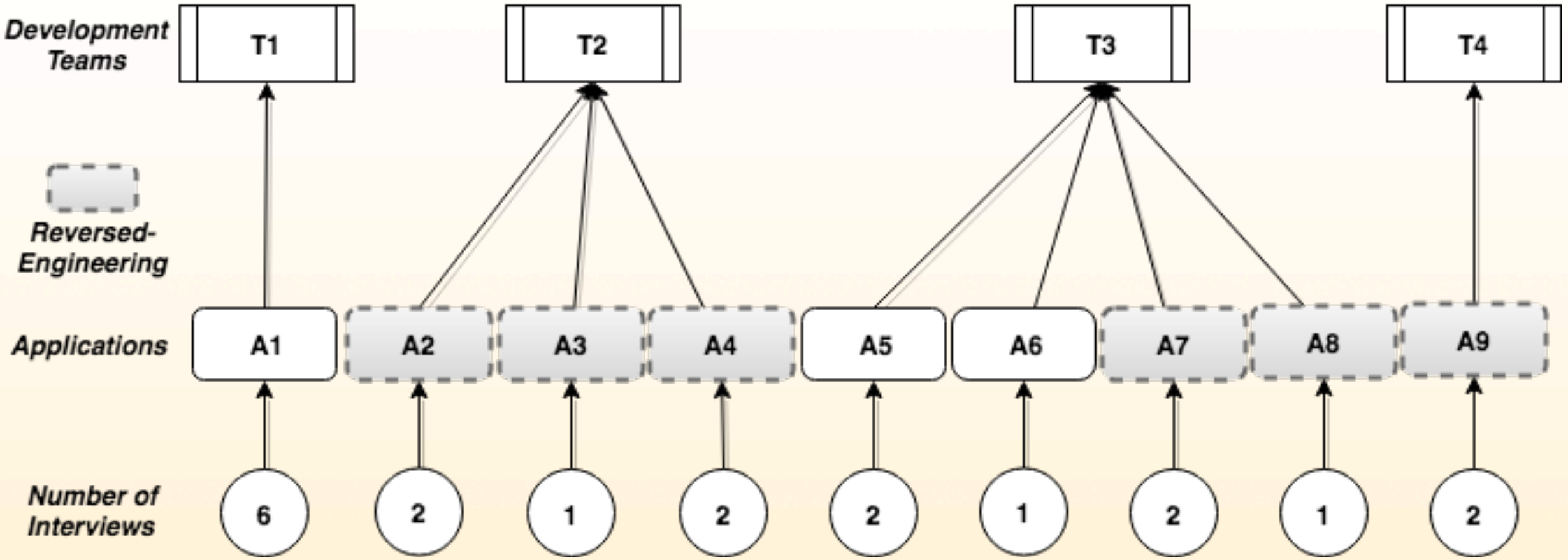
Architectural Pattern
How it is designed

Arch. Documentation

Research Analysis Process



Characterization of Software Selected for Study



Characterization of Software Selected for Study

- **T1: System Engineering Project Center (UFBA)**
  - A1 (RESCUER) is an emergency management solution

- **T2: Development Group for Smart Cities (UFPE)**
  - A2 (Bike Cidadão) is a **mobile traffic application** for information sharing among cyclists
  - A3 (BioNucleus) is a smart collection app that facilitates the **collection of cooking oil residue**
  - A4 (Smart Parking) is a smart application that streamlines the **search for vacant spots within a parking lot**

Characterization of Software Selected for Study

- **T3: Project for Smart Cities (UFRN)**
  - A5 (Campus Seguro - Comunidade Universitária) is intended to speed up **registration of emergency incidents** in the University
  - A6 (Campus Seguro - Vigilante) is integrated with A5 in order to **assist security guards** of the university
  - A7 (Fala Natal) is an app that allows the citizen to report non-emergency problems concerning public services

Characterization of Software Selected for Study

- **T3: Project for Smart Cities (UFRN)**
  - A8 (Visit Natal) is a smart city app that is intended to **enhance tourists' travel experience**

- **T4: Information Technology Management (USP)**
  - A9 (Campus USP) is a communication channel to **report security incidents** and safety-related actions on university campuses

Characterization of the 19 interviewees

#	Role	Experience (years)	Application	Development Team
I1	Manager	5	A1	T1
I2	Req. Analyst	20+	A1	T1
I3	Mobile Developer	8	A1	T1
I4	Web Developer	3	A1	T1
I5	Architect	8	A1	T1
I6	Researcher	1	A1	T1
I7	Req. Analyst, Architect Developer	1	A2	T2
I8	Developer Tester	2	A2	T2
I9	Req. Analyst, Architect Developer, Tester	2	A3	T2
I10	Developer, Tester	1	A4	T2
I11	Developer, Tester	4	A4	T2
I12	Manager	20+	A5, A6	T3
I13	Req. Analyst, Architect, Developer, Tester	2	A5	T3
I14	Developer	2	A6	T3
I15	Manager	4	A7, A8	T3
I16	Developer	4	A7	T3
I17	Developer	1	A8	T3
I18	Manager, Req. Analyst	20+	A9	T4
I19	Developer, Tester	10+	A9	T4

A Grounded Theory about the Development of SCMA

The Grounded Theory Building Process

According to SjØberg's framework (SJØBERG et al., 2008), a theory is created by building the following elements:

1. Theory constructs - The **core categories** that helps to explain a phenomenon.

2. Theory proposition -The **relationship between theory constructs**, which describes how core categories interact with each other.

3. Scope - The **scope of a theory** is the universe for which the theory is expected to be an accurate explanation.

4. Explanation - It **describes "why"** the resulting theory is what it is.

Theory Constructs

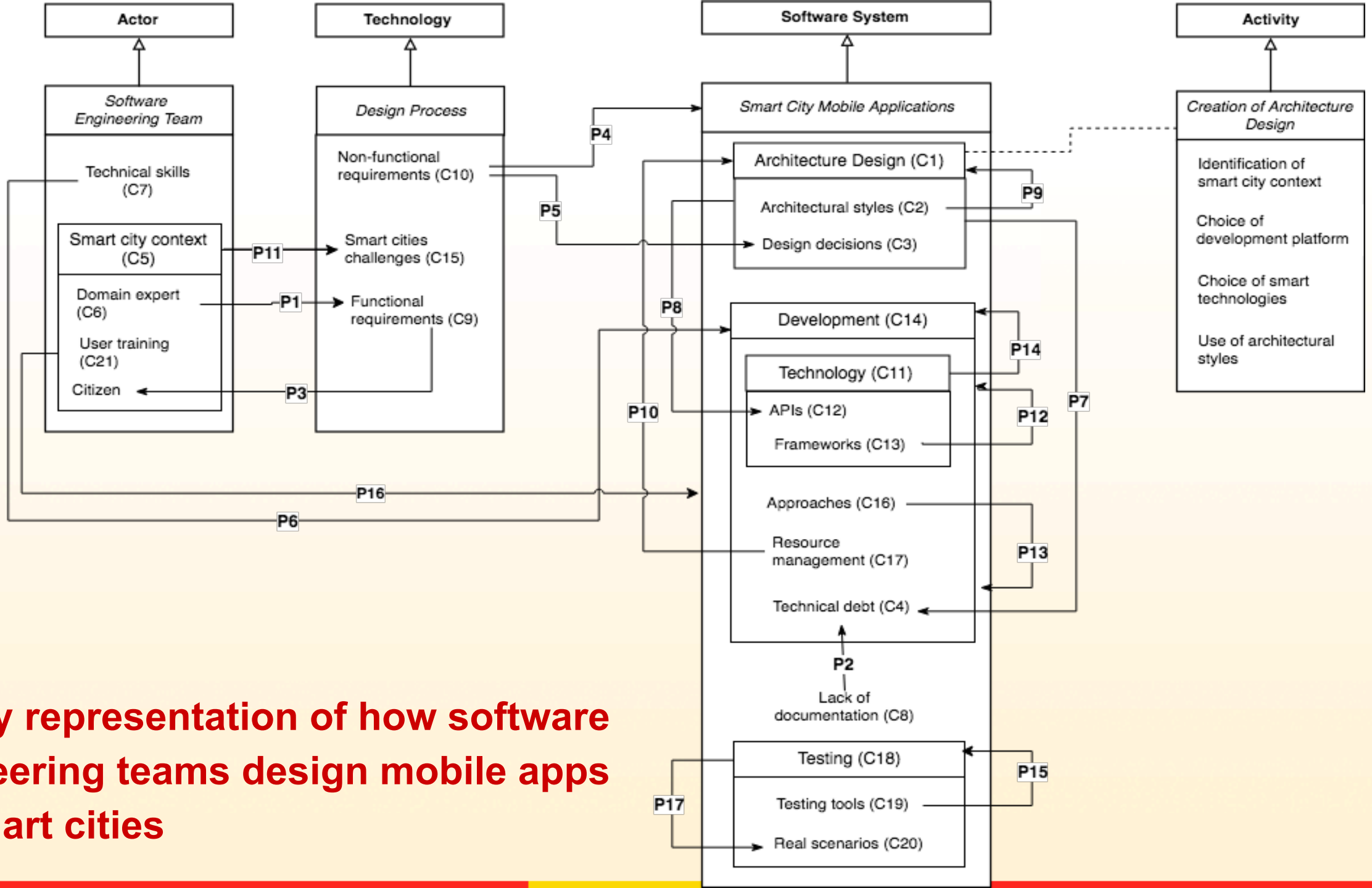
C1	*Architecture design*	A high-level structural design of a software system.
C2	*Architectural styles*	A set of design decisions that identify the kinds of components and connectors that may be used to compose a system or subsystem.
C3	*Design decisions*	A description of the set of rationales, design rules, and design constraints for a given architecture (JANSEN, 2008).
C4	*Technical debt*	A concept in SE that reflects the extra development work that arises when code that is easy to implement in the short run is used instead of applying the best overall solution (JANSSEN; JANSSEN, n.d.).
C5	*Smart city context*	A characterization of a city's infrastructure for collecting and using data in management and policy decisions.
C6	*Domain experts*	A person with special knowledge in the context in the domain of smart cities (e.g., a firefighter is an expert in emergency management).
C7	*Technical skills*	Abilities needed for software programming.
C8	*Documentation*	Artifacts that explain the software (requirement specification).
C9	*Functional requirement*	A requirement that defines what a system is supposed to do.
C10	*Non-functional requirement*	A requirement that specifies criteria that can be used to judge the quality of operation of a system, rather than specific behaviors.

Theory Constructs (2)

C11	*Technologies*	Technical tools that support software development.
C12	*API*	A software intermediary that describes how software units talk to each other.
C13	*Framework*	It is a coherent unit of reuse, both by use-relationships and by extension through sub-classing.
C14	*Software development*	The process of specifying, designing, developing, and testing involved in mobile applications.
C15	*Challenges*	Challenges faced when designing and developing a SCMA.
C16	*Development approach*	There are three primary approaches to building mobile apps: web, hybrid and native.
C17	*Resources management*	The effective use of mobile resources.
C18	*Software testing*	An investigation conducted to provide information about the quality of the software product.
C19	*Testing tools*	Software intended to help software engineers to find bugs in mobile apps.
C20	*Testing issues*	Issues related to testing mobile software (e.g., testing real scenarios).
C21	*User training*	Process of training a staff who will work supporting the citizen through the app.

List of propositions identified in the study

P1	Domain experts positively impact the definition of requirements for a SCMA.
P2	The lack of documentation creates technical debt.
P3	Functional requirements for a SCMA come from a smart cities context, which is citizen-oriented
P4	Most non-functional requirements are not taken into consideration by SE team when making design decisions.
P5	The satisfaction of non-functional requirements depends upon the design decisions made.
P6	The level of technical skills impacts the development of SCMA.
P7	The lack of architecture decisions creates technical debt.
P8	The architecture design of SCMA is API-centric.
P9	The use of architectural styles positively impacts the design of SCMA.
P10	Effective mobile resource management positively impacts the architecture design of SCMA.
P11	The smart cities context brings complexity to mobile applications.
P12	The development or adoption of smart city frameworks reduce the complexity of the development of SCMA.
P13	The adopted development approach brings specific development challenges for SCMA.
P14	Smart technologies positively impact the development speed of SCMA.
P15	The lack of testing tools for mobile applications negatively impacts the testing process of SCMA.
P16	Training users positively impact the acceptance of SCMA products.
P17	Testing SCMA involves the need to simulate real-world scenarios.



Theory representation of how software engineering teams design mobile apps for smart cities

Insights from the Theory

The key Non-Functional Requirements (NFR) for SCMA

The table below shows the five quality attributes most related to mobile apps as reported by the participants in the interviews

Table 4.4 How mobile application aspects are impacted by the QAs

	Battery Life	Mobile Resource Management	Development Approach	Development Challenge
Performance	✓	✓	✓	✓
Portability		✓	✓	✓
Privacy		✓		
Reusability		✓	✓	✓
Reliability		✓	✓	✓

Smart Cities Context

- **Requirements**

> *"In a report about fire, firefighters taught us that the color of the smoke is important, (..) they explained that there is a lighter and a darker gray and (identifying this difference) helped us to understand the type of fire to be treated"* (respondent #I2).

- **Design**

> *the advantages that we had using the Fiware platform was that (it) had components that dealt with security already within the context of the platform"* (respondent #I3).

- **Development**

> *"We had a very big challenge which was the WiFi signal that worked very well inside the mall but in the parking lot (it's six floors of parking) was very bad. How were we going to map the routes if there is no signal?"* (respondent #I11).

- **Testing**

> *"The problem is not the development of the app itself, the big problem in these tests are the people (who take action) in response to some emergency reported by the app"* (respondent #I18).

Candidate anti-pattern on architecture construction

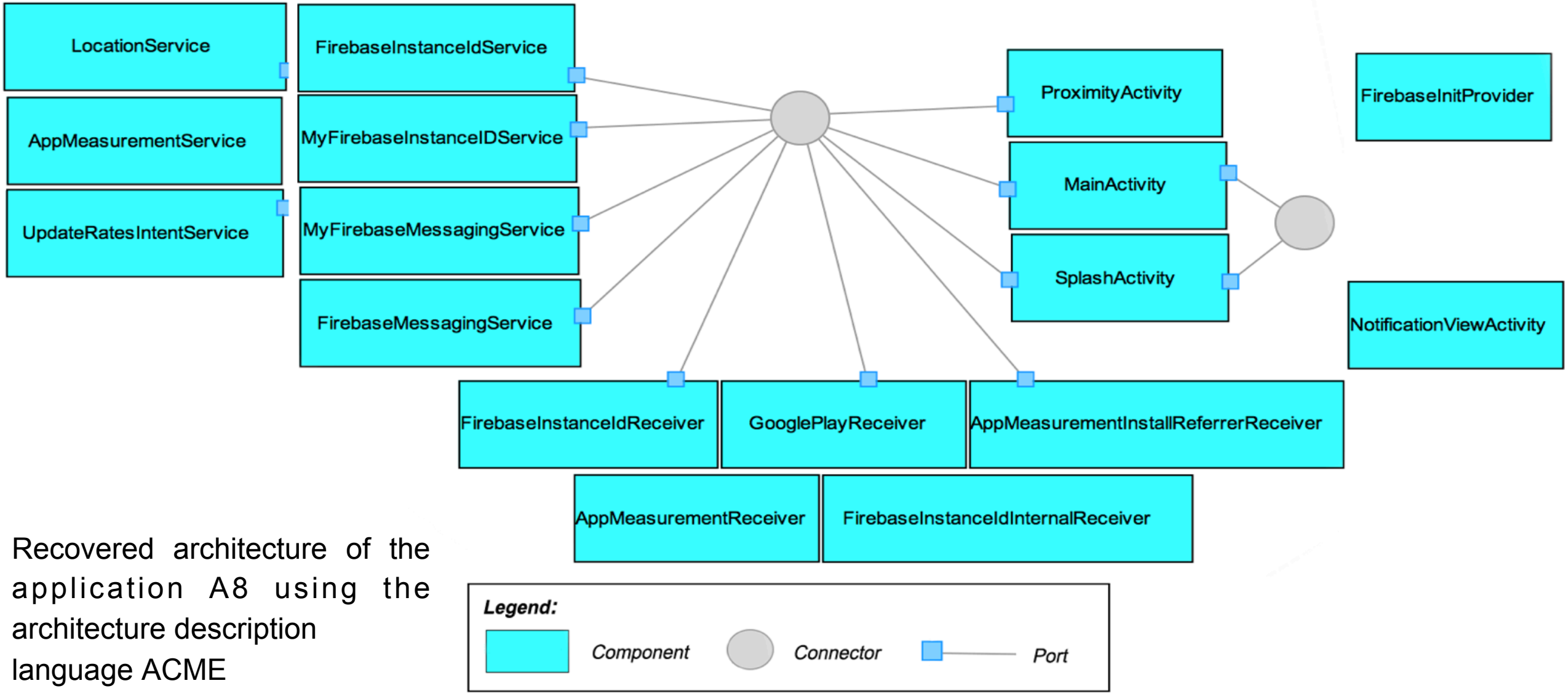
1. **The lack of (at least a technical) documentation creates technical debt.**

> *"I was developing this part, but as I ended up leaving the project, this ended up being discontinued."* (respondent #I7).

2. **Failing to implement architecture decisions creates technical debt**

> *"We did not create an architecture before we developed the application because of the short time we had."* (respondent #I13).

A Deeper look at the Architecture of selected Android Apps



Recovered architecture of the application A8 using the architecture description language ACME

Multi-level Analysis

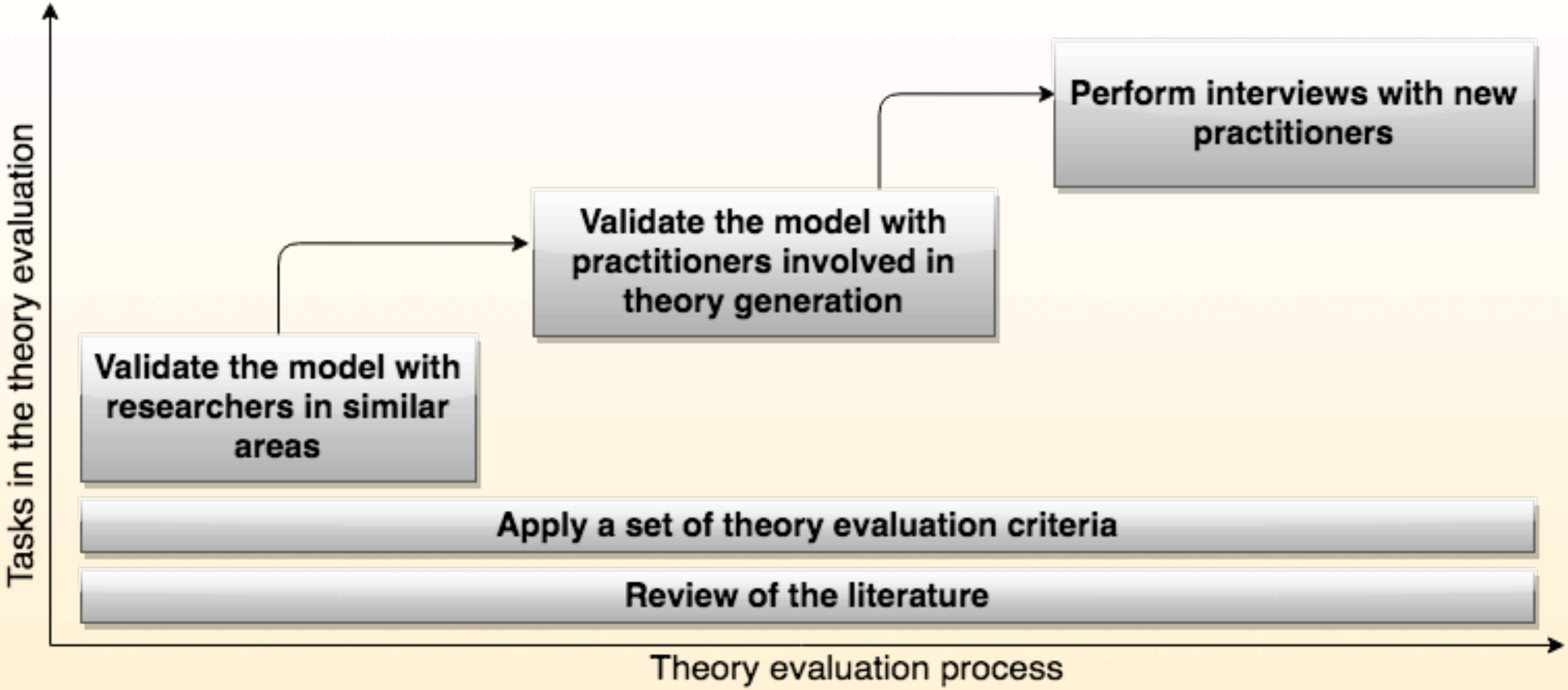
App-Team	Components				Provided
	Activity	Service	Provider	Receiver	Ports
A2-T2	9	1	0	0	18
A3T-2	7	2	1	2	9
A4-T2	6	2	2	1	6
A7-T3	4	8	1	5	14
A8-T3	13	1	0	0	114
A9-T4	17	1	0	0	55

Table 4.6 Architectural styles identified in the reverse engineered apps

	message-based explicit-invocation	message-based implicit- invocation	publish-subscribe	shared state
A2-T2	✓		✓	
A3-T2	✓		✓	
A4-T2	✓		✓	✓
A7-T3	✓		✓	
A8-T3	✓		✓	
A9-T4	✓	✓	✓	

The evaluation of the Initial Grounded Theory Evaluation

Theory Evaluation Tasks



Task #1 - Review of the Literature

- Ivan et al. (2009) stated that **citizen-oriented applications** must be orientated towards **citizen satisfaction**

- Due to the fact the battery is a **scarce resource** for those apps, several studies have proposed ways to measure and to **save energy used for mobile** apps (NAGAPPAN; SHIHAB, 2016).

- Nagappan and Shihab (2016) and Francese et al., (2017), reported that more **work is needed on automated testing of mobile apps**, specially for cross-platform apps.

- Mobile development teams have often adopted **cross-platform development frameworks** (FRANCESE et al., 2017; BIRØN-HANSEN et al., 2019).

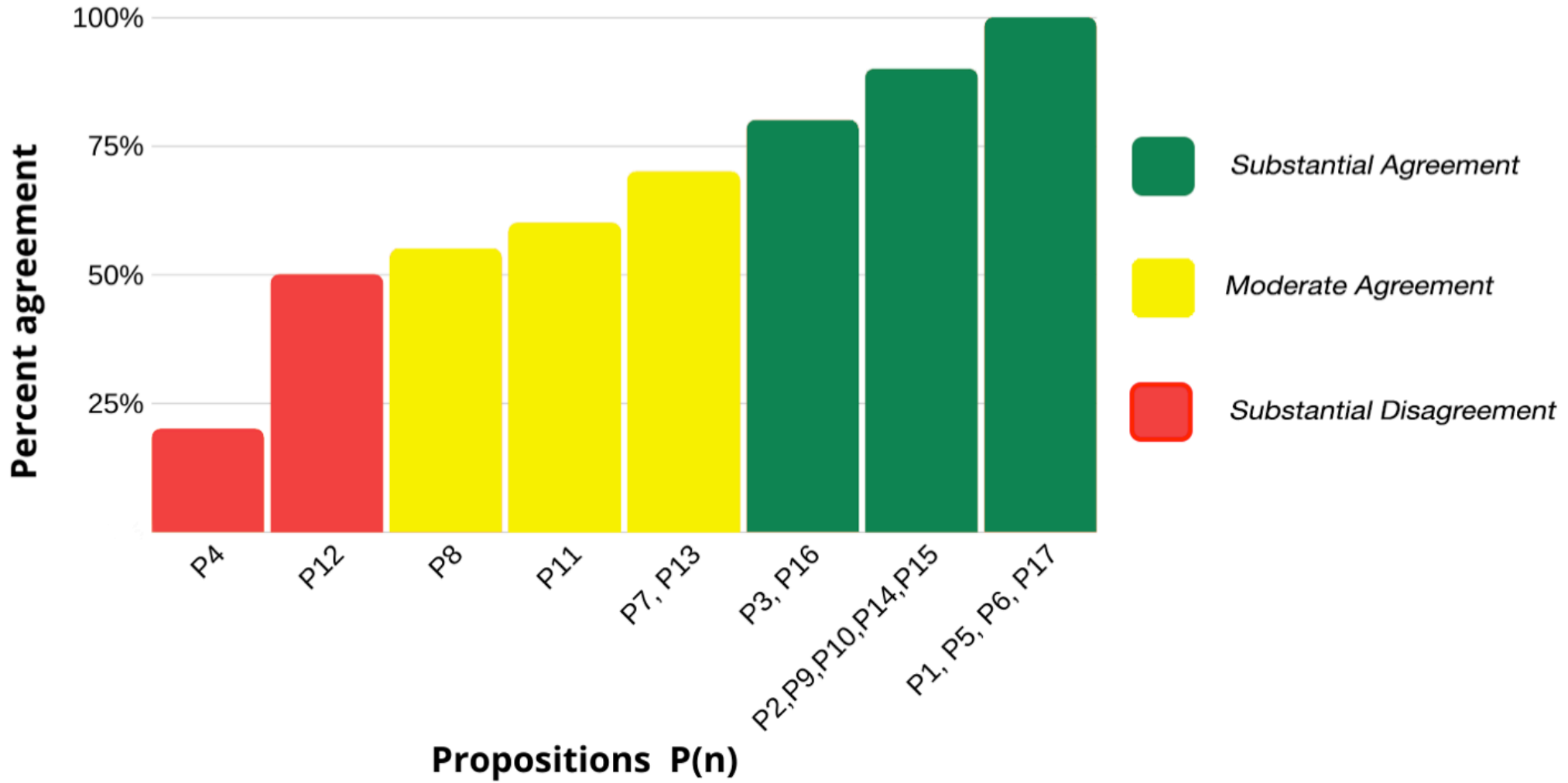
Task #2 - Apply a set of theory evaluation criteria

Testability	The degree to which a theory is constructed such that **empirical refutation is possible**.	**Acceptable level** -> empirical refutation is possible by **replicating the study**.
Generality	The breadth of the scope of a theory.	The generality is considered **low** -> Our planned future work will address this by broadening the scope.
Utility	The degree to which a theory **supports the relevant areas** of the software industry.	The utility is considered **high** -> The study **hit its intended audience**.

Task #3 - Validate the model with researchers in similar areas

- **We got some in-depth feedback from:**
  - Several graduates students of the *Reuse in Software Engineering (RiSE)* research group at Federal University of Bahia in 2018.
  - Visiting professors who work with Software Architecture and Testing in Software Engineering in 2018.
  - Three reviewers through a paper submission to an EMSE Special Issue on Software Engineering for Mobile Applications in 2019.

Task #4 - Validate the model with the practitioners involved



Percentage agreement gathered from the questionnaire about the propositions

Task #5 - Perform interviews with new practitioners

- **T5: A public institution of the government of Bahia (PRODEB)**
  - A10 **(Sac Digital)** is a **digital customer service** system for the Government of Bahia.
  - A11 **(Contrate Aqui)** offers a quality service in **finding the best proles** to be outsourced for the Government of Bahia.

#	Role	Experience (years)	Application	Development Team
I20	Solution Architect	10+	A10	T5
I21	Software Architect	10+	A11	T5

Refined Propositions

P2	The lack of at least technical documentation creates technical debt.
P4	Some non-functional requirements are not taken into consideration by the SE team when making design decisions.
P7	Failing to implement architectural decision creates technical debt.
P8	The architecture design of SCMA is mostly API-centric.
P11	The smart cities context adds complexity to a mobile app's backend.
P12	The development or adoption of smart city frameworks may reduce the complexity of the development of SCMA.
P13	The adopted development approach and its associated tools bring specific development challenges for SCMA.
P15	The lack of known automated testing tools for mobile applications negatively impacts the testing of SCMA.
P16	Training internal users positively impacts the acceptance of SCMA products.

Recommendations for the SE Team

1. Adopt agile methodologies.
2. Bring all stakeholders to the design decision meetings
3. Invest in training on new technologies
4. Adopt a SCMA framework when you are really going to use it.
5. Separate the eort required to plan and perform testing
6. Invest time in user training
7. Try Firebase Test Lab for testing the apps
8. Identify and evaluate those architectures widely used in SCMA.
9. Examine the architecture styles used to realize those SCMA architectures.
10. Native development approaches are more welcome by participants than hybrid approaches.

Conclusions

Contributions

- Empirical Data from a Multi-case Study
  - Intended to produce a larger **knowledge base of empirical data** more quickly than a single case study approach.

- Reverse-Engineered Architectures
  - Reverse engineering tools, such as **COVERT** and **ACME** were used to produce an as-built view of the architecture.

- A theoretical model of developing SCMA
  - The theoretical model with **21 constructs and 17 propositions** created using grounded theory

Research Products

- A paper published in the journal Empirical Software Engineering (EMSE)

Farias, Roselane Silva, de Souza, Renata Maria, McGregor, John D., and de Almeida, Eduardo Santana. ***Designing Smart City Mobile Applications: An Initial Grounded Theory.*** *Empirical Software Engineering, May 2019. ISSN 1573-7616.*

- Replication Package
  - An extensive replication package has been created and made publicly available on github (rose2s.github.io/EMSE2019)

Future Work

- Study Replications
- Deeper Architectural Analysis
- More refined theory evaluation
- A reference architecture for SCMA

Cidade inteligente: Salvador será a primeira capital com plano diretor de tecnologia

Contrato para a elaboração do plano foi assinado nesta quinta; projeto vai permitir gestão pública mais eficaz

Em momentos como o que vivemos, o jornalismo sério ganha ainda mais relevância. Precisamos um do outro para atravessar essa tempestade. Se puder, apoie nosso trabalho e **assine o Jornal Correio** por apenas R$ 5,94/mês.

Bueiros que enviam informações sobre a capacidade de escoamento, sensores para informar a qualidade da água e armazenamento de dados da prefeitura na nuvem, tudo isso é possível em uma cidade inteligente (smart city). Em breve, essas tecnologias podem ser implantadas em Salvador, que vai se tornar a primeira capital brasileira com um plano diretor de tecnologia na busca por ser cada vez mais eficaz nos seus processos.

Nesta quinta-feira (2), o prefeito ACM Neto assinou o contrato que dá início aos trabalhos de elaboração do Plano Diretor de Tecnologias da Cidade Inteligente (PDTCI) na capital. Ganhador da licitação, o Consórcio Salvador Smart City tem até outubro de 2020 para estruturar o plano. Esta primeira etapa recebeu um investimento de R$ 4,5 milhões. Já a implementação dos projetos terá uma aplicação de cerca de R$ 55,5 milhões com recursos captados junto à Cooperação Andina de Fomento (CAF).

O investimento vai permitir que a capital tenha uma nova estrutura de conectividade urbana para se tornar mais eficiente e econômica na gestão pública. O PDTCI tem como base o conceito de "Internet das Coisas", no qual a conectividade permite a comunicação entre os objetos da cidade e os usuários para a transmissão de dados em rede. Com a iniciativa, vão ser realizados diagnósticos multissetoriais e estipuladas metas de curto a longo prazos.

https://www.correio24horas.com.br/noticia/nid/cidade-inteligente-salvador-sera-a-primeira-capital-com-plano-diretor-de-tecnologia/

Questions?

rosesilva@dcc.ufba.br
esa@rise.com.br

Thank you!

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