FAKULTÄT FÜR INFORMATIK

DER TECHNISCHEN UNIVERSITÄT MÜNCHEN

Master's Thesis in Wirtschaftsinformatik

Living Lab Connected Mobility - Analysis and Description of Design Options for the Establishment of a Sustainable Mobility Ecosystem

Stefan Hefele

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Living Lab Connected Mobility - Analyse und Beschreibung von Gestaltungsoptionen für den Aufbau eines nachhaltigen Mobilitätsökosystems

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Date:	June 13, 2016

Ich versichere, dass ich diese Master's Thesis selbständig verfasst und nur die angegebenen Quellen und Hilfsmittel verwendet habe.

I confirm that this master's thesis is my own work and I have documented all sources and material used.

München, den 13. Juni 2016 Stefan Hefele

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Abstract

Transportation is reaching its limits in urban areas today, while world population growth and urbanization are further accelerating the difficulties caused by the wide adoption of individual motorized mobility. Public and private actors are seeking ways to enable smart solutions for future personal mobility, supported by digitalization which opens up a wide array of new possibilities. In Munich, the ”TUM Living Lab Connected Mobility” (LLCM) tries to research and develop a mobility platform and establish an ecosystem around it.
The goal of this thesis is to elaborate governance principles necessary to the establishment such a platform ecosystem. The main results is a set of alternative design options for the strategic establishment and growth of the TUM LLCM mobility ecosystem from a governance perspective.
A literature review in the areas of platform ecosystems and IT governance is conducted to define the vocabulary of platform ecosystems, their players and interconnections. A framework is subsequently derived from literature in order to be able to describe and analyze platform ecosystem governance in a structured manner. With the help of this framework, different successful platforms and ecosystems are analyzed and successful strategies extracted and compared. In a third step, these strategies are synthesized in order to come to two alternative design options for the platform ecosystem governance of the TUM LLCM.

Zusammenfassung

Die Verkehrsnetze in urbanen Regionen sind heutzutage an den Grenzen ihrer Belastbarkeit angekommen. Die wachsende Weltbevölkerung sowie die Urbanisierung tragen außerdem zur weiteren Verschlimmerung der Situation bei, die dem großen Anteil des motorisierten Individualverkehrs geschuldet ist. Öffentliche sowie private Akteure suchen deshalb nach Wegen, in Zukunft šmartereMobilitätslösungen zu ermöglichen, wozu die zunehmende Digitalisierung mit neuen Möglichkeiten beiträgt. In München erforscht und entwickelt das TUM Living Lab Connected Mobility"(LLCM) Wege, eine softwarebasierte Mobilitätsplattform samt Ökosystem dauerhaft zu etablieren. Das Ziel dieser Arbeit ist es, die zur Etablierung einer solchen Mobilitätsplattform nötigen Prinzipien der Governance auszuarbeiten. Das Hauptergebnis dabei ist eine Auswahl verschiedener Gestaltungsoptionen für den strategischen Aufbau und das Wachstum des TUM LLCM Mobilitätsökosystems aus einer Governanceperspektive heraus. Eine Literaturanalyse in den Gebieten Plattformökosysteme und IT Governance wird durchgeführt, um Begrifflichkeiten in diesem Kontext sowie die Akteure und Abhängigkeiten zu definieren. Anschließend wird ein Framework zur strukturierten Beschreibung und Analyse der Governance von Plattformökosystemen aus der Literatur abgeleitet. Mit Hilfe dieses Frameworks werden verschiedene erfolgreiche Plattformen und Ökosysteme analysiert, wobei erfolgreiche Strategien herausgearbeitet und verglichen werden. In einem dritten Schritt werden diese Strategien kombiniert, um zwei alternative Gestaltungsoptionen für das TUM LLCM Plattformökosystem zu erstellen.

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Outline of the Thesis

Chapter 1: Introduction

This chapter presents an overview of the thesis, its links to the TUM LLCM research and its purpose and research questions.

Chapter 2: Literature Review

Literature and research streams concerning platforms and ecosystems are reviewed in this chapter, leading to the definition of important terms, thus answering the first research question.

Chapter 3: Framework for Platform Governance

A framework for platform ecosystem governance analysis is developed in this chapter. This completes the answer to the first research question and serves as foundations for the next two chapters.

Chapter 4: Analysis and Comparison of Selected Platforms

The framework is used to analyze different platform businesses in this chapter. Successful strategies are identified with the help of this analysis, thus answering the second research question.

Chapter 5: Design Options for the TUM LLCM

The strategies from the previous chapter are combined to come to two alternative recommendations for the TUM LLCM in this chapter. This provides an answer to the third and last research question.

Chapter 6: Summary

This chapter summarizes the thesis and its major findings and contributions and also discusses its limitations and avenues for future research.

List of Abbreviations

API	Application Programming Interface
CPM	Cost per Mille
ETA	Estimated Time of Arrival
GUI	Graphical User Interface
ITS	Intelligent Transport Systems
LLCM	Living Lab Connected Mobility
MaaS	Mobility as a Service
MP3	MPEG Audio Layer III
MQB	Modularer Querbaukasten (Modular Transversal Toolkit)
MVV	Münchner Verkehrs- und Tarifverbund ((Public) Transport and Tariff Association of Munich)
OS	Operating System
RQ*X*	Research Question Number *X*
RTTI	Real Time Traffic Information
SDK	Software Development Kit
SLA	Service Level Agreement
TUM	Technical University of Munich
URL	Unified Resource Locator
US	United States (of America)
VW	Volkswagen
WP	Work Package

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1. Introduction

1.1. Motivation

"If we do nothing, the sheer number of people and cars in urban areas will mean global gridlock. Now is the time for all of us to be looking at vehicles the same way we look at smart phones, laptops and tablets: as pieces of a much bigger, richer network." [Fo12]. The fact that Bill Ford, chairman of the Ford Motor Company, and not a representative of one of the many technological start-up companies said this, already illustrates very well the greater problem that this work is embedded into. Transportation in modern cities is reaching its limits. The car is becoming more and more the "victim of its own success" [Fi12, p.1], while additional factors, namely world population growth and urbanization, are accelerating the phenomenon of increasing congestion.

The world's total population is expected to grow up to nearly 10bn people in 2050, of which about 66% are expected to be urban [Un14, p.7], which also leads to urban design, social and sustainability problems. Already today, congestion spills a considerable amount of resources. For example, in the United States (US) a single commuter using his car spilled an equivalent of 19 gallons (corresponding to about 72 liters) of fuel or $960 in the year 2014. In the same year, he was delayed by about 42 hours because of traffic jams on the way [Sc15, p.1]. Calculated for the US in total, this amounts up to 3.1bn gallons (about 11.7bn liters) of wasted fuel, additionally to the fuel required for uncongested driving, whose combustion pollutes urban areas even more. In 2011, 2.9bn gallons (about 11bn liters) of wasted fuel already produced 56bn of lbs (about 25,4bn metric tons) of CO_2 [SEL12, p.1].

In Munich, population will grow by 15.4% until 2020 as compared to 2013, which will further increase the number of trips per day within the city, already at about 7 million in 2015 [La15]. In Munich as well, motorized individual transportation has a very high share in these trips (about 44% in 2015 [La06]), leading to more and more overloaded roads.

Thus, public and private actors everywhere begin to seek for "smarter" alternatives to personal mobility. At this point, the mega trend of digitalization is expected to transform future transportation and personal mobility. Digitalization can help to make personal mobility a service [Bo15], like it has already transformed the way software is provided to consumers.

1.2. New Concepts for Mobility

As detailed above, transportation and personal mobility will have to become services, rather than products (like the car). For this approach, the term ***Mobility as a Service (MaaS)*** is used, which Intelligent Transport Systems (ITS) Finland defines as follows: ”Mobility as a Service is a mobility distribution model in which all users' major transport needs are met over one interface and are offered by mobility operators.” [IT15b]. MaaS thus describes an integrated, holistic ”one stop” perspective on personal mobility.
The term ”interface”, however, is not used in current literature, which uses the concept of ”platform” instead. Around such (mostly software-based) platforms, ecosystems of what the definition above calls ”mobility operators” and users should develop themselves. We will define these terms in Chapter 2.
In Bavaria, a research project called **”TUM Living Lab Connected Mobility (LLCM)”** was initiated in August 2015 to ”deliver innovative contributions regarding the design, the architecture, and the scalable realization of an open, vendor independence [sic] digital mobility platform” [Te16]. The aim is to create an ecosystem that leads to value cocreation, a phenomenon already observed in different IT platform contexts (e.g. [Ce12]). Research areas are ”Platform and Ecosystem Governance”, ”Platform Requirements, Business Models and Value Chains”, ”Platform Architecture and Core Services”, ”Use Cases” as well as ”Geospatial-Temporal Analytics” [Te16].

1.3. Scope of This Thesis

The scope of this thesis lies within the focus area (called ”work package” (WP)) of platform and ecosystem governance. Within this WP it should be investigated which governance processes and methods ”support the subsequent [permanent] operation of the mobility platform and the controlled evolution of the ecosystem” [Te16]. The thesis at hand contributes to this research by providing a broad analysis and description of design options for governing a mobility platform. In order to achieve this, three research questions should guide this thesis:

Research Question (RQ) 1: How can platforms, their players and interconnections be characterized according to existing literature?
Because of the many different research streams in which the terms ”platform” and ”ecosystem” have been used in the past, a systematic literature review has to be conducted in order to establish a common definition of these and related terms (components and actors of platforms and ecosystems, for example) for the focus of this thesis and the surrounding research project. A second part of the answer should consist of a framework or guideline for the examination of successful (software-based) platform ecosystems, as demanded by the following RQ2.

Research Question 2: What have been factors for the successful establishment of platform businesses in the past?

Guided by the results of RQ 1, successful (and maybe also unsuccessful) examples of existing platforms will be studied to come to a collection of ”success (failure) factors” or ”(anti-)patterns” of successful platform and platform ecosystem governance. Basis of this study can be the scientific body of literature, but also monographs as well as technical or popular literature.

Research Question 3: Which design and governance options do exist to successfully establish a mobility platform and ecosystem?
Building on the results of RQ 2, patterns or anti-patterns of platform and platform ecosystem governance success (resulting in success of the ecosystem as a whole) should be transferred and applied to the mobility platform under development. This should take the form of presenting (and perhaps recommending) different design options (preferably by using the analysis framework of RQ 1) for the sustainable establishment of the TUM LLCM mobility platform ecosystem.

1.4. Structure of This Thesis

The remainder of this thesis is organized as follows: in a first step to answer RQ 1, a literature review concerning platform ecosystems will be conducted in Chapter 2. The platform governance analysis framework, completing the answer to RQ 1, will be developed and presented in Chapter 3. In Chapter 4, this framework will be used to gain insight into the factors and possible patterns that helped successfully established platforms grow and sustain themselves. Also, negative examples could be included into this analysis to find ”anti-patterns” of platform (ecosystem) success, if possible (that is, if such examples can be found). The results of this chapter will provide an answer to RQ 2. Finally, the found factors and patterns will be applied to the case of the TUM LLCM mobility platform in Chapter 5 in order to recommend or reject certain design options for platform (ecosystem) governance. This will constitute the answer to RQ 3. Chapter 6 will sum up the findings of this work, review its contributions to theory and practice, as well as its limitations and implications for future research in this area.

2. Literature Review

In this chapter, the conducted literature review will be presented in order to clarify the terms of "platform", "platform ecosystems" and the related terms (components and actors, see Section 2.1 for a complete list) that are important to gain an equal understanding of the characteristics of (software-based) platform ecosystems. After describing the literature review methodology, results will be presented accordingly. Finally, the most important terms will be defined for the scope of this thesis.

2.1. Methodology

For the following literature review, the proceeding proposed by Webster and Watson [WW02] will be used. A literature review is necessary to gain an overview over the field of research and should lead to the development of theoretical models [WW02, p. xiv]. The concept-centric approach, comparing concepts rather than authors, of Webster and Watson's review method is especially well suited to achieve a desired common understanding. By describing different platform concepts, different streams of research clearly appear and can be described, analyzed and eventually merged into a common "current state" understanding.

There are three steps to identify relevant literature: identifying major contributions in leading journals, backward search and forward search [WW02, p. xvi]. Departing from major contributions found by searching in journal databases and tables of content, other relevant literature is uncovered by analyzing their sources. In the third step, citations of the literature found in other literature is analyzed (using the Web of Science) and eventually included into the set of literature.

By applying the review methodology within this thesis, several terms believed to be central to the topic should be defined, following RQ1: "How can platforms, their players and interconnections be characterized according to existing literature?" (see Section 1.3). The terms to be defined are the following:

- Platform
- Platform Ecosystem
- Complementary Software Application
- (Platform) Provider

Table 2.1.: Literature Databases

Name	**Link**
Google Scholar	http://scholar.google.de/
AIS Electronic Library	http://aisel.aisnet.org/do/search/advanced
Business Source Premier	http://search.ebscohost.com
Web of Knowledge	http://apps.webofknowledge.com
ScienceDirect	http://www.sciencedirect.com/
ACM Digital Library	http://dl.acm.org/advsearch.cfm
IEEE Xplore	http://ieeexplore.ieee.org/Xplore/home.jsp

- (Platform) User
- Platform Architecture
- Platform Governance

To identify relevant literature in the first step of the search process, several databases and search services, presented in Table 2.1 were consulted.

After gaining an initial overview over the topic, the search terms were set to the following: **platform**, **software(-based) platform**, **platform ecosystem**, **platform governance**, **two-sided market** and **IT value co(-)creation**. The last two search terms came from the insight gained after having read the first few research papers, revealing that many authors consider software-based platforms or ecosystems as being two-sided markets, or leading to the ”cocreation” of IT value. To capture these streams of research, even when not explicitly naming the construct ”platform” or ”platform ecosystem”, the two terms were included. The results of this first phase were analyzed and added to the body of literature if a) their content seemed relevant for the aim of this review, and b) if their content was freely available within the subscriptions of the TUM. Relevance was determined mostly by reading titles, abstracts and summaries of the search results. The papers found were then subsequently read (completely in most of the cases, only the ”results/discussion” sections in some cases) and classified into a scheme were, on the one hand, basic information such as type of research, key words and content was retained. On the other hand, definitions for the terms mentioned above were searched for and extracted. If the research did not give own definitions but cited those of other scholars, this was taken as a starting point for the backward search. Papers with definitions by the authors themselves served as basis for the forward search. Finally, this resulted in a set of definitions for each term. These were analyzed about their differences and commonalities and then merged into a final definition for the scope of this thesis. In some cases, where existing definitions were considered as suitable for summarizing all aspects, they were adopted. Contrary, if definitions were considered as describing a different stream of research, their aspects were omitted.

2.2. Results

Previous attempts to give a definition of the term ”platform” have identified three major research streams, which Baldwin and Woodard called ”product development”, ”technology strategy” and ”industrial economy” [BW09, p. 20-22]. Ghazawneh and Henfridsson identified two research streams, with product development as a research stream before the ”more recent platform research” that ”paints a somewhat different picture” [GH13, p. 175] compared to the former. Parker and Van Alstyne include all three research streams in their definition of a platform [PA08].
The first research stream that emerged brought up the notion of product platforms. In this context, the platform was the basis from which different products, resulting in a product family, could be derived by modifying features. An exemplary definition is given by citing Wheelwright and Clark, who state that platform products are products that ”meet the needs of a core group of customers but [are designed] for easy modification into derivatives through the addition, substitution, or removal of features” [WC92, p. 73]. Meyer and Lehnerd defined the product platform in their book as ”a set of subsystems and interfaces that form a common structure from which a stream of derivative products can be efficiently developed and produced” [ML97]. This concept thus focuses on reducing product development costs by creating a common product basis from which product instances can be derived, leading to the combination of ”scale economics and product differentiation at the same time” [GH13, p. 175]. A very famous example from practice is the ”Modular Transversal Toolkit” (”Modularer Querbaukasten” (MQB) in German) developed at Volkswagen (VW) in order to derive many different car models from one standardized undercarriage frame (see [WW14, p. 42f.] for a short description of the MQB).
The second research stream, technology strategy, focussing on technological platforms, defined them as ”valuable points of control (and rent extraction) in an industry” [BW09, p. 21]. Scholars of this stream examined platforms that were at the center of whole industries (like the computer industry ([Gr09]), or parts of it, like web browsers or chipsets [CG02, GC02, GC12]. These platforms are no longer internal to one company or part of a supply chain delivering parts of a specific product family (like in the VW MQB case), but ”developed by one or several firms, and [...] serve as foundations upon which other firms can build complementary products, services or technologies” [Ga09a, p. 54].
Finally, the third stream of research by industrial economists extends this view of industry platforms, putting the emphasis on the network effects that arise on such platforms with two or more groups of agents, making them ”multi-sided” ([BW09, p. 21], [RT04]). Network effects arise when the platform mediates transactions between those user groups that would otherwise not have been possible or at least very expensive. Evans calls the platform an ”economic catalyst” in this case [Ev09, p. 100]. Additionally, the presence of one group of users makes the platform more valuable to the other side, and vice versa. This is caused by positive indirect network effects, also called ”positive feedback” [SV99, p. 175f.], consisting of ”cross-group network effects”, which Hagiu and Wright define as follows: ”a cross-group network effect arises if the benefit to users in at least one group (side A) de-

pends on the number of other users in the other group (side B). An indirect network effect arises if there are cross-group network effects in both directions (from A to B and from B to A)" [HW11, p. 5]. Indirect network effects could also be negative. Additionally, there are also same-side, that is direct, network effects, which can either be positive or negative. For example, the more users a road has, the less useful it gets to each of them [Ev09]. Rochet and Tirole define the characteristics of multi-sided platforms as "products, services, firms or institutions that mediate transactions between two or more groups of agents" ([BW09, p. 21], based on [RT03]). However, a market (synonymously used for platform here) is only defined as two sided "if the platform can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount; in other words, the price structure matters, and platforms must design it so as to bring both sides on board" [RT04, p. 26]. Dimensions other than pricing have to be considered as well, such as regulating terms of transactions between users, control of users in other ways and monitoring of intra-side competition [RT04, p. 26] (for example, as a remedy for the negative direct network effects mentioned above).

In Table 2.2 the literature found is classified in a concept matrix according to the platform research stream it represents [WW02, p. xvii]. Some authors, in a first attempt to consolidate existing definitions, utilize aspects of two or even all three streams to define their understanding of a platform.

However, Baldwin and Woodard's classification of platform literature is not the only one. Gawer [Ga14] uses two categories to classify literature, namely "engineering design" and "economics" [Ga14, p. 1240]. She argues that platforms have been viewed as technological architectures within the former, as markets in the latter research category, which comes with limitations in both streams. "Bridging" the differences between both, she proposes an unified framework by defining platforms as "evolving organizations or meta-organizations that: (1) federate and coordinate constitutive agents who can innovate and compete; (2) create value by generating and harnessing economies of scope in supply or/and in demand; and (3) entail a modular technological architecture composed of a core and a periphery" [Ga14, p. 1239]. Furthermore, Gawer postulates that platforms can be sorted into a continuum of three types of platforms, shown in Figure 2.1: internal platform, supply-chain platform and industry platform, a classification she already employed in her 2009 book chapter, where she additionally mentioned "multi-sided markets or platforms" as a fourth type ([Ga09a, p. 47] in [Ga09b]).

In another paper Gawer and Cusumano [GC14] propose a slightly different classification by dividing platform research into two categories: internal and external platforms. Internal platforms comprise what Baldwin and Woodard call "product platform", but also the special case of a supply chain platform that is not entirely internal, but serves for the production of a family of products of only one firm with the help of its suppliers [GC14, p. 419]. External platforms, by contrast, are defined as "products, services, or technologies developed by one or more firms, and which serve as foundations upon which a larger number of firms can build further complementary innovations and potentially generate network effects" [GC14, p. 420]. It is not difficult to observe that this largely corresponds to

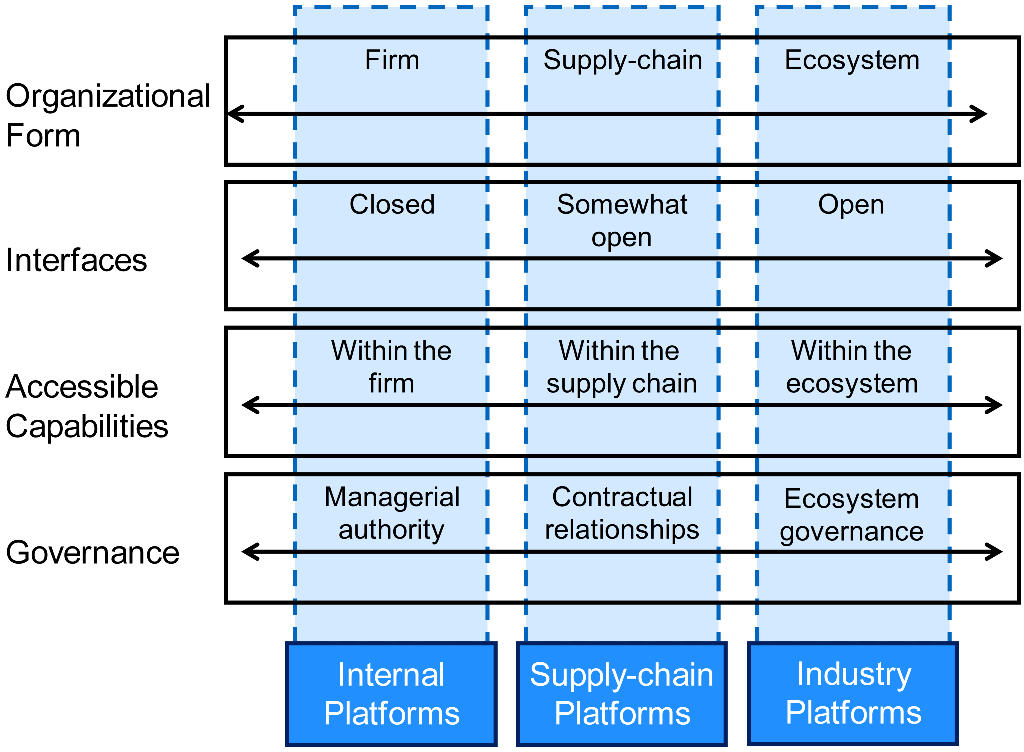


Figure 2.1.: Organizational Continuum of Technological Platforms, According to Gawer [Ga14, p. 1246]

an aggregation of the research streams ”technology strategy” and ”industrial economics” mentioned above. The difference between those two consists in the fact that not all technological industry platforms generate network effects, whereas not all two-sided markets (with network effects) are technological platforms (dating clubs and websites are an often cited example, see [GC14, p. 422], [Ga14, p. 1241], [ES05, p. 110], [RT04, p. 18] and [RT06, p. 651]).

Table 2.2.: Different Streams of Platform Research

Article	Platform research streams		
	Product development	Technology strategy	Industrial economy
Bakos and Katsamakas [BK08]			X
Baldwin and Woodard [BW09]	X	X	X
Basole and Karla [BK11a]		X	
Boudreau [Bo10]	X		
Boudreau and Haigu [BH09]		X	X
Ceccagnoli et al. [Ce12]	X		
Cusumano and Gawer [CG02]		X	
Cusumano [Cu10]		X	X
Economides and Katsamakas [EK06]			X
Eisenmann et al. [EPVA09]			X
Eisenmann et al. [EPVA11]		X	X
Evans [Ev09]			X
Evans and Schmalensee [ES05]			X
Gawer [Ga09a]		X	
Gawer and Cusumano [GC12]		X	
Greenstein [Gr09]		X	
Hidding et al. [HWS11]		X	X
Le Masson et al. [LMWH11]		X	
Parker and Alstyne [PA08]	X	X	X
Rochet and Tirole [RT04]			X
Rochet and Tirole [RT06]			X
Scholten and Scholten [SS10]		X	
Suarez and Cusumano [SC09b]	X		
Suarez and Kirtley [SK12]		X	X
Tatsumoto et al. [TOF09]	X		
Tiwana et al. [TKB10]		X	
Tiwana [Ti14]		X	X
Wheelwright and Clark [WC92]	X		

In the process of defining the term ”platform ecosystem”, it became visible that not only the existing research streams, categorized differently by different authors - some of which already incorporate the notion of external contributors or ”secondary developers” - exist to do so, but yet another stream of research, investigating the field of ”software ecosystems”. Surprisingly, this stream remained nearly uncovered using the search terms and databases described above. However, taking the systematic literature review by Manikas and Hansen [MH13] as a starting point, it becomes clear that their understanding of (sotware-based) ecosystems is fundamentally the same. Therefore, this work relies on the work by Manikas and Hansen to integrate the software ecosystems stream, and does not conduct a second literature review on software ecosystems. Table 2.3 gives an overview over the most employed software ecosystem definitions and their integration of terms to be defined here. The consolidated definition of a software ecosystem by Manikas and Hansen is the following: ”we define a software ecosystem as the interaction of a set of actors on top of a common technological platform that results in a number of software solutions or services. Each actor is motivated by a set of interests or business models and connected to the rest of the actors and the ecosystem as a whole with symbiotic relationships, while, the technological platform is structured in a way that allows the involvement and contribution of the different actors” [MH13, p. 1297f.].
Figure 2.2 illustrates the different classifications of platforms that were mentioned above.

Finally, the analyzed research streams also hold definitions for what are parts of platforms, platform ecosystems and which actors are present in such ecosystems. For example, Bakos and Katsamakos state that ”a two-sided Internet platform embodies a design, which defines the architecture of the services offered and the infrastructure that facilitates the interaction between the participating sides, and a set of rules, such as pricing terms and the rights and obligations of the participants” [BK08, p. 172]. Put in terms that are consistent with the rest of this work, this means that a platform consists of its architecture and its governance. This is also what Tiwana suggests for characterizing the constituents of platforms [Ti14].
A platform ecosystem is mostly defined as consisting of the platform, secondary software applications and, in some cases, the actors interacting with both and between each other. While Tiwana only names platform and secondary software applications (”Ecosystem: the collection of the platform and the apps specific to it” [Ti14, p. 7]), Scholten and Scholten also integrate the different actors into their definition: ”the platform ecosystem embraces (a) the platform provider, operating the platform and core platform offerings as well as mediating between service consumers and platform providers [note from the author: ”service providers” is most likely meant here, this is also what Scholten and Scholten describe in their paper a few lines later]; (b) the service ecosystem of complementary product and service providers enabling the ’whole’ customized solution as offered to (c) the customers” [SS10, p. 2]. Baek et al., when describing the Salesforce.com ecosystem, tap into the same direction by stating that ”the ecosystem consists of a platform provider (Salesforce.com), and the platform users. A platform user is categorized into a developer (i.e., a user en-

Table 2.3.: Definitions of Software Ecosystems [MH13]

Software ecosystem definition	**Corresponding platform terms**					
	Platform	Complementary Software Application	(Platform) Provider	(Platform) User	Platform Architecture	Platform Governance
Messerschmitt and Szyperski [MS05]		X				
Jansen et al. [JFB09]	X	X			X	X
Bosch 2009 [Bo09]	X		X	X		
Bosch et al. [BBS10a, BBS10b]	X	X	X	X		
Lungo et al. [Lu10]		X				
Manikas et al. [MH13]	X	X	X	X	X	X

gaged in the application development) and a customer (i.e., a user consuming the application created by developers)" [BKA14, p. 40].

Secondary software applications are not defined specifically in the most cases, such that concrete definitions could only be found by Tiwana et al. and Tiwana: "an add-on software subsystem or service that connects to the platform to add functionality to it" ([TKB10, p. 675], [Ti14, p. 7]). In his book, Tiwana adds other words for what is called "secondary software application" in this thesis, in an attempt to cover as much different manifestations as possible: "also referred to as a module, extension, plug-in, or add-on" [Ti14, p. 7].

Table 2.4 gives an overview over all sources that have defined - themselves, instead of adopting other author's definitions - all or some parts of platform, platform ecosystems, secondary applications and the different actors involved.

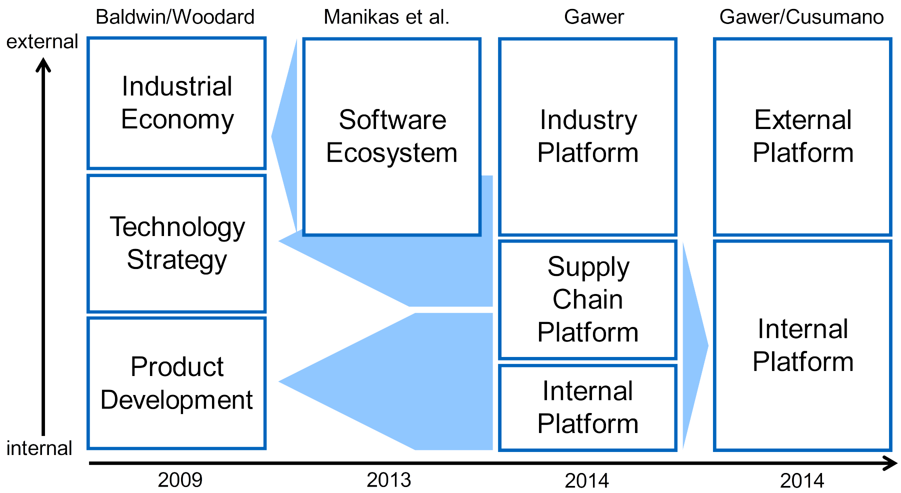


Figure 2.2.: Comparison of Different Platform Classification Schemes and Their Overlappings (Own Illustration, Based on [BW09], [Ga14], [GC14], [MH13])

Table 2.4.: Definitions of Platform Terms in Literature

Articles and Authors	Terms defined					
	Platform	Platform Ecosystem	Secondary Developer	Customer	Platform Architecture	Platform Governance
Baek et al. [BKA14]	X		X	X		
Bakos and Katsamakas [BK08]	X					
Baldwin and Woodard [BW09]	X				X	
Basole and Karla [BK11b]	X					
Boudreau [Bo10]	X					
Boudreau and Hagiu [BH09]	X					
Ceccagnoli et al. [Ce12]	X	X				
Cusumano [Cu10]	X	X	X			
Cusumano and Gawer [CG02]					X	
Eisenmann et al. [EPVA11]	X					X
Eisenmann et al. [EPVA11]	X		X	X		X
Evans [Ev09]	X			X		
Evans and Schmalensee [ES05]	X					
Gawer [GC12]	X					
Gawer and Cusumano [GC14]	X		X			
Greenstein [Gr09]	X					
Hidding et al. [HWS11]	X					
Jansen and Cusumano [JC12]	X	X				X
Le Masson et al. [LMWH11]	X					
Manner et al. [Ma12]						X
Parker and van Alstyne [PA08]	X					
Rochet and Tirole [RT04]	X					
Scholten and Scholten [SS10]	X	X				
Suarez and Cusumano [SC09b]	X					
Tatsumoto et al. [TOF09]	X					
Tiwana [Ti14]	X	X	X	X	X	X
Tiwana et al. [TKB10]	X	X			X	X

2.3. Definitions

After describing the different research streams and giving an overview of existing definitions in the previous section, the definitions for the scope of this thesis, i.e. for the scope of the sustainable establishment of a mobility ecosystem, will be presented in the following. As stated in Section 2.1, these definitions have been derived by merging existing ones while considering two aspects: first, all relevant aspects already mentioned by other scholars should be retained, and second, the definitions should be as general as possible while still having in mind the background of the mobility ecosystem to be developed within the TUM LLCM. The terms presented below reflect this careful consideration, also with respect to their proper names, which sometimes were divergent or conflicting in literature. Figure 2.3 presents a graphical representation of the terms defined in the following.

Platform

We define a software-based platform as the core of a digital multi-sided market. Within such markets, the volume of transactions characteristically not only depends on the overall platform fees, but also on the balance of their allocation to the different (market) sides [RT06, p. 646]. The core functionality is extensible, reusable and provides stable interfaces (architecture) and other rules for interaction (governance). A platform provider makes the platform available to secondary developers and customers (end-users).

Platform Ecosystem

A platform ecosystem consists of the platform, secondary applications developed for it, the actors providing, extending and using the platform and applications, as well as their interactions and the effects of these interactions.

Complementary Software Applications

A complementary software application is a ”software subsystem or service that connects to the platform to add functionality to it” [Ti14, p. 7, Table 1.1].

(Platform) Provider

The platform provider creates, configures and makes the platform available to the users. Configuring involves building the architecture and interfaces as well as implementing the governance.

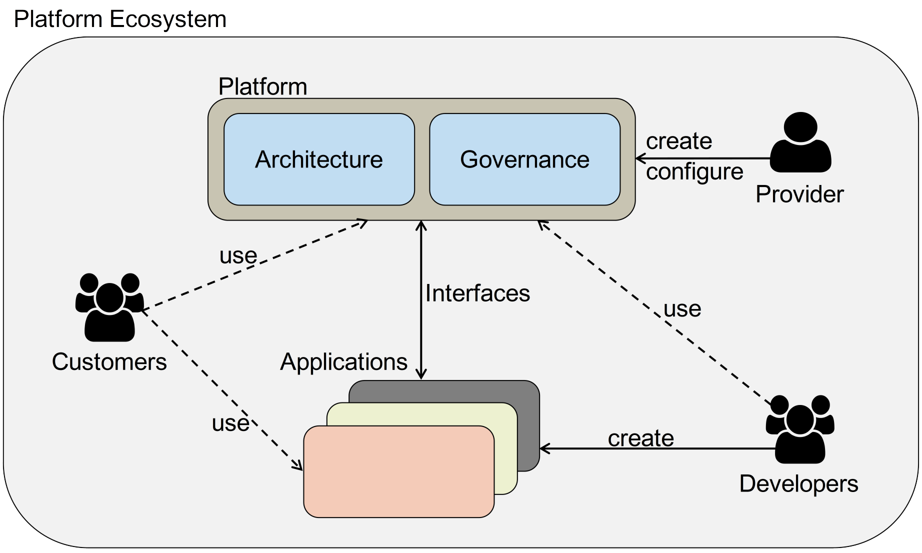


Figure 2.3.: Illustration of the Definitions of Components and Actors Within a Platform Ecosystem (Own Illustration)

(Platform) User

Users are ecosystem actors not directly involved in providing or sponsoring the platform. Developers are users who extend the platform's core functionality by adding complementary software applications. Customers are end users who customize the platform and its complementary software applications by "mix-and-match" [Ti14, p. 67] to meet their specific needs. Developers can simultaneously act as customers and vice versa.

Platform Architecture

A platform's architecture is comprised of high-level design rules for the platform itself as well as (preferably stable) interfaces that specify how secondary software applications can interact with it.

Platform Governance[1]

Governance essentially defines who decides what about a platform (ecosystem) ([TKB10, p. 679], [Ti14, p. 39]). We distinguish between platform governance and platform ecosystem governance. Platform governance comprises two dimensions: decision rights partitioning and the internal structure of the platform provider. Governance of the platform ecosystem additionally requires control and pricing strategies, aimed at customers and secondary developers.

2.4. Summary of Literature and Definitions

In this section, a literature review following the methodology of Webster and Watson [WW02] was conducted. The results are the following: First, there are three major "platform" research streams, who adopt product development, technology strategy and industrial economy points of view. Their definitions of the term "platform" seem incompatible at first sight; however, they share at least one common aspect: low variety and high reusability of core components on the one hand, high variety and low reusability of "complements" on the other hand [BW09, p. 25]. Second, there are different approaches to classify existing platform research streams and definitions by Gawer [Ga14] and Gawer et al. [GC14]. Third, there is an additional research stream concerning "software ecosystems" that shares many commonalities with "platform ecosystems". As there exists a peer reviewed literature review of this stream [MH13], this was integrated in our review to be sure not to miss important aspects. Altogether, this leads to "platform" and "platform ecosystem" definitions that integrate elements of all previous research streams, but have remained quite intuitive and short. All other definitions for elements connected to platforms and platform ecosystems were subsequently derived from mainly the same literature.

These definitions answer the first part of RQ1 (see Section 1.3) in that they consolidate the understanding of platforms in different research streams and provide a common understanding for the remainder of this thesis. To complete RQ 1, a framework for platform governance analysis is needed, which will be developed and presented in the following Chapter 3.

[1] The additional literature upon which this definition is based on will be described in 3 when designing the governance analysis framework

3. Framework for Platform Governance

The previous chapter answered the first part of RQ1 (see Section 1.3). In this part, a framework for the analysis of platform and ecosystem governance will be developed to complete the answer to RQ1.
The remainder of this chapter is organized as follows: first, the foundations of governance and IT governance will be shortly summarized, mainly with the help of an existing literature review on IT governance frameworks [BG05]. Second, platform governance analysis framework will be developed and described in detail. Finally, the framework will be reviewed for its ability to provide useful results for RQ2 and RQ3.

3.1. Foundations

In this section, a short overview of the terms "governance" and "IT governance" is provided to understand the framework detailed in the next section.
The term "governance" has many different and sometimes contradictory meanings [Rh07, p. 1246]. In a very broad definition, governance can be understood as the "establishment of policies, and continuous monitoring of their proper implementation, by the members of the governing body of an organization" [Bu16b]. Within the context of a company, the term "corporate governance" is mostly used, being defined as "the framework of rules and practices by which a board of directors ensures accountability, fairness, and transparency in a company's relationship with its all stakeholders (financiers, customers, management, employees, government, and the community)" [Bu16a]. Finally, on the level of IT, Weill gives a definition that was adopted also in a deep literature review of the IT governance field by Brown et al. [BG05] by stating that IT governance represents "the framework for decision rights and accountabilities to encourage desirable behavior in the use of IT" [We04, p. 2]. However, these definitions do not seem to be well suited in the context of a platform and its ecosystem as they focus on the "use of IT" within the boundaries of one company. This is not the case, or at least should not be the case if the platform is intended to draw on network effects, for platform ecosystems. Therefore, this term has to be defined separately, drawing on existing literature.
A first, very simplistic definition comes from Tiwana et al. (2010): "We define platform governance as who makes what decisions about a platform" [TKB10, p. 679]. This is detailed further by stating that "a platform's governance design can be studied from three distinctive perspectives: (a) decision rights partitioning, (b) control, and (c) proprietary versus shared ownership" [TKB10, p. 679]. Tiwana refines his definition in his book (2014),

now arguing that the dimensions of platform governance are: (a) decision rights partitioning, (b) control, and (c) pricing policies [Ti14, p. 119f.]. The replacement of ownership structure with pricing is not further justified. However, both dimensions, ownership and pricing policies, seem to play important roles for platform governance at first sight. Thus, the author concluded that an own definition of platform governance should not only cover a set union of the four dimensions mentioned, but also extend the pricing domain to other business related aspects as well, which is the reason for naming it ”business”. As the definition by Tiwana has formed the basis for, or at least influenced many other scholars' works (see [Ga14, GH13, Ma12]), it provides a good foundation for the framework in this thesis.
A justification for this assumption comes from the paper by Hein et al. [He16a], who also propose a framework for platform and ecosystem governance, which was published only after the elaboration of the framework presented here. A comparison between the two frameworks showed great conformity and is seen as a first validation. Although Hein et al. categorize elements of governance into more domains than the framework elaborated within this thesis, all factors (namely ”governance structure”, ”resources & documentation”, ”accessibility & control”, ”trust & perceived risk”, ”pricing” and ”external relationships”) of the former can also be represented in the four domains of the latter.
Before presenting the framework used to answer RQ2 and present RQ3 in Section 3.2, some clarification seems necessary in order to fully understand the difference between ”platform governance” as opposed to ”ecosystem governance”. Most scholars use these terms interchangeably, however, for the sake of clarity, this should be avoided. As stated in Section 2.3, we define platform governance as a subset of ecosystem governance that is concerned only with the platform itself and the actor providing it, without other actors or secondary applications involved. Thus, platform governance can be controlled by the platform provider alone. On the contrary, ecosystem governance also comprises governance structures and activities that try to exert influence or deal with actors and systems other than the platform. The main difference lies in the fact that secondary actors cannot be directly controlled by the platform owner via hierarchical power or authority [Ti14, p. 117]. Figure 3.1 illustrates our understanding of platform and ecosystem governance.

3.2. Framework

In this section, the framework for analyzing existing platform ecosystems' governance, based on the definition by Tiwana [TKB10, Ti14], will be elaborated and presented in detail. As a starting point, the four dimensions mentioned in Section 3.1 (namely ”platform provider structure”, ”decision rights partitioning”, ”business” and ”control”) were employed as columns of platform ecosystem governance, see Figure 3.1. This represents the merging of Tiwana's definitions. Subsequently, each column was filled with aspects derived from literature and logical reasoning as well as intuitive ideas that were reviewed with the help of literature.[2]

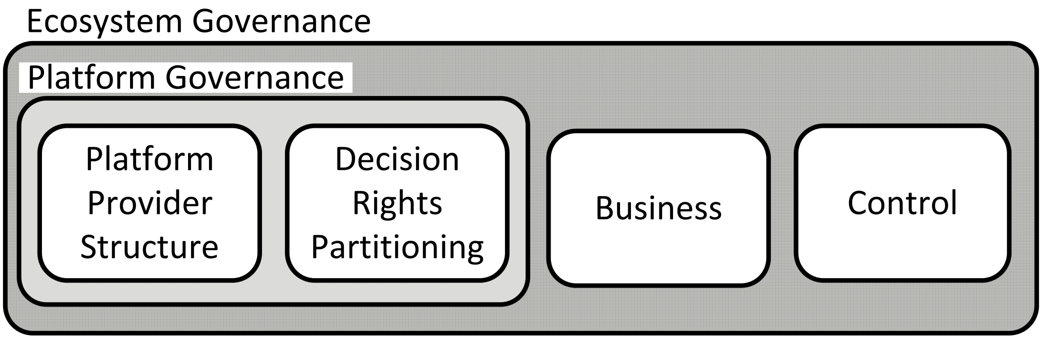


Figure 3.1.: Overview of Platform and Ecosystem Governance (Own Illustration, Based on [TKB10], [Ti14])

3.2.1. Platform Provider Structure

For the first column, the question is about the structure of the platform provider. First of all, there is an important distinction to be made: the term "provider" in this context denominates the entity that actually administrates and runs the platform. However, there exists another actor, the platform sponsor. This is the entity or person that is funding the platform provider, thus also indirectly the platform. However, he is not directly concerned with the allocation of decision rights, determining the pricing policy and controlling secondary developers (which he can influence though) [EPVA09, p. 132]. For the sake of simplicity and clarity, our framework will only consider the platform provider and consequently use the term provider (as opposed to [PA08], for example, who use "platform sponsor" instead for naming the same role). The main question thus is how the entity of the platform provider is organized, i.e. whether the provider consists of a single company or several. Second, the general characteristics of the platform provider may have its impact: typically, a start-up, whose whole existence depends on the platform will act differently than an incumbent, for whom the platform is only one source of revenue out of many. Follwing Tiwana [Ti14], the main characteristics were concluded to be: age, size, number of employees at the time the platform was started, and whether the provider was a start-up or an incumbent.

[2]In this chapter, as well as in the following one, the term "literature" will be used for both academic and technical literature.

3.2.2. Decision Rights Partitioning

In the second pillar of the framework shown in Figure 3.1, the division of decision rights between platform provider and secondary developers is discussed. This is mainly about three areas of decision rights: the platform itself, the platforms interfaces, and the secondary applications. For each of these areas, decision rights can be splitted differently between the two stakeholders: either completely residing on one side or taking the place ”somewhere in the middle”, which means that both sides have some sort of influence on the decisions to be taken in the domain. In order to visualize this column very easily, we adopted the ”decision rights partitioning framework” by Tiwana [Ti14] who introduces four classes of decision rights (platform and application decision rights, each divided into strategical and implementation-related rights). His visualization will not be adopted, but replaced with the symbols shown in Table 3.1. However, some additional textual information is necessary to fully grasp all aspects of this column for each analyzed platform.

3.2.3. Business

In a multi-sided market environment, pricing was long time considered as the only possible governance in an ecosystem [Ga14, p. 1244] - a perception that has been doubted more and more in recent literature [Ha07, EPVA09, BH09]. Therefore, not only pricing and its structure (that is the balance of allocating the charges to the different sides of platform [RT06, p. 646]) is considered here, but also other business aspects, namely the general business model of the platform, the strategy to achieve it, the overall market structure the platform and its ecosystem are placed within and the relations with the ecosystem's secondary developers. These relations cover incentives (for desirable behavior in the sense of the platform provider) on the one hand, and support (in forms of API (application programming interface) documentation, personal assistance, mailing lists or support forums) on the other side.

3.2.4. Control

Finally, the fourth domain of the framework contains control measures to be applied by the platform provider towards secondary developers. Control measures have been combined from different papers in literature: Tiwana [Ti14] names ”Gatekeeping”, ”Process Control”, ”Output Control” and ”Social Control” (the last one is also referred to by [Ma12]). Gatekeeping refers to a sort of ”access control” to the ecosystem. The platform provider thereby decides whether he wants to admit certain secondary developers to the ecosystem or not. As a result, some ecosystems are considered to be more ”open” than others (for example Google's Android versus Apple's iOS (see also [HKS15] and [BK10] for studies about the differences and similarities of the respective developers within these ecosystems)).

Secondly, process control denotes whether the platform provider insists on the usage of certain methods (for example agile programming frameworks like Scrum) when creating complementary software applications.
Thirdly, output control, or quality control, means the measures taken by platform providers to ensure quality and desirable characteristics of secondary developer's outputs (from the ecosystem's perspective, it could therefore also be called "input control"). Besides gatekeeping, this form of control largely contributes to the perception of an "open" or "closed" ecosystem. Tiwana et al. state: "open versus closed platform architectures therefore simply represent differences in input control exercised by a platform owner" [TKB10, p. 680].
Finally, social control refers to an "informal control" that builds on common values and beliefs that platform provider and secondary developers share and that are used by the provider to influence and guide their behavior ([TKB10, p. 680], [Ti14, p. 125]).
Additional to these four types of control, two other types have been added by other authors: Rochet and Tirole [RT04, p. 23-25] introduce the notion of "regulation of transactions" by the platform provider. The provider therewith exerts control over how secondary developers can interact with customers. They provide three different measures to achive this: by regulating prices (this can also be done by setting price levels among which developers must choose, like in the case of Apple, where there is no price level for apps between €0,00 and €0,99 [Eq16]), by acting as a licensing authority[3] (for example imposing minimal standards for advertisements) and by acting as a competition authority. Finally, Scholten and Scholten mention sanctional control, defined as the "coercive action up the exclusion of services or service providers"[4] [SS10, p. 4].
Control exerted over secondary developers will be represented by differently filled Harvey Balls, like shown in Table 3.1, accompanied by additional textual information about the reasoning behind the concrete instances.

3.2.5. Dependencies Between Domains

Having explained the different parts of the framework, it remains to discuss some assumed dependencies between them (see Figure 3.2). First, the structure of the platform provider might influence the division of decision rights between the platform provider and the other ecosystem members. One could think that a platform provider consisting of different entities would be more inclined to share decision rights also with secondary developers, as there exists a logic of collaboration already within the provider. However, this needs to be validated with the help of empirical studies. The structure of the provider might secondly also have an influence on business domain of the framework. This is mainly because a single provider with a single business model might want to focus on different aspects (for example types of users or secondary applications) that especially suit his needs, whereas a

[3] This aspect of regulation closely resembles Tiwana's quality/output control.
[4] This considers the exclusion of secondary applications and developers after admitting them in the first place, which means that this control is not the same as quality/output control and gatekeeping.

group of actors forming the provider will decide for a more balanced approach, requiring some sort of alignment of their interests beforehand. Third, the control portfolio established by the platform provider is dependent on the decision rights that provider and secondary developers have, respectively. The platform provider can only control areas where it can exert the corresponding decision rights. For example, if the platform provider states that the internal architecture of secondary applications do not affect their admittance or refusal to the ecosystem, it will not be able to justify the refusal of applications for that reason. Transparency and consistency between those two domains is of great importance, as we will explain in the next chapter with the example of Apple and the research by Eaton et al. [Ea15].

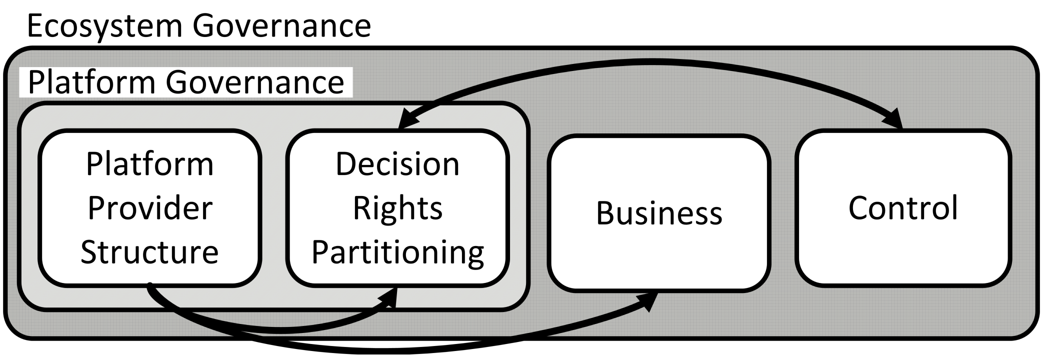


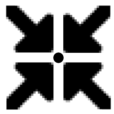
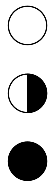
Figure 3.2.: Dependencies Between Parts of the Governance Framework (Own Illustration, Partly Based on [TKB10, Ti14])

The final framework with detailed columns is presented in Table 3.1. While the platform provider structure and the business domain will be filled with textual content, decision rights partitioning and control can be easier displayed figuratively. Decision rights can either be centralized (arrows pointing to the middle) or decentralized (arrows pointing outwards), a control can be used extensively (depicted by a filled Harvey Ball), to some extent (half-filled Harvey Ball), or not at all (empty Harvey Ball).

3.3. Summary of Governance Framework

In this chapter, the analysis framework for platform and platform ecosystem governance was developed and presented. After a short overview of the terms "governance" and "IT governance", the term "governance" was adapted to platform ecosystems. It was highlighted that there exists a difference between platform and platform ecosystem governance, where the latter comprises the former. Elements of platform ecosystem governance were derived mainly relying on previous work from Tiwana et al. [TKB10, Ti14]. This resulted in four columns of platform ecosystem governance: platform provider structure,

Table 3.1.: Platform and Platform Ecosystem Governance Analysis Framework

Platform provider structure	No. of Stakeholders Age Size Type	[Textual information]
Decision rights partitioning	Platf. strategic Decision Rights (DR) Platf. implemenation DR App. strategic DR App. implementation DR	 or 
Business	Market structure Business plan Strategy Pricing structure Incentives for Dev. Support for Dev.	[Textual information]
Control	Gatekeeping Regulatory activities Process control Output control Social control Sanctional control	 for each control

Legend:

centralized decision rights

decentralized decision rights

No control

Some control

Extensive control

decision rights partitioning, business and control. These constituents were detailed further and a possibility of presenting the results gained with help of the framework was presented. Thus, this framework completes the answer to RQ1 by providing a tool for the subsequent analysis of successful platforms and platform ecosystems and adding it to the definitions that were found through a literature review in the previous chapter. The analysis of existing platform ecosystems will be subject of the next chapter.

4. Analysis and Comparison of Selected Platforms

In this chapter, existing platforms and platform ecosystems will be analyzed regarding their governance. This will be done with the help of the framework developed in the previous chapter. The remainder of this chapter is organized as follows: first, the approach to the analysis will be described. Second, the results of the analysis of four different platforms and platform ecosystems will be presented, organized in three sections: Waze and Moovit (discussed in one section, as their characteristics are very similar), Apple and ITS Factory. The results will then be compared and successful strategies and patterns will be extracted. Finally, the section will be summarized and the answer to RQ2 will be given.

4.1. Approach

As already mentioned before, the framework from the previous chapter (see Section 3.2 and Table 3.1) will serve as a guideline for the analysis of existing platforms and platform ecosystems and their governance. Each unit of analysis will be described further in its own section, extending the overview with additional information and specific characteristics, as well as citing the sources that were used to obtain the results. These sections will be organized according to the columns of the governance framework.

There was no premature setting about which type of information source would be considered valid or invalid when analyzing existing platforms and ecosystems. Different types of sources were analyzed, as scientific literature concerning the specific cases is oftentimes delayed and thus not yet available. Therefore, technical literature as well as popular literature was taken into account besides academic papers. The most important source in most cases, however, was the information gathered from the provider itself. This was done by browsing the platform's internet presences and available artifacts, such as press releases, promotional or tutorial videos and developer documentations, to name just a few.

The selection of platforms to be analyzed was made according to two criteria: on the one hand, platforms in the selection should have an ecosystem according to the definition, see Chapter 2. On the other hand, platforms should operate in a context somehow related to the topic of personal mobility. Table 4.1 gives an overview of the platforms considered before selection.

The first platform considered, Alibaba, was finally not included as it did not fulfill the requirements. The analysis showed that, additionally to not being related to the topic personal mobility and traffic, there was no real ecosystem of secondary contributors around

it. Although many publications named it the ”Alibaba ecosystem”, nearly all important parts of it have been founded by Alibaba itself or acquired at a certain point in time. Thus, in reality, there is only one very large platform provider that provides all secondary applications itself (see [Re15] and [Ch14], for example).
Many other platforms did not have any connections to mobility, which is why only Apple iOS was selected, being the ”picture perfect” example for an ecosystem like defined in Section 2.3. Of all public and city-related mobility platform projects, ITS Factory was chosen, because it was the only one clearly building upon secondary developers from the beginning, which was not the case for others (Vienna) or not clearly visible yet (Kansas, Portland). The four platforms presented in the following thus fulfilled either both requirements (ITS Finland) or provided very good evidence for one of the two areas, respectively (Waze/Moovit, Apple).

Table 4.1.: Overview of Platform Businesses According to Criteria for Selection

Platforms	Selection Criteria	
	Mobility-related	Platform Ecosystem
Alibaba		
Ally	X	
Amazon		X
Android		X
Apple iOS		X
Apple iTunes		X
eBay		X
Facebook		X
Future Urban Mobility (MIT/Singapore)	X	
Google Search Engine		X
ITS Factory (Tampere, Finland)	X	X
Kansas City Living Lab	X	X
Microsoft Windows		X
Moovel	X	
Moovit	X	
Mozilla		X
SAP		X
smile (Vienna)	X	
Ubiquitous Mobility for Portland	X	X
Waze	X	

4.2. Waze and Moovit

In this section, the mobility platforms Waze[5] (see Figure 4.1) and Moovit[6] (see Figure 4.2) will be analyzed. These two platforms provide excellent evidence on the topic of mobility platforms as well as crowdsourcing, which will also be of major importance for the TUM LLCM. As stated above, the analysis will follow the columns of the governance framework developed in Chapter 3. Both platforms are presented together because they are very similar, as we will see throughout the presentation of the results. Before, however, the important notion of ”crowdsourcing” has to be clarified for the context of Waze and

[5]https://www.waze.com/
[6]http://moovitapp.com/

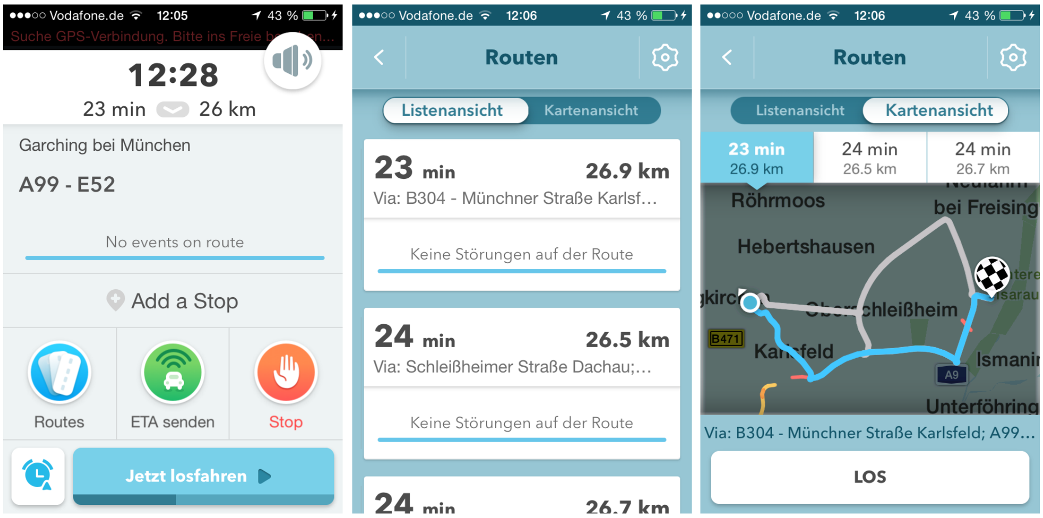


Figure 4.1.: Navigation Within the Waze App, With Routing Alternatives Displayed as List (Middle) and on the Map (Right) (Source: German Waze App)

Moovit. This will be done after presenting the general characteristics of both platforms in the following section, which will then help to define crowsourcing.

4.2.1. General Characteristics

Waze

Waze provides an app for smartphones that enables step-by-step navigation and real-time traffic information (RTTI). Traffic information is based on crowdsourced data, that is movement data of Waze users in certain areas as well as their manually supplied additional data (such as traffic density, road construction works or police/radar controls). With this data, Waze detects congestions on the route and suggests potential alternatives. Users of the app can register themselves as map editors to add missing information and rectify changed design and lay-out of roads. Additionally, Waze provides traffic data to public entities and broadcasters (mainly radio and TV stations). Revenue is generated by placing location-based advertising on the map. For users, advertisement-based financing of the application provides the advantage of free RTTI, which is not the case for most other gratuitous navigation services.

Moovit

Moovit provides an app for smartphones that is intended to improve the use of mainly public transportation. Users can plan their travel with public transportation and other selected mobility services (to be detailed further in Section 4.2.4). Similar to Waze, Moovit

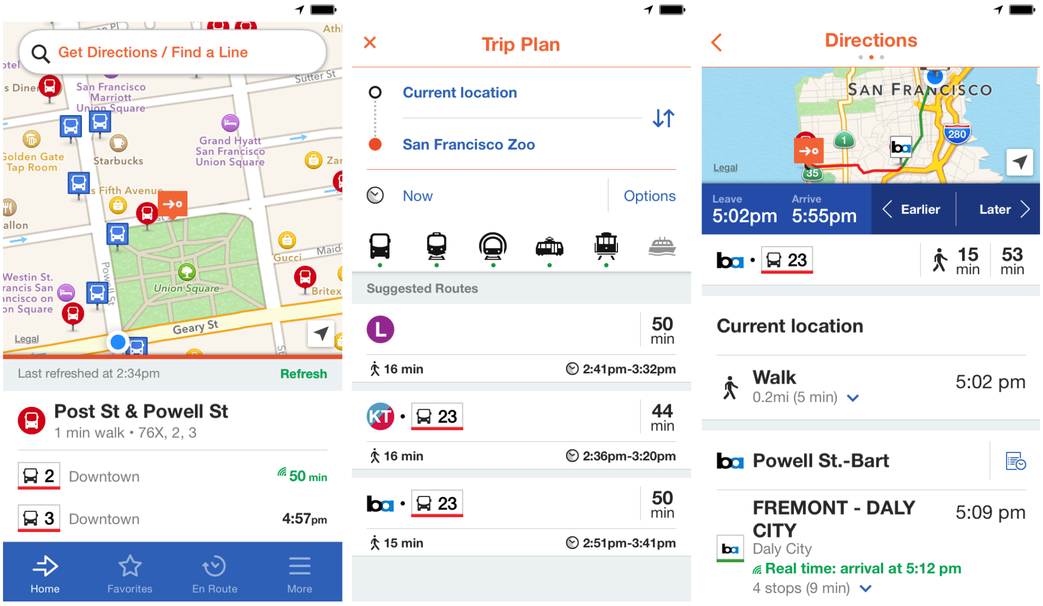


Figure 4.2.: Navigation With the Moovit App, With Stations Nearby (Left), Routing Alternatives (Middle) and Directions (Right) [Mo16e]

relies on crowdsourced data to add real-time information about delays, cancellations and other characteristics of individual trains or buses, like crowdedness, cleanliness and temperature. The data is captured by tracking the user's location, who can also contribute the additional information already mentioned. Users can also register as editors in order to edit or add lines, routes and timetables. Moovit does not generate any revenue yet, but plans do to so in the future by location-based advertising and commissions from transit agencies [Da15]. Added value for the user lies in the provision of real-time information not only on punctuality but also on crowdedness or friendliness of the bus driver, which can currently not be found in applications of most transit agencies.

4.2.2. Crowdsourcing

Both Waze and Moovit rely on so-called "crowdsourced" data to be able to offer their service. To define crowdsourcing, we follow Estellés-Arolas et al. [EAG12, p. 197]: "Crowdsourcing is a type of participative online activity in which an individual, an institution, a non-profit organization, or company proposes to a group of individuals of varying knowledge, heterogeneity, and number, via a flexible open call, the voluntary undertaking of a task [...]". For the case of Waze and Moovit, the task consists in tracking the own movement, either by car (Waze) or public transportation (Moovit) and thus making it possible for the platform provider to derive whether there are congestions or delays on certain routes and lines and give recommendations to other users accordingly. Further, the defi-

nition states that the ”undertaking of the task [...] always entails mutual benefit”. This is also the case for Waze and Moovit, as we will see when describing their business models, where their value proposition to customers as well as their ways of generating profits will be described.
However, there is one serious problem to be considered in the context of crowdsourcing: the absence of the crowd, or at least the presence of a crowd that is not big enough to allow the platform provider the derivation of an useful service. In the case of Waze, this can lead to traffic data being available only for major routes or being very outdated[7]. Both leads to calculation of routes that one would also have taken without using Waze (or using any other navigation software without RTTI), thus leading the idea behind it - avoiding congestion, ”outsmarting traffic” - ad absurdum. In the case of Moovit, the absence of a crowd to source from can also lead to outdated or wrong data and delayed arrival, which the author experienced himself: when planning a trip, Moovit showed departures for a bus line that were already four months old and not valid anymore. This led to missing a bus that only departs once an hour by ten minutes and to a trip of more than two hours instead of one hour. The problem here was that the public transportation agency does not share its schedule and line routing data, which then has to be maintained more or less manually by the crowd. In the city of Munich, this does not work very well yet: when registering for editor rights, it became visible that there were only ten other people active in a Google spreadsheet that manages the edits of bus lines for the whole region. In the Munich community of Moovit’s editor, there are currently 164 editors registered, most of which have not been active for more than six months (as of May 13, 2016). The German Moovit Facebook group, as another example, currently only has 48 members [Fa16]. Another result is that Moovit is currently available in only nine cities in Germany [Mo16b], as public transportation plans have to be constructed by the crowd where they are not available yet or where, like in Munich, the public transportation agency refuses to share them with external service providers. In summary, one could say that crowdsourced services without the crowd often lead to results that perform worse than the initial solution they tried to improve. Like the example above showed, Moovit’s promise of ”constantly updating the schedule, so you don’t get sent to a bus that doesn’t run” [Go16] does not hold true everywhere. Therefore, getting the crowd ”on board” is an often-researched problem (e.g. in [Ev09] or [GC12]).

4.2.3. Platform Provider Structure

In this section, the company structures of Waze and Moovit will be presented. Both companies share the characteristics of start-ups, although Waze has been acquired by Google.

[7] There is no use in knowing that there was a traffic jam three hours ago on the road you want to take now.

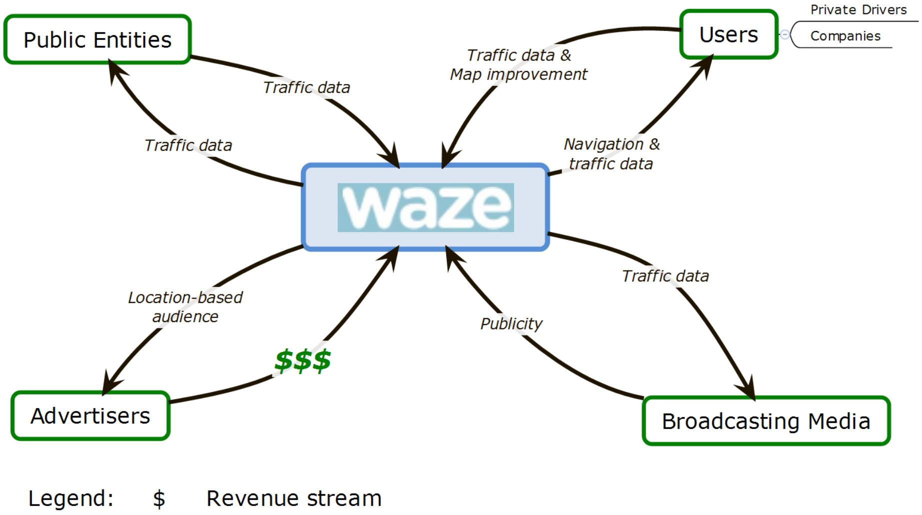


Figure 4.3.: Waze Business Model (Own Illustration)

Waze

Waze was founded in 2008 by Ehud Shabtai, Uri Levine and Amir Shinar in Ra'anana, Israel [Bl16]. After raising $67M in three rounds of funding [In16a], it was acquired by Google in 2013 for approximately $966M [Gr13]. However, it continues to operate as a single entity to this day. The number of stakeholders is thus limited to Waze itself. Currently, Waze employs about 120-200 people in Ra'anana and Palo Alto, US ([Qu13], [Li16]).

Moovit

Moovit was founded in 2012 by Nir Erez, Roy Bick, and Yaron Evron in Tel Aviv, Israel [Mo14]. It has subsequently raised $81.5M in three stages and launched its app worldwide in the last three months of 2013 [Mo14]. The last round of financing included partners like Nokia Growth Partners, BRM Capital, but also BMW i Ventures [Mo15, BM15]. Additionally, it received an undisclosed amount of investment from Sound Ventures in 2015 [Zi16]. It has not been acquired yet and thus remains a single entity as in terms of the platform provider structure. Currently, Moovit employs about 60 people in San Francisco and Tel Aviv [Mo14].

4.2.4. Business

Waze

The market for Waze's mobile application is in fact partly an existing one and partly a new one, created by Waze itself. The existing market is the one for route guidance systems with

turn-by-turn directions, as offered by many providers either via additional devices or via applications on the user's smart phone. This market can be considered as mature. Most of the existing devices and applications also integrate RTTI, derived from other users of the system and other data sources.[8] Thus, Waze cannot differentiate itself in this domain, except by the aspect of crowdsourcing (explained in Section 4.2.2): traffic data as well as additional information such as radar controls, detours and road works are generated by Waze's users. Additionally, Waze targets another market: daily drives that usually do not require any directions. In this market, Waze is even considered most useful ("Get the best route, every day"[9]). It can therefore be viewed as not (only) solving the problem of finding a destination, but finding the best way to the same destination every day.
Waze's business plan relies on the sale of hyperlocal advertising, which means giving advertisers the possibility of geographically targeting audiences [Vi14]. For users, Waze tries to deliver meaningful and accurate RTTI in order to avoid congestions on their daily trip. In exchange, users make their movement data availabe to Waze and provide additional information if they wish to do so. Additionally to those two user groups, there are relations to broadcasters and public entities, to whom traffic data is made available for different reasons: broadcasters like radio and TV stations can use the data for their traffic service; in exchange, they have to mention Waze as the data provider in order to "grow the community" [Wa16d]. On the other hand, information is provided to public entities like cities, counties or even police departments in exchange for other sources of real-time information not yet present on Waze [Wa16c, Un15]. Waze's business model, as it has been assumed from these sources, is illustrated in Figure 4.3.
Departing from the business plan, Waze's strategy appears very clear: users and broadcasters are combined into a virtuous cycle where more users lead to better data quality, which in turn attract more users and broadcasters, of whom the second further promotes Waze as it has to mention it in every traffic report when using Waze data. In a special case of users, companies like Lyft (a peer-to-peer ridesharing service), Cabify (a ridesharing service in Spain and other countries) and others use Waze for navigation (Waze Transport Software Development Kit (SDK) [Wa16h]), increasing the number of users by several thousand at once [Pe16]. Public entities are given the data for free as well - an offer they "cannot decline" [Un15] and which can be very useful if enough users assure good data quality. In exchange, Waze's data quality is enhanced by these entities' data which is also not available to competitors. As a side effect, Waze establishes close relations to administrations and governments [Un15]. Same-side network effects between these three groups of users are intended to lead to a network of Waze users as big as possible. Finally, revenue is extracted from cross-side network effects by selling hyperlocal advertisements to local businesses who can target users nearby by showing a pin on the map. Ads are deeply integrated into the application, such that a click on it shows additional information and even directions and calculated extra driving time for the case of visiting the respective location

[8] An example would be [Ga16a], section "Where does the traffic data come from?"
[9] https://www.waze.com/

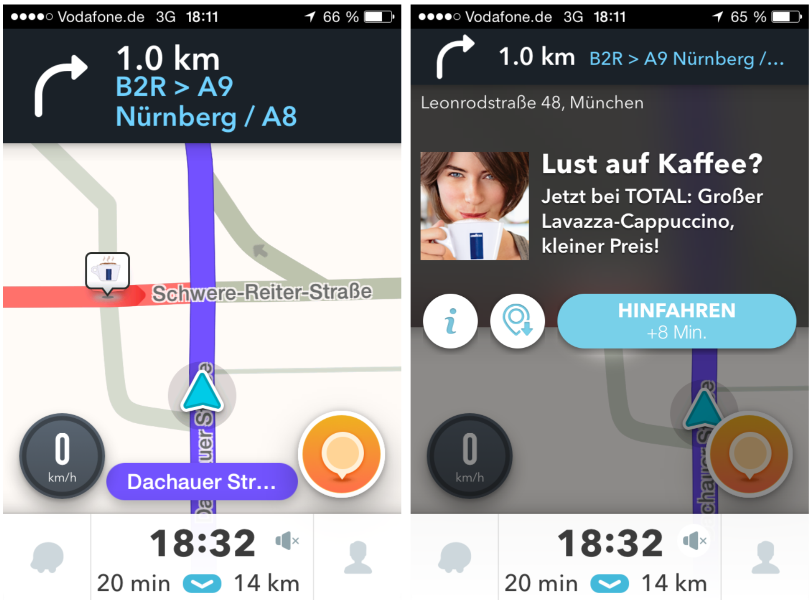


Figure 4.4.: Hyperlocal Advertising Within the Waze App (Source: German Waze App)

(see Figure 4.4).

As incorporated in our definition of platform ecosystems, the "volume of transactions characteristically not only depends on the overall platform fees, but also on the balance of their allocation to the different sides" [RT06, p. 646]. This is why the pricing structure is particularly important when examining platforms. In the case of Waze, only one of the four sides mentioned above is priced monetarily: the advertisers. All other sides "pay" with either their personal data (users) or data available to them (public entities) or by making the application known to a broader public (broadcasters). At least on the user side, this is not perceived as a constraint. The exact pricing structure towards the side of advertisers is not known and of subordinate importance, as it is mainly the pricing structure *between* different sides that matters. However, some characteristics are visible from Waze's website [Wa16b]. Advertisers can define a budget that specifies how much they are willing to pay for each 1.000 impressions (Cost per mille (CPM) or cost-per-thousand, see [Am16] and [Wa16a]). This decides on the appearance of their advertisement on the map (as a simple pin versus more advanced modes of display like logos or pictures). Additionally, they can define a monthly maximum budget that may not be exceeded. Advertisers pay only if their advertisement is displayed on the map; the minimum budget per month is $50. Advertisments appear within the application as already shown in Figure 4.4 and explained in the paragraph above. Additionally, advertisers appear "prominently" in Waze's search results and get a detailed activity report at the end of each month. This report contains the impressions and clicks the advertisement had as well as participants of possible special

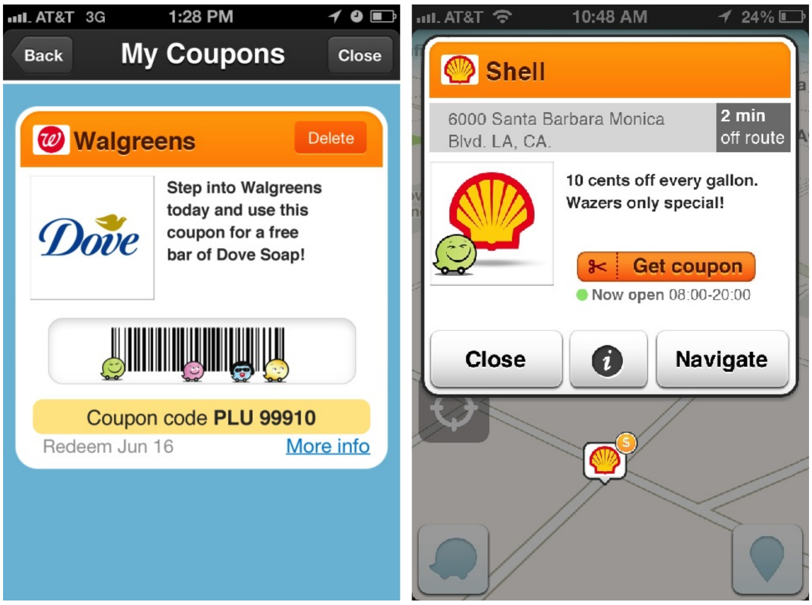


Figure 4.5.: Special Offers Within the Waze App [Ki12]

offers combinable with them [Wa16a](see Figure 4.5 for an example).

With the Waze Transport SDK, it is possible for secondary developers to integrate Waze into their own application. There are three main use cases for doing so [Wa16h]: integrating estimated times of arrival (ETA) and routing points into the map within your own app, letting the user switch to Waze easily to get navigation and improving one's own business by being able to predict arrival times more precisely (for example for package delivery or service technicians). While the latter provides an advantage for business users (see paragraph about Waze's strategy), the former only provides the incentive of having an easy and ready-to-use navigation application that can be integrated into one's own application in order to provide additional services for the users. Apart from this fact, the Transport SDK does not provide any possibilities to create own solutions or enhancements of the platform.

Waze provides all forms of support to its developers, map editors and also to its users. There is a "Waze Help Center", aimed primarily at users [Wa16e], as well as a "Community Wiki", aimed at map editors. For developers, using the Transport SDK and the API,[10] there is the respective documentation, which is rather short due to the limited functionality of the API. Additionally, there is a community forum where users and map editors can discuss their questions and receive announcements from Waze employees. Specifically for map editors and interested users, there are tutorial videos explaining the use of the editor

[10] The API only allows to open Waze through an external URL with some parameters such as search for an address, centering of the map to specific coordinates or starting the navigation to specific coordinates

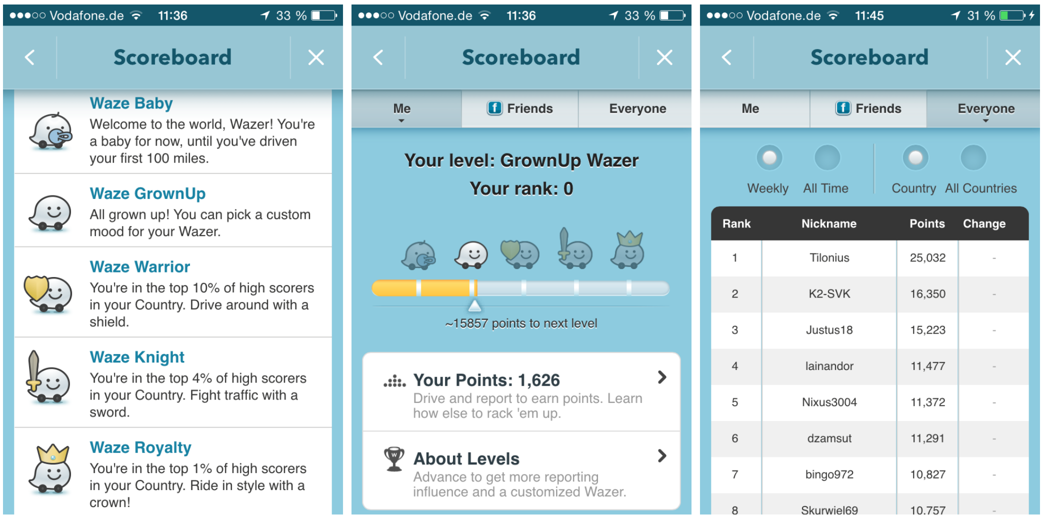


Figure 4.6.: Ranks and Scoreboard Within the Waze App (Source: Waze App)

and a ”tryout” editor where everybody can test the functionality without submitting the results into the production environment.
Finally, the incentives for users contributing more than only passively their position and movement can broadly be characterized with the notion of ”gamification”. Deterding et al. define the term as follows: ”’Gamification’ is the use of game design elements in non-game contexts” [De11, p. 10]. According to their classification of game design elements, Waze uses the level of ”Game interface design patterns”, where the examples mentioned are ”badge, leaderboard [and] levels” [De11, p. 12]. Waze users can collect points by many different mechanisms: by providing additional information (for example, reporting road-related information like traffic jams is rewarded by six points [Wa16i]), by reporting map problems, posting photos of specific locations and many more. There is also a specifically interesting concept: the so-called ”road goodies” appear on arbitrary locations on the map and can be collected by driving across this point in reality. This reward element is used by Waze especially in places where the exact course of the road is not clear and has been used in the map creation process to collect average speeds for different road segments [Na16b]. Taken together, the points collected by the users add up to a combined local scoreboard and rank system, the ”Waze Levels” (”Baby”, ”Grown-Up”, ”Warrior”, ”Knight”, ”King”, see also Figure 4.6). An important right granted for ”Grown-Ups” is the customization of the user’s avatar (”mood”) shown on the map and visible to other users (see Figure 4.7 for examples of Waze moods). Higher ranks require being in the top 10% (4%, 1%, respectively) of one’s region. Similarly, there are points and ranks for map editors, which comes with different editing rights: for example, new users (”Cone Rank 1”) can only edit in a radius of one mile around locations they have already visited with Waze turned on, whereas editors of cone rank three can edit an area of three miles around their visited locations. Ad-

Figure 4.7.: Waze Moods Available for "Adult Wazers" (Adapted From [Na16a])

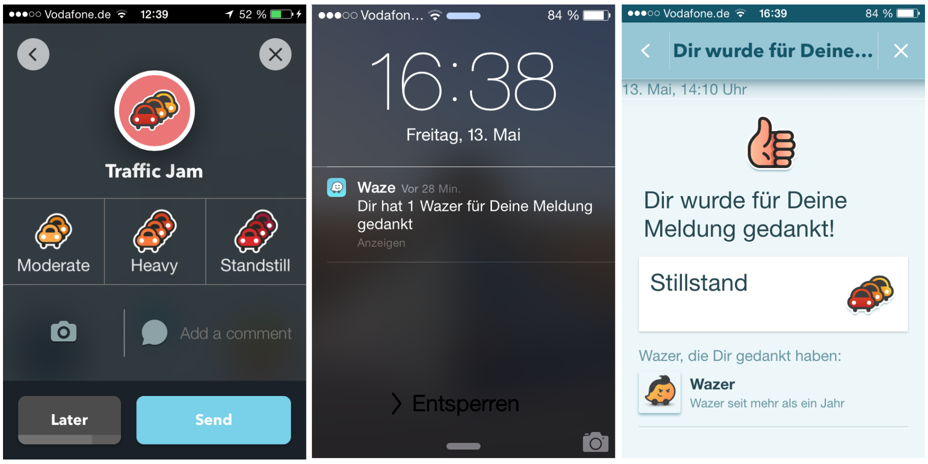


Figure 4.8.: Reporting a Traffic Jam (Left) and a "Thank You" Message for Doing so (Middle, Right) (Source: German Waze App)

ditionally, there are so-called "Forum Badges" that users can earn by completing specific tasks, like the "Wiki Master", awarded for "organizing, modernizing and updating the wiki" together with a member of Waze's staff. Finally, users can be thanked for reporting, which further incites to doing so (see Figure 4.8 for an example). Apart from gamification incentives, the rewards and especially the leaderboards and moods are desirable for users because of their visibility to the Waze community, which leads to higher prestige and reputation within the community.

Moovit

The market for applications that facilitate public transit planning used to be exclusive to the public transit providers, for example the "Münchner Verkehrs- und Tarifverbund" (MVV) in Munich. Because of this, many applications are restricted to one specific city or region that corresponds to the region the provider is operating in. There are of course

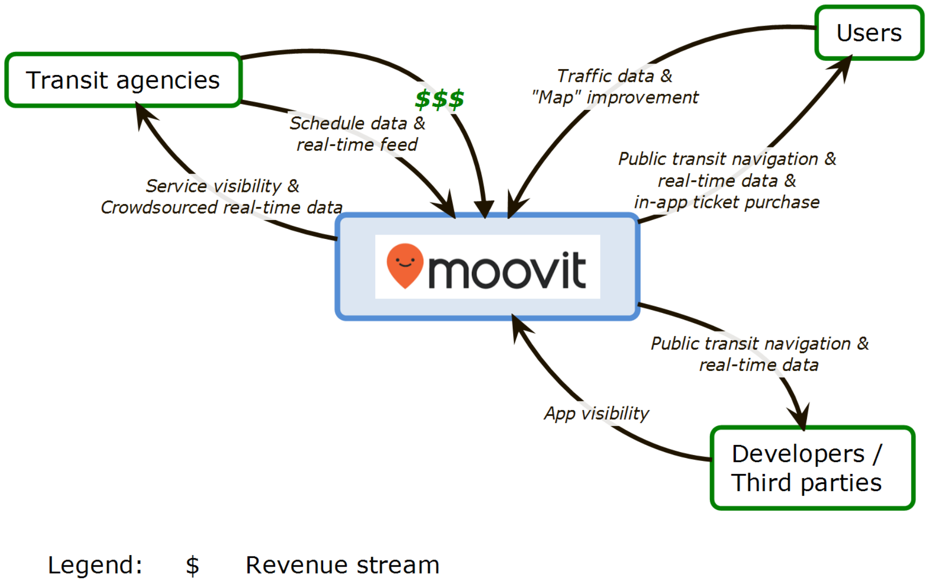


Figure 4.9.: Moovit's Assumed Future Business Model (Own Illustration)

examples of country-wide applications: "DB Navigator",[11] "moovel"[12] or "Ally"[13] are just some of them. However, Moovit is the only one that highly relies on crowdsourcing in order to provide its information to users. In the field of real-time information, primarily for the purpose of punctuality, it can be considered as a pioneer. User-generated information about delays and cancellation of trips can be much more precise than what established applications tried to implement in the past. For example, the "S-Bahn München" smartphone app[14] also tries to present a real-time visualization about where trains of Munich's S-Bahn currently are. However, this information is no real-time information based on actual location data of trains, but on data from certain points of measurement the trains pass on their way. Departing from this information, their current position (and delay) is estimated [S-16a]. Additionally, this information is based on train numbers, which leads to unavailability of the visualization in the case of cancellation of trips because train numbers then change, which the system cannot handle at this point - visible through the warning when opening the page [S-16b]. Thus, Moovit has the advantage of both knowing which line and trip the user is currently on, from which the delay can be deduced provided that he is using the "En Route" feature, and having him entering delay information manually. Concerning the relation to public transit agencies, Moovit tries to cooperate with as many

[11] https://www.bahn.de/p/view/buchung/mobil/db-navigator.shtml
[12] https://www.moovel.com/
[13] https://www.allyapp.com/
[14] http://www.s-bahn-muenchen.de/s_muenchen/view/fahrplan/muenchen_navigator.shtml

of them as possible in order to obtain schedule data. However, if transit agencies choose to provide no data or in case this data is not even centrally available yet, Moovit creates schedule data for whole cities and regions with the help of the community, like in the case of Munich's busses.

Moovit's business model is not clearly visible yet. According to interviews with the founder Nir Erez [Bi15], the Vice President Product Marketing Alex Mackenzie Torres [Da15] and the Country Manager for Germany, Jan Lüdtke [Wa15], Moovit has gathered "enough money for the next few years" (Erez), so that the application can be developed further and expand into more countries and cities without having to be profitable. In the long run, Moovit wants to generate profit from five business areas: integration of taxi services, cooperation with transit agencies in mobile ticketing, cooperation with carsharing and carpooling providers, cooperation with other businesses - Erez mentions the example of ordering and paying a cup of coffee at the place of arrival while still on the way, which would all generate commission revenues, as well as hyperlocal advertising, as Waze does. Departing from this information, Moovit's future business model has been assumed like shown in Figure 4.9.

Moovit's strategy is similar to Waze's, although the reasoning behind it is not completely comparable. In the case of Waze, less users in a certain area certainly diminish the usefulness of the app, as less traffic data is available for that area. However, the app does not become unusable. In the case of Moovit, areas without an active community and no schedule data available due to inability or reluctance of the transit provider can hardly be added to the list of supported areas. Adding these areas would require an amount of work that would possibly be too expensive for Moovit to carry out with interns. Thus, gaining more users around the world is vital for Moovit. In trying to attract users, it can rely on the same "same-side network effects" as Waze: more users in an area produce more crowdsourced data, which in turn makes the app more useful for others. To expand into new countries and cities, Moovit has to rely on the crowd to create schedules themselves where they are not available. At the moment, this seems to work quite well, as a new city is added every 24 hours according to Moovit's founder [Bi15]. Having acquired a large user base, Moovit can then acquire partners among taxi services, transit agencies and carsharing providers, as well as sell advertisements and provide additional services to local businesses.

Secondary developers can integrate Moovit into their own application in nearly the same way as they can with Waze - by two schemes that both direct the user into Moovit's own application: "Show nearby lines & stations" and "Get directions" [Mo16c]. As with Waze, this allows for easy integration of navigation directions into one's own app, this time for public transportation. Other possibilities are not available.

Support for secondary developers is as limited as the possibilities of integrating Moovit into own projects are: the only existing documentation components are the "Deeplinking Docs" [Mo16c] that explain how developers can link to Moovit's app by the methods described above. For users and map editors, there is a more detailed "Knowledge Base" [Mo16d] available that tries to answer all questions arising from using the application as well as editing lines and schedules. For registered editors, an additional "Community

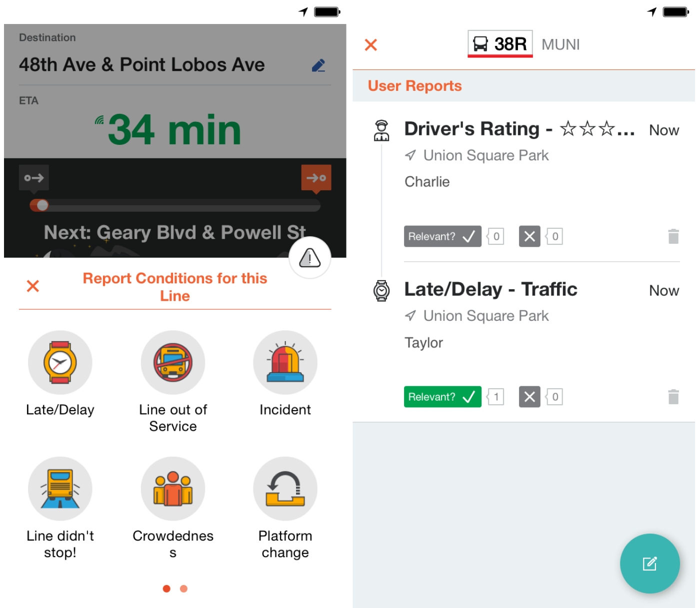


Figure 4.10.: Reporting Within the Moovit App (Left) and Overview of Reports (Right) [Mo16e]

Wall" is provided in order to communicate with employees of Moovit and post questions or suggestions. Tutorial videos are also available within the editor area. For users, gamification plays a large role also in Moovit. Users get points and derived ranks for reporting delays, crowdedness, temperature inside the vehicle or friendlyness of the bus driver (see Figure 4.10). Even the ranks or "levels" ("Newbie", "Traveler", "Driver", "Captain", "Pilot") are conceptually the same: beginning from the second rank, the user can choose his or her own avatar, higher ranks are defined as being in the top 40% (20%, 5%) of the user's country. Additional incentive for editors is the "Community Spotlight", where particularly active editors are presented to the community within Moovit's blog.[15]

4.2.5. Decision Rights Partitioning

Waze

The decision rights about the Waze platform, its APIs and the Transport SDK remain completely with Waze, that is, Google. As stated in the previous business section, there are no possibilities for secondary developers to add own functionality to the platform, interaction is reduced to standardized interfaces, controlled by the provider. This lead to the platform

[15] An example would be [Mo16a]

and secondary applications being completely decoupled and subsequently to full decision rights of secondary application developers over their applications. Decision rights over Waze's platform include also data ownership and setting of standard formats. In the privacy policy, Waze states that all information about the user is connected to his user name or device (if not registered), aggregated, and can be used for many purposes, including sharing with other affiliated companies [Wa16f]. This has been subject to criticism, stating that Waze was a "privacy accident waiting to happen" [Co13].

Moovit

As Moovit offers only one possible connection point to secondary developed applications, decisions rights between Moovit and secondary developers are restricted to the offered API. As developers have no influence on design and implementation of this interface, all decision rights about the platform, strategically and implementation-related, lie within Moovit. Similarly to Waze, Moovit does not influence decisions of secondary application developers about strategy or implementation of their application, as platform and secondary applications are decoupled.

4.2.6. Control

Waze

As Waze is based on crowdsourcing, or "wisdom of the crowd", as Dror et al. call it [DDD15], gatekeeping is unsurprisingly as low as possible for prospective users. All that users have to do in order to use Waze is downloading the app via App Store, Play Store or Windows Store onto their smartphone. Once installed, Waze is already usable without any further steps necessary. However, registration with email, phone number, user name and password is required if the user wants to get access to map editing and synchronize his data and trips across devices. Additionally, rights for map editors are much more restricted in the beginning, when having lower ranks, as explained in Section 4.2.4. For the user group of broadcasters, registration is more complex, as they have to fill out a "Partner Interest Form", accept the online agreement, after which Waze initiates personal contact with the prospective broadcasting partner [Wa16d]. Similarly, prospective advertisers have to fill out a form ("what is your biggest marketing challenge?") in order to get in contact with Waze. Brands are offered an additional information website with different solutions, success case studies and statistics about Waze's users driving behaviors [Wa16a]. Without possibilities for secondary developers of extending the platform, there is no need for regulatory activities of its provider. Regulatory activities towards advertisers are not known, and would definitely not make sense economically.
To the author's best knowledge, there is no process control in the sense that the development process of secondary applications is regulated. This is due to the fact that platform and applications are completely decoupled, as reported in previous sections. Thus, sec-

ondary application do only have to fulfill the specifications set by the API and the Transport SDK. The same reasoning apply to output control or metrics.
The element of social control is similarly not applied towards developers. However, contributors to Waze, that are map editors, can be considered being under some sort of social or relational control. Map editors share the common vision of "outsmarting traffic" with Waze, and thus can be influenced guided in their behavior [TKB10, p. 680].
Finally, there is only "straight forward" sanctional control towards secondary developers and map editors. Technical abilities allowing to exclude certain secondary applications from connecting to the API or using the Transport SDK are presumeably available at Waze, although conditions for this measure are not stated anywhere. For map editors, a simple deletion or blocking of the user account is sufficient in order to prevent users from accessing the platform. As usual, this is fully covered by their terms of service: "Waze retains the right to block your access to the Service and discontinue your use of the Service, at any time and for any reason Waze deems appropriate, at its sole and absolute discretion" [Wa16g].
To the best knowledge of the author, no users have been excluded yet, although there have been some security incidents by users that could entail such measures, for example in 2014, when Israeli students faked a traffic jam [At14], just like described by Jeske one year earlier [Je13].

Moovit

Moovit does not employ any type of gatekeeping control towards its prospective app users. As soon as the application is installed, it can be used. Creating an account or using one's Facebook or Google account is only necessary if favorite places, profile data or points acquired should be stored and remain synchronized across different devices. Also, gatekeeping towards secondary developers is not visible. Calls to Moovit's API have to provide the calling secondary application's name [Mo16c]; however, this seems to be intended for performance measurement purposes and not for denying access to specific secondary applications. The relation towards transit agencies is twofold: on the one hand, Moovit does not deny access to its network to transit agencies, as this facilitates its business model. Transit agencies partnering with Moovit will usually provide their schedule data, which comes with cost and time savings for Moovit, as these plans are available faster and in better quality and reliability than if they were community-created. On the other hand, some transit agencies seem to be very reluctant in partnering with Moovit - thus, gatekeeping by transit agencies towards Moovit is very common. An important reason for this behavior might be the fear of getting into some sort of dependency from Moovit, loosing "control" over own customers, or already having invested in own smartphone applications that are accepted by the users. Moovit tries to overcome this gatekeeping with the help of its community of editors. As a consequence, gatekeeping towards editors is nearly not existent: prospective map editors only have to provide email address and user name in order to get

access to the community.
Just like in the case of Waze, no process control measures are known to the author. Similarly, no output control or metrics are installed. The requirement of providing the calling secondary application's name with every API call seems to be the only aspect that could be used for that purpose, for example by tracking the frequency of recurring API calls of specific applications and demanding improvements if those calls lead to performance limitations for Moovit. However, no such case is known to the author.
Social or relational control is not exerted over secondary application developers that connect their own applications to Moovit's API, as these developers do not necessarily share Moovit's vision of facilitating public transit navigation, but simply use it in order to provide additional service to the users of their application. On the contrary, social control over users and especially the community of editors can be substantial, as the action of becoming an editor already implies identification with Moovit's vision.
Finally, sanctional control can be achieved by deleting or blocking accounts. This is not necessary for users, but can become helpful if their are malicious editors within the community that purposefully enter wrong information.

4.2.7. Summary

In this section, we have analyzed the two mobility platforms Waze and Moovit. Whereas Waze tries to improve personal mobility by car, especially daily commutes, Moovit's goal is to enable better use of public transportation. Both platforms are based on a crowdsourcing approach in order to provide their services: users share their location to enable the detection of congestions on the road (Waze) or delays of certain subway, bus, or tram trips (Moovit). Additionally, users registered as editors improve the existing maps (Waze) or transportation network data (Moovit). While Waze has been acquired by Google and seems to be profitable by selling hyperlocal advertising, Moovit is independent, financed by investors and currently not making money. However, their business model will also rely on hyperlocal advertising as well as commissions by taxi services, transit agencies and carsharing providers. Based on their crowdsourcing approach, both also apply equal decision rights partitions and control mechanisms.
We can thus conclude that Waze and Moovit share many similarities. The conclusions from this analysis for answering the second research question will be drawn in Section 4.5.

4.3. Apple

4.3.1. General Characteristics

Apple Inc. was founded in 1976 by Steve Jobs, Steve Wozniak and Ronald Wayne, who sold his 10% share 12 days later [Ra16]. Today Apple develops and sells a range of mo-

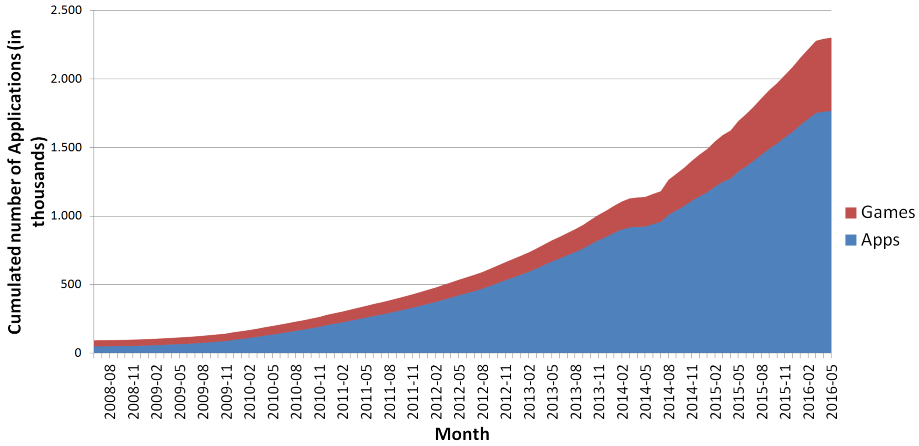


Figure 4.11.: Cumulative Number of Apps in the Apple App Store [Po16]

bile devices (iPhone, iPod, iPad, Apple Watch), laptops(MacBook) and desktop computers (Mac). All mobile devices (except Apple Watch) are running on the same operating system (OS), "iOS", which contains several built-in standard applications, such as camera, calendar, music, photos, messages and video calls [Ap16d] and allows the user to download and install additional applications via the official "App Store",[16] also built in on any iOS device. Currently, there are about 2.3M applications available (see Figure 4.11), making Apple state that "with the App Store, there's almost no limit to what your iOS device can do" [Ap16d]. In terms of market share, iOS is currently installed on about 16% of all smartphones worldwide ([Ga16b], see Figure 4.12) and has sold 231M units of its iPhone models in 2015 (see Figure 4.13). Apple's iOS platform and ecosystem has been selected for analysis because it is a "picture perfect" case within the scope of our platform ecosystem definition. Such extreme cases tend to be "prototypical or paradigmatic of some phenomenon of interest" [Ge06] and thus are very useful in this context to represent the case of an idealized (because tremendously successful) platform ecosystem.

4.3.2. Platform Provider Structure

Apple began its business with developing, producing and selling the first personal computers (Apple I, II and III) in the 1970s.[17] After commercially failing with one of the first graphical user interface (GUI) computers (Apple Lisa), it subsequently lost more and more market share in the desktop computer market and suffered losses because of expensive research for personal digital assistants (PDA). The return of Steve Jobs 1996, who had left the company in 1985, marked the return to profitability. He canceled several research projects, concentrated on fewer products and signed a deal with Microsoft in order to bring the Of-

[16] http://www.appstore.com
[17] This paragraph is based on information from [Ra16]

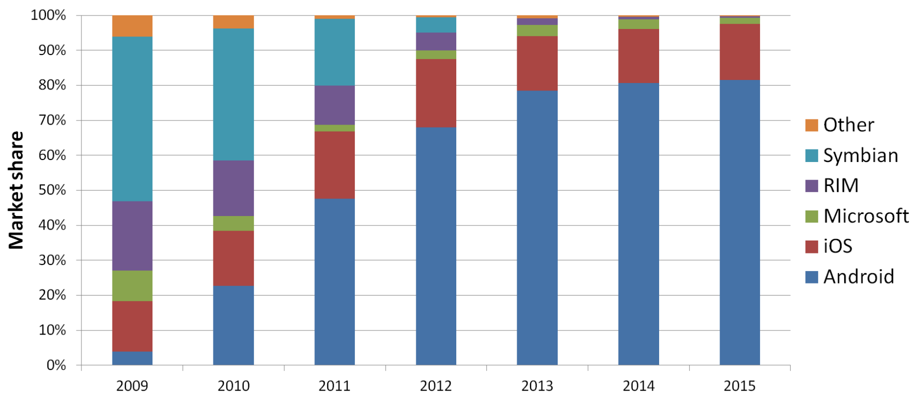


Figure 4.12.: Global Market Share Held by Smartphone Operating Systems From 2009 to 2015 ([St16, Ga16b])

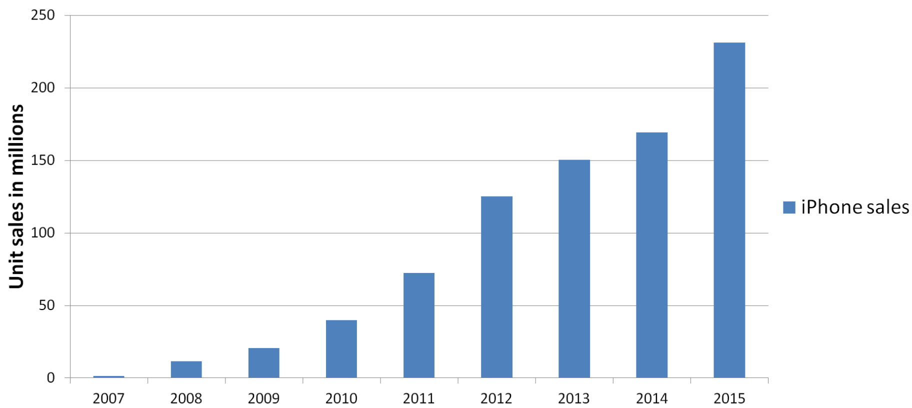


Figure 4.13.: Unit Sales of the Apple iPhone Worldwide From 2007 to 2015 [Ap15b, p. 25]

fice Suite to Macs, as Apple's personal computers were called by then. In the early 2000s, the iPod, together with Apple iTunes, revolutionized not only the portable music player industry but the music industry as a whole. In January 2007, the first iPhone was introduced, followed by the App Store in July 2008 [GH13, p. 182].
Currently, Apple is the world's most valuable publicly listed company with a market capitalization of $544bn (as of June 7, 2016 [Ya16]) and employs about 110,000 people (as of September 2015 [Ap15b, p. 7]). In summary, Apple thus is clearly not a start-up like Waze or Moovit, and already was a multi-national company when starting the platform ecosystem in 2008. However, it has always remained a radical innovator with a special corporate culture. This can at least partly be attributed to the person of the longtime CEO and founder, Steve Jobs (see for example [La11]).

4.3.3. Business

As shown in Figure 4.12, Apple's iOS platform ecosystem (called "iPhone OS" until version 4) is the second largest smartphone operating system in the world, currently (as of 2015 [Cy15]) being installed on about 475M devices (ranging from the iPhone 4 and earlier to the iPhone 6 Plus). The market share of competitor Google's Android operating system is more than four times as large - however, there are several manufacturers using Android, whereas Apple is itself the only device manufacturer using iOS. Therefore, iOS is the only operating system that is deeply integrated into the hardware in order to exploit the hardware's capabilities to a maximum - a fact that Apple uses regularly in marketing ("And because iOS 9 is engineered to take full advantage of the advanced technologies built into Apple hardware, your devices are always years ahead" [Ap15b]).
Apple's business model[18] is rather simple (see Figure 4.14) with the presentation of the first iPhone in 2007, it offered a technologically superior product with an appealing design and a radically improved user interface. The resulting user base was then used to attract first secondary developers that were offered access to this installed base. Thus, Apple solved the "Chicken-and-Egg-Problem" ([Ev09, p. 99] [Ti14, p. 41]) relatively quick and subsequently could rely on the indirect network effects that attracted more secondary developers the bigger the installed base of iOS users grew, and vice versa. Apple's business model thus generates revenue from (1) selling iOS devices to customers and (2) retaining a 30% share from every secondary application sale on its platform, the App Store [Ap16c].
Apple is one of the rare examples of platform providers that is profitable at both sides of the platform. On one side, secondary application developers have to purchase a license in order to get access to developer tools ($99/year for private developers, $299/year for a company license) and yield 30% of their application's sales to Apple. On the other side, customers buy an iOS device in order to get access to the ecosystem. However, in reality, revenue mainly comes from the customers, as they are the ones purchasing applications in the App Store and thus financing developers' as well as Apple's share - see Figure 4.15

[18] "Business model" in this context only refers to the business model concerning the iOS products and ecosystem, not Apple's business model(s) as a whole.

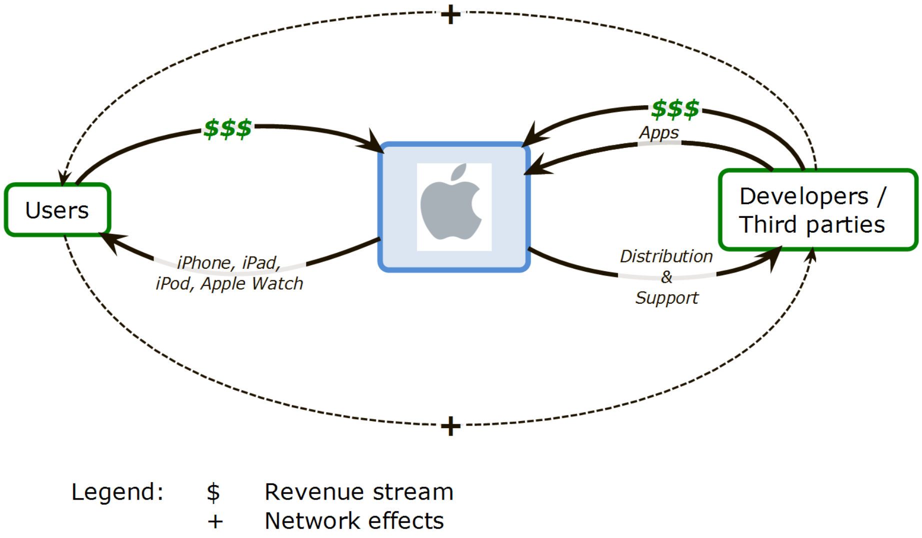


Figure 4.14.: Apple Business Model (Own Illustration)

for a visualization. The developer license price is comparably low and probably does not cover all costs of support and development arising from maintaining an ecosystem this large.

As indicated in the paragraph about Apple's business model, the strategy consists in preserving the virtuous cycle of indirect network effects between iOS users and secondary application developers. Thus, Apple develops new iOS devices with improved hardware nearly every year and additionally tries to expand the market of iOS devices to other product categories (as with the iPad for tablet computers). However, it remains to be seen if this strategy can be successful in the future, as iPhone sales have been declining in the first quarter of 2016 for the first time since the introduction of the iPhone in 2007 [In16b].

The main and probably most important incentive for secondary developers to join the iOS ecosystem is the direct access to millions of devices and its users. Like Steve Jobs put it when introducing the App Store: "[...] our developers are gonna be able to reach every iPhone user through the App Store" [GH13, p. 182]. From the beginning, Apple provided a SDK, including a development environment, graphical user interface builder and analysis tools for performance measurements and testing, together with APIs that gave access to core services (address book, file access, location services, net services) [GH13]. The SDK and APIs were substantially extended with the introduction of iPhone OS 3.0, where over 100 features and 1000 new APIs were introduced in order to give developers the possibility to use more capabilities of the hardware [GH13, p. 183]. Further characteristics of the SDK and APIs will be discussed in the next paragraph; it can be retained here that the well-built development environment is an incentive for developers. A third incentive is the higher willingness to pay of iOS users, compared to Android users [BSC15, p. 1212] and (at least

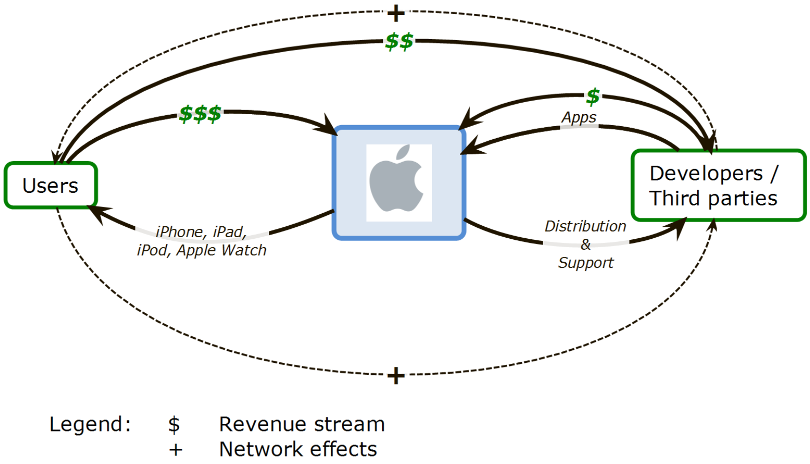


Figure 4.15.: Adapted Apple Business Model (Own Illustration)

in the past) more possible ways of monetization of secondary applications [Bu11a]. Support for Apple's developers is vast. Departing from the sheer number of APIs and their usable elements, about 13,000 as of iOS 9.0 [Sm15], support is structured in several layers: the first layer are overview pages on Apple's developer website, like the "Apple Developer Program" page [Ap16c]. They explain general features and modalities of the developer program. A second layer, still presented on well formatted web pages with corporate design, presents resources that are available to developers in more detail.[19] Clicking on different elements like "iOS" or "3D Touch" opens new pages with more detailed descriptions. On these pages links to the next and deepest layer, the documentation, also become available. Additional tabs at the top of the page link to the complete documentation,[20] support videos[21] or forums.[22] Thus, every developer can start at the level he or she needs, depending on his or her current knowledge. The quality and easiness of use of both development environment and documentation are highly recognized by developers [Bu11a]. Personal technical support "on code-level" can be requested twice per membership year [Ap16c]. Once the app is created and admitted to the App Store (the corresponding control will be discussed in Section 4.3.5), Apple provides full service - developers do not have to worry about hosting, distribution via the App Store, any administrative concerns or payment [Ap16c]. Thus, once a secondary application is admitted, the only thing the developers has to do is to figuratively lean back and wait for the money, as Apple does not charge any of its distribution services separately. In addition, analytic tools are provided for developers in order to better understand how users find their applications, how much

[19] https://developer.apple.com/resources/
[20] https://developer.apple.com/library/ios/navigation/
[21] https://developer.apple.com/videos/
[22] https://forums.developer.apple.com/

paying users the application has or how many times a day the application crashes [Ap16a].

4.3.4. Decision Rights Partitioning

Decision rights are clearly unbalanced in the iOS ecosystem, with strong bias towards Apple. Platform decision rights are completely centralized, strategical as well as implementational decision rights. However, the past has shown that in some cases, Apple had to change some parts of its control policies due to public pressure. Eaton et al. call this process "distributed tuning of boundary resources" [Ea15], where boundary resources best correspond to the columns decision rights partitioning and control of the framework used in this work. This has been the case both at strategical and implementational level. At strategical level, Apple allowed the distribution of native applications inside the iOS ecosystem by introducing the App Store. On an implementational level, APIs providing access to more of the hardware's resources were provided in order to incentivize more developers to join the iOS ecosystem [GH13, p. 23]. Apart from that, there exist decision rights that have never been influenced by developers and still remain in their status quo [Ea15, p. 223].

In the application domain, Apple does not have decision rights to be exerted directly over the work of secondary developers. However, as every application can be refused by Apple, strategic decision rights over what application can be distributed within the ecosystem remain, at least partly, with Apple. On the implementational level, quality control imposes a long list of requirements that applications have to meet in order to be admitted to the App Store. Therefore, decision rights for applications are not decentralized.

Apple uses the great power it has within the ecosystem to establish data standards and even new programming languages used for application development. Regarding data and privacy protection, Apple controls vast amounts of user data, which it seems to be protecting appropriately, however, as the "FBI-Apple encryption dispute" in 2015/2016 showed.[23]

4.3.5. Control

In this section, Apple's control measures towards secondary developers will be described. As the existing iOS ecosystem is very large, the controls are accordingly numerous, diverse and oftentimes rather complex.

Gatekeeping happens at two levels in the iOS ecosystem: secondary developers wishing to create applications for the iOS platform have to register for a developer account, which includes the payment of a yearly membership fee of $99 per single developer and $299 per company license. This is a rather low hurdle, compared to other ecosystems like the "SAP PartnerEdge Program for Application Development", where yearly fees start at €500 minimum [SA16]. The second level of gatekeeping is applied to applications, which have to

[23] This "Time" article gives an overview of the dispute: [Gr16]

pass Apple's review (see the review guidelines [Ap16b]). This is where applications that do not fulfill Apple's criteria are sorted out and not admitted to the App Store. These criteria have been largely disputed and are being avoided by certain developers to this day - by "jailbreaking" their devices in order to be able to install content that is not approved by Apple - however, they have only been adapted slightly and can still exclude secondary applications for a wide range of possibilities (see Eaton et al. for a description of the development of the app approval process [Ea15]). Not only can applications be excluded because they do not function properly [Ap16b, sec. 2] or do not use Apple's guidelines for user interfaces [Ap16b, sec. 10.3], but also because they mention the name of other platforms in their metadata [Ap16b, sec. 3.1] or use other systems than the "In-App Purchase API" for providing additional content [Ap16b, sec. 11.2] or simply because they contain "objectionable content" [Ap16b, sec. 16]. In the introductory statement, Apple tells the developers that it will reject apps "for any content or behavior that we believe is over the line. What line, you ask? Well, as a Supreme Court Justice once said, "I'll know it when I see it". And we think that you will also know it when you cross it" [Ap16b]. In the same passage, its own review board is named as the only possible means to appeal against rejection, because "if you run to the press and trash us, it never helps" - a statement that was already proven wrong at multiple occasions, as Eaton et al. note [Ea15, p. 239]. In summary, it can be observed that Apple uses the application review not only as quality control, but also as "strategy-driven restrictive product range management to avoid conflicts with its own base value contribution or with its own products" [SS10, p. 5]. As a result, however, the perceived and actual overall application quality level is significantly higher in the iOS ecosystem than for instance in the Android ecosystem [Bu11b, p. 5].

Apple did, and still does, engage in regulatory activities. This is also done via gatekeeping. In the past, the company has been protecting the interests of business partners like AT&T (American Telephone and Telegraph Company Inc.), which was the reason for denying access to the App Store for VoIP (voice over internet protocol) applications in 2009 [Ea15, p. 231]. Apple also engages largely in regulatory activities protecting its own business, stating that applications doubling core, built-in iOS functionality, thus not being "useful", will not be admitted to the App Store [Ap16b, sec. 2]. At the same time, however, Apple reserves all rights to "develop, acquire, license, market, promote or distribute products, software or technologies that perform the same or similar functions as, or otherwise compete with, any other products, software or technologies that you may develop, produce, market, or distribute" [Ap15a, sec. 11]. This elicits broad discontent with developers, like in 2011, when Apple announced a function to remind the user to pick up milk at a certain time, throwing companies that had developed similar functionality into insignificance from one release to another [Bu11a]. However, as there is no balance of power in the iOS ecosystem, influence of developers remains marginal.

Apple organizes its extensive output control of application via the "App Store Review Process", described in the paragraph above concerning gatekeeping. As mentioned by Eaton et al. [Ea15], this process has often been disputed, sometimes with successful outcomes for developers. The main difference compared to the Android ecosystem is the fact that

applications may only be distributed via the official App Store, whereto admittance is only given after quality control. With the successful establishment of the App Store in the years that followed its introduction (by consequently preventing "jailbreaks" with every new update of iOS [Ea15, p. 226] and thus rendering alternatives difficult and more and more irrelevant), the "only way in" is now solely controlled by Apple. This leads to higher quality and higher willingness to pay [BSC15, p. 1212], which can be considered as the reward for developers engaging in developing against these high standards. On the other hand, the unregulated access to the Android ecosystem with unlimited sources from where secondary applications can be installed leads to higher diversity of applications available to users, but lower quality and even danger of malicious applications [Bu11b, p. 5f.].
Social control is not prevalent in the iOS ecosystem, as it is very obvious for secondary developers that Apple's only goal is to generate as much revenue as possible, and that extensive support for developers is only a means to achieve this goal. Developers hence will most likely adopt a similar approach and strive to be as commercially successful as possible. Common visions or spirit like in open source communities is not visible in the iOS ecosystem.
As with all other formal controls, Apple retains a maximum of sanctional controls. This applies to applications, which can be excluded "for any reason", even when fulfilling the review guidelines [Ap14, sec. 6.5b], as well as developers, who can be suspended or excluded as a registered developer "at any time in Apple's sole discretion" [Ap15a, sec. 10].

4.3.6. Summary

In this section, we have analyzed Apple's iOS platform ecosystem. The ecosystem is based on the platform of iPhones, iPods and iPads that all use the same operating systems iOS. Secondary developers can gain access and sell to the users of nearly 500 million iOS devices by developing secondary applications for Apple's official App Store. However, Apple has always taken measures to ensure full control over the ecosystem and extract the maximum profit from it, leading to rather centralized decision rights and tight controls. This also leads to only high quality applications and applications not challenging Apple's business model being admitted. On the other hand, developers are incentivized with a wide range of support material and complete relief from all distribution-related activities. With this strategy, Apple has been extremely successful in the past. This success was based on an initially outstanding product (the first iPhone model) and a fast handling of the "chicken-and-egg problem" of getting both sides (consumers and secondary developers) "on board" when trying to establish a two-sided platform. Since then, positive indirect network effects as well as devices recognized for innovativeness and design (even hyped most of the time) have led to the continuous enlargement of the iOS ecosystem, making Apple the currently largest company in the world by market capitalization.

4.4. ITS Factory Finland

4.4.1. General Characteristics

The ITS (Intelligent Transport Systems) Factory is a mobility platform project in Finland's third largest city, Tampere, which is also the largest inland centre in the Nordic countries. Tampere has about 225,000 inhabitants itself, and about half a million in the surrounding region [Ci16]. The project, which was initiated in the years 2012 and 2013, mainly aims at opening up public and private traffic data in an "open data" approach, which means that data of "any operator, of high quality, in real-time, against free or at least fair standard conditions" [eP12, p. 2] should be available with "published interfaces and standard-based definitions" [KL13, p. 3]. It is organized as a joint initiative of the city of Tampere, regional and national transit agencies, companies, service providers and research institutions, like the two universities of Tampere [KL13, p. 2]. The city and transit agencies aim to provide as much data as possible to everyone via public APIs - like real-time bus positions, traffic light circuits and more.
ITS Factory thus represents a mobility platform that could evolve into an ecosystem, and is also mainly publicly financed. These similarities with the TUM LLCM make the ITS Factory an adequate case for this research.

4.4.2. Platform Provider Structure

The structure of the joint initiative currently consists of 32 private companies and 11 public entities [He16c]. It is assumed that the project is mainly financed publicly, however, the exact financing structure is not disclosed publicly. Similarly, the internal organization of the initiative is not visible from the outside, but it can be assumed that decisions are taken collaboratively, as there are many different parties involved. Decisions will definitely be more balanced than with only one single company involved, as cooperative discussion oftentimes leads to changed points of view. The characteristics of the ITS Factory initiative are thus neither that of a start-up company, like Moovit or Waze, nor that of an incumbent company, like Apple, simply because it does not act as a company, but as a sort of public-private partnership (PPP) for the purpose of promoting the development and use of open data concepts and developing new solutions with them.

4.4.3. Business

Before analyzing this domain, it should be clarified that, as the platform provider is an association of private and public actors and publicly funded, ITS Factory's goal is not to establish a profitable business. Still, some aspects can be described for every sub-domain. The market of the platform is currently limited to the city of Tampere (about 225,000 inhabitants on a surface of about 550km^2, about half a million inhabitants in the region [Ci16]),

as data is only available for this area. Nevertheless, this constitutes a sufficiently large market for developing and testing new ideas, concepts and applications.
As stated above, there is no business model in the common understanding to be analyzed here. The ITS Factory is organized as non-profit association, aiming at providing as much traffic and mobility data as possible to developers via public APIs. It does not expect any consideration for using the data, neither is there an obligation to return any of the data an application generates or gathers from users (like movement profiles or most used bus routes). The focus clearly lies on opening up public, but also private, traffic data sources. While the open data principle does not demand payment of any fees for using the data sources, developers can still monetize the secondary applications developed on their basis.
The strategy of the ITS Factory is to develop capabilities in the domain of data- and software-driven traffic and mobility solutions, and to "improve the awareness of Finnish ITS expertise", as the website of ITS Finland, one of the community members, states [IT16d]. The intelligent transport solutions developed and tested within the mobility lab can then present opportunities for internationalization and export for the companies involved [He16b]. Thus, the project constitutes a measure of promotion of economic development for local and national companies in order to develop capabilities that can be exported into the rest of the world and strengthen the Finnish economy.
Incentives for secondary developers are mainly the access to (1) data of quality and depth not available elsewhere and (2) a testing environment to experiment with these kinds of data. The access to freely available real-time and real-world data is a strong argument to start developing within the ITS Factory ecosystem. Resulting applications can be tested extensively in the so-called "sandbox"[24] and with real users. If successful, developers have access to a large number of potential customers in the third largest city and region of Finland. Furthermore, successful concepts can be transferred to other cities and regions once they also adopt open data standards and publish their data.
Finally, support for developers is mainly concentrated on documentation of existing APIs and information about future enhancements, for example in the developer newsletter. This information is organized in the form of a "Wiki", such that registered members can add and edit it [IT16a], as well as giving developers the possibility of connecting and interacting. There is also documentation about the different data format standards and justification of their use in the different APIs [IT16b]. Testing facilities in place for developers have already been mentioned in the previous paragraph. Additionally, there is support for searching and finding financing for application ideas [IT15a]. A common roadmap of all currently running projects[25] gives developers an overview of the ecosystem and the intentions of other actors, pointing out possibilities for collaboration.

[24] http://dev.itsfactory.fi/
[25] https://app.productplan.com/p/BPFJwPm28bZxuiU2Ljxn6kJe_y8ZbVA3

4.4.4. Decision Rights Partitioning

Departing from the information given within the developer wiki [IT16a], we can conclude that developers can play an active part in decisions about the platform, or at least give feedback about certain aspects. For example, in the newsletter 1/2015, developers were asked to name sources out of a list which they would find useful to be integrated into the traffic light API [IT15a].
Platform implementation decision rights, however, seem to be rather concentrated with the platform provider, more specifically by the City of Tampere or its delegates, like the University of Tampere, who defines what standards will be used for data formats and how APIs will be designed. The definition and usage of data format standards is considered very important and treated accordingly [IT16b].
Application strategic decision rights are completely with the provider, as the goal is to find new modes of transport and mobility services. On the implementation side of applications, the only restriction is the obligation to use the data formats imposed by the platform's APIs.

4.4.5. Control

In general, controls are purposefully very low for joining the ITS Factory ecosystem and using the platform. Developers should have access to all public data ”against minimum bureaucracy and formalities” [KL13, p. 1]. Thus, there is no gatekeeping, except the need for registration as an ITS Factory participant or developer. Additionally, access to some few APIs needs to be requested separately.[26]
To the best knowledge of the author, there is no process control or similar measures. Taking such measures would be contradictory to the goal of giving room for as much experimentation and creativity as possible to secondary developers.
Apart from some - presumably performance-related - access limits for certain APIs, for example a maximum of 5,000 weighted queries per hour and account for the ”TRE API Cycling” [IT14], there are no output controls or metrics which secondary applications have to pass. This is only consequent, as the real goal of the project, as mentioned above, are not outputs of high quality, but the development of capabilities in a ”learning-by-doing” approach.
While the vision of smarter urban transportation systems and new mobility services certainly unites platform provider and secondary developers, every party has also its own targets: public entities sponsoring the project have the goal of stimulating economic development, while many secondary developers, whether single one-man projects or software companies, will probably try to monetize their development in later stages and elsewhere. Companies acting as community members and providing funding will always supervise whether their investments are generating appropriate returns. Social control thus is possi-

[26] An example would be [IT14]

ble to a certain extent, but economic considerations will outweigh them at some point. Finally, there is no sanctional control envisaged within the ITS Factory ecosystem.

4.4.6. Summary

In this section, we have analyzed the initiative ITS Factory in the Finnish city of Tampere, which is mainly publicly funded and has many partners, public entities as well as private companies. Thus, its primary goals do not include establishing a successful business model. Its approach is to make as much data as possible available for developers. Therefore, controls are very low in order to allow for as much experimentation and testing as possible. However, when it comes to decision rights, the setting of standards for data exchanged are defined centrally in order to guarantee a maximum of standardization over the whole ecosystem.
ITS Factory deems itself being quite successful in terms of participating developers, where it grew from 40 developers in 2012 up to 200 in 2014 [Pi14, p. 5]. In terms of access operations to its APIs, ITS Factory has grown significantly, from on average 69 thousand access operations per day in May 2014 up to 353 thousand operations per day in May 2016 [IT16c].
ITS Factory comes the closest to the vision of TUM LLCM of establishing a mobility ecosystem that is open for all, not dominated by one or more privately owned companies. Its open data approach attracts developers because of the many new possibilities that arise from using "official" real-time data instead of relying on estimations based on user movement or feedback, like Moovit does. However, its success is not really measurable, as it currently is geographically restricted and does not guarantee any service level agreements (SLA) that would render the data usable for commercial purposes.[27] Also, questions of viability in the long term arise concerning its business model. It can be doubted that public financing will be continuous in a longer perspective, as governments tend to avoid long-term commitments on such projects. However, public financing can be an alternative.

4.5. Comparison

It has become visible that each type of platform considered and analyzed in this chapter employs different strategies to achieve its goals. These strategies will be presented in the following: ecosystem strategy, crowdsourcing strategy and open (public) data.
Apple's iOS turned out to be the only real ecosystem according to the definition developed from literature. Waze and Moovit do not provide developers with the possibility of really adding new services to their existing ones, and ITS Factory is not yet in the stage of being an ecosystem as applications are not distributed yet and mostly for testing purposes. Apple's ecosystem is based on an innovative product, the iPhone. In its development process,

[27]Source: email contact with Jukka Lintusaari, University of Tampere's School of Information Sciences

Apple incurred high initial development costs (not only for the product, but also for the built-in applications that showed what was possible with it), a typical process in establishing a platform, as Baek et al. noticed [BKA14, p. 44], to incentivize secondary developers to join the platform. The platform has two sides, customers and developers. Apple quickly managed to ”get both sides on board”, thus ensuring what Evans calls ”catalyst ignition” [ES05] and could subsequently rely on positive indirect network effects where more iPhone users (and later iOS users in general, including iPod touch and iPad users) make the platform more appealing to developers, which in turn leads to more available applications, attracting new users. Apple concentrates on developing a constant stream of improved devices and on maintaining the perceived high quality of available secondary applications, by applying mainly two control measures, gatekeeping and output control, both of which are also used for securing own interests, as many examples show [Ea15]. Apple’s tremendous success since the release of the first iPhone in 2007 suggests that this combination is an extremely fruitful avenue, although it might not be easily imitable.

The strategy employed by Waze and Moovit relies on crowdsourcing. Its basis is not a product, but the idea of an innovative and useful service. It uses smartphones as devices to deliver the service as well as collect data from its participants, thus in fact creating a platform on top of these smartphone platforms (like Apple’s iOS). In order for these services to work properly, they have to acquire a large user base, which is why the strategy relies on a maximum of visibility (Waze partnering with broadcasters which have to mention their data source in every traffic report) and a gamification approach to foster user retention and incite them to share additional information. Business models of Waze and Moovit (although the latter has not been profitable yet) rely on hyper-local advertising, a fact that could limit the indirect network effects attainable with these business models [HJT16, p. 45]. This leads to a pricing structure where profits are made on only one side of the platform (advertisers), whereas the service is free in a monetary sense for users, who agree to provide their data, of course.

The third strategy observed, employed by the ITS Factory in Finland, is based on making available data to developers and other interested parties that was disclosed before. Currently, this includes bus location, traffic flow, parking, weather data and many others. The goal behind this open data strategy is in fact the political will to enhance domestic innovativeness in a special technological area with good future prospects by providing a ”playground” for experimentation with data that will most likely become available in more and more cities and areas of the world in the near future. To provide open data in the first place, high investments from mostly public entities are necessary. In order to develop into a full ecosystem, two steps are required: First, commercial usability of data has to be ensured, mainly by guaranteeing SLAs towards secondary applications. Only then can applications attract users and start a virtuous cycle of indirect network effects. Second, in order for the ecosystem to grow further after all public data has been made accessible, data of applications has to be ”played back” to the platform to some extent, which further enlarges its data pool. This recommendation will be detailed in Chapter 5.

Finally, Table 4.2 gives an overview of the analysis results of this chapter.

Table 4.2.: Overview of Analyzed Platforms' Governance

	Waze & Moovit	**Apple**	**ITS Factory**
Platform provider structure	Single company < 10 years old < 200 employees Start-up	Single company 40 years old 10.000 employees Very large incumbent	Large association < 10 years old No direct employees Publicly funded research project
Decision rights partitioning	(Waze / Moovit) Platf. strat. centralized / centralized Platf. impl. centralized / centralized App. strat. decentralized / decentralized App. impl. decentralized / decentralized	Platf. strat. centralized Platf. impl. divided/contested App. strat. divided/contested App. impl. divided/contested	Platf. strat. divided/contested Platf. impl. centralized App. strat. decentralized App. impl. decentralized
Business	Personal mobility market Based on crowdsourcing Revenue generation with advertizing Gamification Documentation, Wiki, Forums	Smartphone/Tablet market Based on strong ecosystem Revenue through devices and commissions Access to large ecosystem Documentation, Extensive support, full service for distribution	Personal mobility market Based on open data No revenue Access to real data Documentation, Wiki, Forums
Control	(Waze / Moovit) Gatekeeping ◐ / ○ Regulatory act. ○ / ○ Process control ○ / ○ Output control ○ / ◐ Social control ● / ● Sanctional control ○ / ○	Gatekeeping ● Regulatory act. ● Process control ○ Output control ● Social control ◐ Sanctional control ●	Gatekeeping ○ Regulatory act. ○ Process control ○ Output control ○ Social control ◐ Sanctional control ○

Legend:
centralized decision rights; decentralized decision rights; divided/contested decision rights
○ No control; ◐ Some control; ● Extensive control

In an attempt to generalize the results of this analysis, the following key findings can be named as success factors for platform ecosystems:

- **Using network effects:** platform providers have to ensure "catalyst ignition" of their platform ecosystems [Ev09], that means getting both sides on board of the platform quickly. This is possible in most cases by attracting one user group with an offer that is already useful on its own, for example an innovative product, service, or access to data that is not available anywhere else. With this user base on one side, the other side can easier be convinced to join the platform ecosystem (see Sections 4.2.4, 4.3.3 and 4.4.3).

- **Retaining strategic platform decision rights:** platform providers should retain strategic decision rights over the platform, in order to be able to direct its current and future development. This does not exclude reacting on input from other actors (see Sections 4.3.4 and 4.4.4).

- **Finding the right balance for quality control:** platform ecosystems providers have to balance quality control very carefully to incite secondary developers to experiment with the possibilities of the platform and giving them real prospects of commercialization of the results on the other hand. A careful combination of gatekeeping (rather low) and quality control of secondary applications (rather high) is necessary to ensure a sustainable ecosystem. High quality control has to be rewarded with access to a large number of customers with high willingness to pay (see Sections 4.3.3 and 4.3.5).

- **Extensive developer support:** developers have to have access to high quality documentation and support in order to make the contribution of secondary applications to the platform ecosystems as easy as possible. This ensures higher quality of resulting applications, which in turn further strengthens network effects within the ecosystem (see Sections 4.3.3 and 4.4.3).

4.6. Summary of Analyses

In this chapter, four platforms and respective ecosystems have been analyzed with respect to their governance. For this purpose, the governance analysis framework developed in Chapter 3 was used. Waze and Moovit are crowdsourced platforms that try to improve personal mobility by car and public transportation, respectively. They do not offer enough possibilities for secondary developers to enhance their platform to be characterized as ecosystems. Apple produces smartphones and tablets that run on the same operating system iOS, which constitutes the platform to which secondary developers connect to in order to provide additional services via apps. By the definition compiled from literature, Apple's iOS is the picture perfect of a platform ecosystem. Finally, ITS Factory is a publicly funded research initiative that opens up access to more and more mobility data. At the moment, this is only a platform for secondary developers, but could very well grow into a ecosystem in the future.
The strategies of establishing an ecosystem, crowdsourcing and open data all gave important insight into what a mobility platform should incorporate in order to successfully establish itself. All strategies are successful on their own, as the cases showed: Waze was acquired by Google for $996M, Moovit funded with $81.5M, while Apple has grown to the biggest company in the world by market capitalization. In summary, this answers RQ2

("what have been factors for the successful establishment of platform businesses in the past?") by naming these strategies and factors in a structured way. Applying these strategies and factors in order to get to recommendations for the TUM LLCM will be the subject of the next chapter.

5. Design Options for the TUM LLCM

In this chapter, success factors, strategies and lessons learned from the cases in Chapter 4 will be applied to the prospective mobility platform TUM LLCM. It will be discussed which strategies can be adopted, adapted and whether or how they can be combined for establishing the mobility platform.

5.1. Approach

By analyzing the platforms of Apple, Waze, Moovit and ITS Factory, it was possible to identify various success factors: Apple provides innovative products and profits from massive indirect network effects in its ecosystem of secondary developers. It controls its ecosystem tightly by gatekeeping and quality controls, which leads to high quality of applications. Waze and Moovit started with a good idea for services in personal mobility and use direct network effects as much as possible to further grow their crowd of users, which improves their services and yields higher profits later. However, they do not orchestrate an ecosystem as defined in this work. Finally, ITS Factory in Finland opens up completely new data sources and incentivizes developers in learning to use them so that they can employ the capabilities acquired here in newly developing markets all around the world later.
These different strategies cannot be combined to form a TUM LLCM strategy - at least not all of them and not completely. The most obvious restriction lies in the fact that TUM LLCM will not develop any hand held smart device, like Apple did, to form the basis of its ecosystem. Theses devices, namely smartphones, but also other smart devices, like smartwatches or other, do already exist and are perfectly sufficient for the purposes of the TUM LLCM. Future devices could even be more useful. Means of transport also do not have to be reinvented, but simply be combined and used "smarter". Thus, Apple's strategy can only be adapted. Additionally, the strategies are contradictory at some points (especially concerning the domains of decision rights and control), such that one of them has to be chosen for the mobility platform under development at TUM. Other success factors however, more precisely crowdsourcing and open data, can and should be combined within the TUM LLCM ecosystem.
The possibilities and recommendations for TUM LLCM will be presented in the same manner as the analysis of the successful platforms in Chapter 4, by platform ecosystem governance domains. There are two alternatives being discussed that have been named "Powered by TUM LLCM" (Section 5.2) and "TUM LLCM App" (Section 5.3).

5.2. Design Option "Powered by TUM LLCM"

5.2.1. Platform Provider Structure

In the cases analyzed, providers were single, privately owned firms - with the exception of ITS Factory, which is a publicly funded research project. However, there are many platforms with other ownership structures like open source (Linux), open community (Java [Sc09a, p. 198]), platforms where ownership is shared (Nissan Micra / Renault Clio common platform [Ga09a, p. 52f.]) or completely centralized (like Apple's iOS or the Alibaba ecosystem). We can thus conclude that the ownership structure of the platform provider is not decisive for its success. What is more important is the platform's evolvability in the long term and its flexibility in reacting to external threats and opportunities in the short term. As long as the internal decision making at the platform provider supports these issues, the structure of the provider does not influence success or failure.

5.2.2. Business

Before describing the different aspects of the business domain, one remark about the guiding element in recommending the business model and related aspects the way they are recommended in the following should be made: the author is favorable to the idea that public funding, like it is granted for ITS Factory and TUM LLCM, can only be a temporary solution. "Temporary", in this case, can also mean several years, if local projects like in Tampere, Finland (ITS Factory) or Munich, Germany (TUM LLCM) are strongly supported by the cities or public transit agencies. These projects fulfill valuable purposes as training and experimentation areas. However, in the long run and at a country-wide or even global scale, only monetarily profitable solutions will most likely prevail. Therefore, the business domain of the prospective TUM LLCM presented here does not depend on perpetual public funding. However, on a smaller scale, such as cities or single states or regions, public funding can be an option, which will be discussed at the end of this chapter.
The market in which the TUM LLCM will operate does not have to meet any special criteria - except one: customers have to be equipped with a smart device. In a first time, conditions will certainly be more favorable in metropolitan regions where there are real alternatives in multi-modal travel planning, and enough customers available to attain a critical mass.
Business model and strategy are at the heart of the TUM LLCM if it is to be profitable in the long term. The proposed strategy would, just like ITS Factory, try to provide as much (public, but also private) traffic-related data as possible as open data, publicly accessible to secondary developers. This will only be possible with the help of public funding, as it does not yield direct rewards for any of the involved parties. With this approach, the

platform can attract first developers who provide innovative ideas for new applications, like ITS Factory successfully demonstrated. In a second step, data provisions has to be rendered commercially reliable by granting SLAs to secondary developers. Additionally, TUM LLCM could offer assistance for developers seeking investors, business angels or other, non-monetary support. With the offer of reliable data sources and support in commercialization, the prerequisites for developers ”going live” and providing actual service to their customers are fulfilled. At this point, the platform would have to reach one very important agreement with the respective secondary developer: the developer would have to ”play back” data that his or her application produces while being used by customers. Of course, many issues have to be solved before such two-way data exchange between platform and secondary applications can take place. To name the most important: First of all, data protection and privacy concerns must be addressed very carefully and thoroughly - not only according to applicable laws in the respective area or country of usage (as Munich and Bavaria are only the starting points for TUM LLCM), but by developing principles that every application (and also the platform itself) has to adhere to before it can access data from the platform and be published. Secondly, standards have to be defined by the platform to ensure the measures taken in the first step, and to promote standardization in order to prevent creating a fragmented market because of many isolated ecosystems. Thirdly, each secondary application will have to undergo some rating by the platform provider in order to determine the usefulness of the data it provides to the platform. This could also be combined with negotiating an usage fee for using the platform’s data, depending on the result of the prior assessment. Thus, this steps entails consequences in many other governance domains as well (that is decision rights, control, business).
As a result, the platform’s repository of data will start to grow and enable new uses for new developers. This could generate either direct (more applications lead to more data lead to more developers lead to more applications) and indirect (more applications lead to more customers lead to more developers lead to more applications) network effects and thus enlarge the ecosystem as a whole. Developers, who sell their applications via existing ways, like App Store, Play Store and others, can then be charged for using the platform’s data (see the next paragraph for a detailed description of the pricing structure). In fact, TUM LLCM would become a platform on the existing smartphone platforms. In summary, this would lead to a business model where ”Powered by TUM LLCM” would become a sign of quality of a mobile application, by signaling that (1) this application relies on the large and of high quality TUM LLCM data pool, and (2) the application was admitted to the TUM LLCM platform, which requires compliance with very strict protection of personal data. This would in some aspects resemble Intel’s microprocessor strategy ”Intel Inside”, signaling to PC users that their device works with an Intel processor [Er01, p. 53].
Pricing structure should concentrate on developers, as the platform would be visible to customers only via the ”Powered by TUM LLCM” slogan, but not have direct contact with them. In pricing developers, TUM LLCM should be very careful in elaborating a structure that does not hinder the development of the ecosystem. For example, one-time access fees should be avoided, or at least be very moderate, such that the goal of attracting a large

number of developers and inciting experimentation is not put in danger by these access fees. The usage fee could consist either in a percentage of application sales, or, more consequently, based on which and how much data is consumed compared to the data that is played back into the platform. This rate and the resulting charges should be determined during the review process before admitting the application to the platform. It is clear that processes have to be established in order to handle the review in acceptable time and accuracy. Developer's income would result from selling their applications in the existing app stores or other sources of revenue inside their applications (advertisements, services provided within the application).
In the proposed approach, incentives for developers would, in the first phase, be the same like for ITS Factory: access to real-world data and an environment for testing and experimentation for free (see access fees above). In a second phase, developers would have access to even more data, as the platform and its ecosystem grows. "Powered by TUM LLCM" would become an attribute of the developer's application, making it a sales argument.
Finally, support for developers would be a challenging task in TUM LLCM: not only because documenting all data sources and APIs is obligatory because of the newness of the data, but also because this helps in spreading the data format standards set by the platform provider (see the section about decision rights partitioning for details about setting standards). Moreover, extensive support is necessary in the application review process, as not only compliance with standards and quality control have to be checked, but also the application's contribution to the data "pool" and an individual usage fee derived from it have to be assessed. This process cannot be automated and needs skilled personnel. However, no SDK or similar have to be provided and documented, as developers will use already existing SDKs from mobile OS providers. Documentation thus is only necessary for the TUM LLCM's own APIs.

5.2.3. Decision Rights Partitioning

Decision rights are derived mainly from ITS Factory. Concerning the platform strategy, the provider of TUM LLCM should be able to make decisions independently, that is hold these decision rights centrally. Yet, input from developers should be possible, and the process of getting developer's feedback should be "institutionalized", such that no ideas get lost and developers feel that their input is valuable and respected. Feedback mechanisms could be regular developer meetings, workshops or surveys.
Platform implementation should be fully centralized in order to be able to force the introduction and use of standards in data formats, exchange and data and privacy protection. These standards have to be set according to clearly stated principles, thus creating trust with developers on the platform's reliability. Standards should be defined to be as long-living and accepted as possible, as the long term goal should be to create a single market for great regions of the world, not only one city.

At the application level, strategic decision rights should remain completely with the developer, to allow for as much experimentation and innovation as possible. The implementation of applications should only be restricted in the sense that standards set by the platform regarding data are fulfilled. As long as this is the case, there should be no limits regarding programming frameworks or which mobile OS the developer uses.

5.2.4. Control

The last governance domain to be looked at in the design option "Powered by TUM LLCM" is the control domain. It is combined from elements of Apple's and ITS Factory's control structure. Gatekeeping should be the first level of two access levels: initially, all developers can register themselves as developers at TUM LLCM. This is possible with a minimum of personal information by paying a preferably low, if any, registration fee. At this stage, developers are granted access to all API documentation, but only dummy test data access, ensuring that applications can be developed against the APIs. Once a developer has finished his or her secondary application, it will enter the review process (described in the paragraph about quality control), which constitutes the second level of access to the platform.
There are two possibilities for regulatory activities in the TUM LLCM ecosystem: on the one hand, TUM LLCM could admit all services fulfilling the standards set, which will lead to competition on the platform. On the other hand, TUM LLCM could try to protect already existing secondary applications on its platform. This would most likely raise antitrust problems, however. It would also lead to an ecosystem that is not open anymore and does not fulfill the goal of TUM LLCM anymore (compare [Te16]). Thus, the first option should be the primary choice, given that TUM LLCM is, at least currently, publicly funded will be measured against these goals.
While process control should not be implemented to give developers freedom in experimentation, output control is one very important pillar of control. In this step, compliance with standards of the platform and ecosystem is assessed, as well as the application's played back data valued, leading to individual prices for the application using the platform. Additionally, a formal quality control should be conducted in order to ensure a high overall quality in the ecosystem.
Social control will most likely be limited in an environment where actors try to earn money, whereas sanctional control exerted by the TUM LLCM provider should reserve the right to exclude developers and applications that change over time, resulting in conflicts with established standards, for example by exploiting personal data in ways not covered by the platform's privacy and data protection standards.

5.3. Design Option ”TUM LLCM App”

The second alternative, ”TUM LLCM App” will be presented in a similar manner, guided by the platform ecosystem governance framework domains. However, as many dimension do not change significantly compared to the first design options, only deviations from the former will be discussed. Just like the first design option, this alternative is proposed to be at least economically self-supporting.

5.3.1. Platform Provider Structure

The internal structure and other characteristics are, as stated above, not considered to be decisive. Thus, there are no other recommendations to give here than for the first design option.

5.3.2. Business

Contrary to the first design option, TUM LLCM would develop and provide an own mobile application in the second option. Secondary developers would then have to connect their services, which they developed relying on data from the TUM LLCM platform or not, to this application, and be integrated into it. The application would thus integrate all kinds of services into one user interface. Additionally, the TUM LLCM application could provide a service to the user that could be described with ”my personal data belongs to me”, making it very attractive to users compared to existing platform ecosystems and applications. Secondary developers would be granted access to only as much personal information as necessary, and as little as possible. For example, it is not necessary to know the exact coordinates of a mobile device to show the user weather data, as this data is not available in such fine granularity anyway. Requesting weather data by sending a request containing the ZIP code would thus be sufficient in most use cases. Of course, users should be able to specify manually which data they want to share with which secondary service provider. As a result of this strategy, the TUM LLCM platform would not be able to grow its data pool as described in the first design option. Data sources would be those initially provided by public and private actors, and adding of new data sources would be independent of the number of secondary developers and services.
The pricing structure would attribute costs to the same side as in the first alternative, the developers. However, negotiations about the usage fee would not be individual, as no data would be played back to the platform, reducing the individual application’s usage fee. Additionally or exchangeably, there could be a commission imposed for every user that is directed to the specific secondary service inside the TUM LLCM application. Finally, the application and the platform could be financed through advertising and a priced version of the application without advertising.
Incentives for developers to join the platform in this case would remain the same concerning the access to new data made available by the platform provider in the first phase of

platform establishment. On the contrary, the data protection concept of the TUM LLCM application can be a disincentive for developers, as they do not get access to personal data of their clients anymore, at least to a lesser extent than with an own application. Developers will probably carefully weigh this against the access to the TUM LLCM App user base. Support for developers would have to stay on the same level concerning documentation of data format standards and APIs. Additional documentation would be necessary to explain the data protection mechanisms employed by the application and which data secondary services can request from it to provide their services. In return, the review process would not be as complex as in the first design option, as only data requirements from applications have to be critically reviewed and approved or rejected. This review process should also be documented extensively to allow for a maximum of transparency for both developers and users.

5.3.3. Decision Rights Partitioning

Platform decision rights could be organized like in design option "Powered by TUM LLCM". For application decision rights, the balance of power would incline more towards the platform's side, as developers are restricted in the amount and type of user data they can obtain. The "last word" in this case would always be spoken by the platform provider.

5.3.4. Control

Many of the controls could also remain the same for the "TUM LLCM App" scenario, namely gatekeeping, process control, social control and sanctional control. There are two differences in regulatory activities of the provider and output control. Regulatory activities could again try to limit the number of secondary developers providing the same service on the platform. In the case of a TUM LLCM application, this becomes a more pressing issue, as it cannot integrate an unlimited amount of services in order to still be usable and user friendly. Thus this aspect requires careful consideration.
The output control for secondary services connected to the TUM LLCM application would differ from above in that not the compliance with data protection and privacy standards would be checked in a review, but whether the amount and type of data requested by the application is really necessary to provide the promised service. Based on this review, data access rights can then be granted to the secondary service.

5.4. Summary of Design Options

In this chapter, two different design options for the TUM LLCM were presented, namely "Powered by TUM LLCM" and "TUM LLCM App" (see Table 5.1 for an overview). The basis for both of them was the attempt to combine strategies uncovered through the analysis of successful platforms in the previous chapter. Both design options place an emphasis on data and privacy protection. However, ”Powered by TUM LLCM” also tries to use data created by applications and their customers to come to a data- and crowd-based ecosystem with network effects (a combination of all three analyzed strategies), whereas ”TUM LLCM App” concentrates even more on the protection of personal data by not giving any personal data to secondary service providers and developers before thoroughly reviewing their data requests. Thus, it relies on the data made available in the first phase of platform establishment (similar to ITS Factory Finland) and network effects generated by the mutual attraction of developers and customers. Also, it integrates all services into one application.

While both design options were deliberately designed to at least pay for themselves, one could also think of a more public welfare oriented solution. In the case of the TUM LLCM, the state of Bavaria could analyze prospective costs for maintaining and extending public infrastructure, especially those for individual motorized traffic. In a second step, it could invest a certain percentage of these costs already today in the development of the TUM LLCM (like it is already doing by financing the project), and at the same time setting goals of smarter use of public transportation and existing infrastructure for the project. Thus, by investing only a percentage of possible costs in an innovative solution, it could create a win-win-win situation: the state of Bavaria lowers its expenses and citizens get access to better transportation services and could even improve their carbon footprint, thus reducing the greenhouse effect.

In summary, this chapter answers RQ3 by combining successful strategies from practice to recommend promising avenues for the sustainable establishment of a mobility platform and ecosystem, the TUM LLCM.

Table 5.1.: Overview of Recommendations for the TUM LLCM

	"Provided by TUM LLCM"	"TUM LLCM App"
Platform provider structure	Structure not decisive	Structure not decisive
Decision rights partitioning	Platf. strat. [centralized | decentralized] Platf. impl. [centralized] App. strat. [decentralized] App. impl. [decentralized]	Platf. strat. [centralized | decentralized] Platf. impl. [centralized] App. strat. [decentralized] App. impl. [decentralized]
Business	Personal mobility market Based on open data Revenue through commissions or advertising Acces to real data Documentation, Wiki, Forums, extensive support	Personal mobility market Based on open data Revenue through commissions, advertising or application sale Access to real data Documentation, Wiki, Forums, extensive support
Control	Gatekeeping ◐ Regulatory act. ◐ Process control ○ Output control ● Social control ○ Sanctional control ◐	Gatekeeping ◐ Regulatory act. ◐ Process control ○ Output control ◐ Social control ○ Sanctional control ◐

Legend:

- [centralized] centralized decision rights
- [decentralized] decentralized decision rights
- [centralized | decentralized] divided/contested decision rights
- ○ No control
- ◐ Some control
- ● Extensive control

6. Summary

6.1. Review

This thesis tried to shed light on the governance of a mobility platform and ecosystem to be developed within the research project TUM LLCM. The need for new concepts for personal mobility arises from two human megatrends, world population growth and urbanization, which both lead to larger and denser urban agglomerations. Within these agglomerations, transportation as we know it has reached its limits, already today. Mobility platforms, made possible through the digitalization of all areas of life, could be an element of the solution to these problems.

In the first RQ, the goal was to gain an understanding about what existing literature defines as "platform", "platform ecosystems" and other related terms. The question was answered with the help of a literature review according to Webster and Watson [WW02]. The result presented in Chapter 2 is a comparison of existing definitions and classifications as well as a list of derived definitions for the scope of this thesis and future research on the topic of platform ecosystems. Additionally, a platform ecosystem governance framework was derived from existing literature and presented in Chapter 3.

RQ2 was answered by analyzing four platforms, selected for their positioning in the mobility domain, their ecosystem characteristics and their similarities to the TUM LLCM project, were examined using the platform ecosystem governance framework. The platforms analyzed (Waze, Moovit, Apple iOS and ITS Factory) were described extensively guided by the framework's different domains platform provider structure, business, decision rights partitioning and control. The different strategies and success factors were extracted and shown in the final part of Chapter 4. Although the success factors and strategies result from only four cases examined, their fundamental characteristics are considered to cover many other platform ecosystems as well.

Finally, RQ3 was answered by giving two alternative design options for the implementation of TUM LLCM's governance. "Powered by TUM LLCM" would set strict standards for data formats and data and privacy protection while still trying to use the data generated by users and applications to enlarge an initially provided pool of data sources. "TUM LLCM App", on the contrary, would protect customer's data by forcing secondary developers to connect their services to an application controlled by TUM LLCM, which would also control for the amount, type and specificity of personal data used by developers providing services within the application. Both design options would, based on the findings about success factors in RQ2, be suitable to "successfully establish a mobility platform and ecosystem", as demanded by RQ3. Even if none of these recommendations would be applied in their entirety, they still offer useful elements for the design of a mobility platform ecosystem's governance.

6.2. Contribution to Theory

This thesis contributed to theory by consolidating different research streams concerning platforms, platform ecosystems and their governance, by reviewing them and deriving definitions for all relevant terms. Research could build upon this consolidated view - not only for mobility platforms, but for software-based platform ecosystems in general.
Further, this work contributed a high-level understanding of platform and platform ecosystem governance, also derived from existing literature. This framework and its presentation of results in an overview table can be used by researchers to get a rather quick overview over platforms and their ecosystems, as well as indicating interesting aspects or problematic areas of the platform. By using the platform ecosystem governance framework as proposed, researches can ensure not missing important aspects when researching a platform ecosystem for the first time. Additionally, the framework helps by making different platforms and their ecosystems easily comparable.
Finally, the description of two different design options for the governance implementation of a mobility platform ecosystem can incite researchers, especially within the TUM LLCM project, to further extend this work by searching for additional design options that could lead to the sustainable establishment of the TUM LLCM mobility platform ecosystem.

6.3. Contribution to Practice

For practitioners, this thesis contributes by proposing the governance analysis framework, with the help of which platform providers can analyze their own platform as well as competitor's platforms, compare them to each other, and draw conclusions from it. Another possible application for platform providers can be the examination of success factors and strategies identified in this thesis regarding their applicability to the own platform.
For the concrete implementation of a mobility platform ecosystem within the TUM LLCM research project, this thesis proposes two different approaches that could be followed to establish the mobility platform on the market and create an ecosystem around it. Even if none of these design options will be followed in the final approach, parts of them could still be used as input, whereas the framework would help in not forgetting important aspects of TUM LLCM's governance.

6.4. Limitations and Future Research

This research is of course not without limitations. First of all, the low number of only four platforms considered raises concerns about generalizability of the results. While the success strategies found most likely are valid, they may not be complete and their list not be exhaustive. Future research should thus try to analyze more relevant cases and validate not only the success factors and strategies found, but also the platform governance analysis framework itself.

Furthermore, no negative examples of platforms or platform ecosystems were conducted within this research, as negative examples are very hard to find. Although some research has already been done on failed platforms (see [HWS11]), their examples were either very outdated (from before 1995) or unrelated to the topic of this thesis because of their very wide scope of the term "platform". If possible, future research should try to find failed platform ecosystem businesses and try to validate the success strategies by comparing their governance framework implementation with that of successful examples. With the establishment of more and more platform businesses, the search for failed examples will possibly also become easier in the future.

After validation of the framework and success strategies in the two steps above, future research could subsequently codify the platform ecosystem governance framework in order to allow for a quantitative evaluation of platform ecosystem governance strategies with large numbers of platform ecosystems considered. Before, however, it should be ensured that there are enough research objects available for the quantitative analysis to lead to meaningful results.

Finally, the platform ecosystem governance framework - just like most of the existing literature - did not consider any "external aspects", like regulatory interventions of governmental actors, legislation aspects or other. Partly, this was included in some of the domains, especially within the recommendations given about data standards and data and privacy protection, which should be "compliant" to existing laws. However, these external aspects are most likely not restricted to regulatory activities and laws and should be researched separately.

6.5. Conclusion

This thesis made contributions about how platform ecosystems can be defined and what characterizes their governance. It analyzed success factors and strategies and applied these to give recommendations for the TUM LLCM mobility platform research project. With these recommendations, the TUM LLCM could grow into a successful mobility ecosystem, becoming a part in the big puzzle of future human mobility, which will be much smarter and lead to less pollution and destruction of natural resources.

A. Appendix

A.1. List of Definitions

A.1.1. Platform

- ″the set of components used in common across a product family whose functionality can be extended by applications″ [Ce12, p. 263]
- ″technology platforms are multi-sided markets since they bring together various types of participants, or sides, such as buyers and sellers″ [BK11b, p. 314]
- ″the extensible codebase of a software-based system that provides core functionality shared by apps that interoperate with it, and the interfaces through which they interoperate″ [Ti14, p. 7]
- ″we define a software-based platform as the extensible codebase of a software-based system that provides core functionality shared by the modules that interoperate with it and the interfaces through which they interoperate″ [TKB10, p. 675]
- ″systems are products made up of multiple components; computers, automobiles, telecommunications services, and video games are all examples of systems. The platform consists of those elements that are used in common or reused across implementations. A platform may include physical components, tools and rules to facilitate development, a collection of technical standards to support interoperability, or any combination of these things. Serving as a stable nexus or foundation, a platform can organize the technical development of interchangeable, complementary components and permit them to interact with one another″ [Bo10, p. 1851]
- ″in line with [Ga09a], we conceive platforms as ′a building block [...] that acts as a foundation upon which other firms can develop complementary products, technologies or services′. It ′consists of a modular architecture of related standards, controlled by one or more sponsoring firms′ [We03] and provides leverage for its multiple complementors within the platform ecosystem″ [SS10, p. 1]
- ″a software platform provides services for applications developers; these services help developers obtain access to the hardware for the computing device in question as well as other helpful services. Users can run these applications only if they have the same software platform as that relied on by the developers; developers can sell

their applications only to users that have the same software platform they have relied on in writing their applications" [ES05, p. 10]

- "we conceive of a platform as the components used in common across a product family whose functionality can be extended by applications and is subject to network effects. A platform is "open" to the extent that it places no restrictions on participation, development, or use across its distinct roles, whether developer or end-user" [PA08, p. 2]
- "there is an important difference between a product and an industry platform. Put simply, a product is largely proprietary and under one company's control, whereas an industry platform is a foundation technology or service that is essential for a broader, interdependent ecosystem of businesses. The platform requires complementary innovations to be useful, and vice versa. An industry platform, therefore, is no longer under the full control of the originator, even though it may contain certain proprietary elements" [GC12, p. 28]
- "a platform is a good or system providing a technological architecture that allows different types of users and complementary business partners (often called 'complementors') to connect and benefit from the platform's base functionality" [SK12, p. 36]
- "an industry platform has two essential differences [from a product platform]. One is that, while it provides a common foundation or core technology that a firm can reuse in different product variations, similar to an inhouse product platform, an industry platform provides this function as part of a technology 'system' whose components are likely to come from different companies (or maybe different departments of the same firm), which we called 'complementors'. Second, the industry platform has relatively little value to users without these complementary products or services" [Cu10, p. 32]
- "the platform encompasses the set of components and rules employed in common in most interactions between network users. Components include hardware, software, and service modules, along with an architecture that specifies how they fit together. Rules encompass information visible to network participants that is used to coordinate their activities" [EPVA11, p. 3]
- "[...] which we define as a set of stable components that supports variety an evolvability in a system by constraining the linkages among the other components" [BW09, p. 19]
- "[platform product are products that] 'meet the needs of a core group of customers but [are designed] for easy modification into derivatives through the addition, substitution, or removal of features'" [WC92, p. 73]

- ”[a platform in technology strategy research is a] valuable point[s] of control (and rent extraction) in an industry” [BW09, p. 21]
- ”[a platform in industrial economy research are] products, services, firms or institutions that mediate transactions between two or more groups of agents” [RT03]
- ”industry platforms are building blocks (they can be products, technologies or services) that act as a foundation upon which an array of firms (sometimes called a business ecosystem) can develop complementary products, technologies or services” [Ga09a, p. 45]
- ”a set of common components and a general design or architectural ’blueprint’ that supported product variations and extensions through part substitution and part extension” [SC09b, p. 78]
- ”a standard bundle of components that users employ together as a system to regularly deliver services” [Gr09, p. 221]
- ”features of an industry platform: (1) a set of fixed attributes that are always present in the final system; (2) networks of platform users; (3) utility functions of the fixed attributes for the networks members” [LMWH11, p. 276]
- ”under modular architecture, the platform is a special module that provides a means for mixing and matching other modules and for constructing numerous combinations to achieve the most valuable design” [TOF09, p. 346]
- ”we define internal (company or product) platforms as a set of assets organized in a common structure from which a company can efficiently develop and produce a stream of derivative products. We define external (industry) platforms as products, services, or technologies that act as a foundation upon which external innovators, organized as an innovative business ecosystem, can develop their own complementary products, technologies, or services” [GC14, p. 417]

Platform Definitions With Focus on Two-Sidedness

- ”a business is an ’economic catalyst’ if it creates value by bringing two or more groups of customers together and getting them to interact. Catalysts create value by reducing transactions costs faced by multiple distinct economic agents that would benefit from coming together. Catalysts reduce search efforts, facilitate matching, and make it easier for the two groups of economic agents to exchange value between each other. In the traditional literature, a catalyst is referred to as a ’two-sided market’ or as a ’multi-sided platform’” [Ev09, p. 4f.]
- ”a key property of platforms is their multisidedness, where each ’side’ refers to a distinct group of stakeholders that the platform brings together” [Ti14, p. 31]

- ”here we use the term 2SP [two-sided service provider] to refer to the entity – the business, cooperative, standard, or government entity – that provides a physical or virtual platform for distinct customer groups. SPs compete in what we will call 2SP industries” [ES05, p. 4]
- ”a market is two-sided if the platform can affect the volume of transactions by charging more to one side of the market and reducing the price paid by the other side by an equal amount; in other words, the price structure matters, and platforms must design it so as to bring both sides on board” [RT04, p. 26]
- ”platform industries tend to have more than one market ’side’ to them” [Cu10, p. 34]
- ”a firm that controls a proprietary platform makes strategic pricing decisions for the products it sells directly to the end-user, as well as with respect to complementary products to its platform sold by other firms. We call this two-sided platform pricing” [EK06, p. 1057]
- ”a market is two sided when the ratio of the platform prices matters in the equilibrium interactions between the two sides” [RT06, p. 646]
- ”a platform-mediated network is comprised of users whose interactions are subject to network effects, along with one or more intermediaries who organize a platform that facilitates users’ interactions” [EPVA11, p. 3]
- ”every platform-mediated network has a focal platform at its core, although other platforms may play subordinate roles in the network” [EPVA11, p. 3]
- ”platform industries, which are gaining considerable attention [...], are information technology industries with components and rules that facilitate interactions among a network of users [HWS11, p. 29]
- ”an increasing number of internet intermediaries provide platforms that are two-sided networks. These networks have two types of participants (’sides’), where each side derives positive externalities from the participation of members on the other side in the network” [BK08, p. 171f.]
- ”[. . .] platform-mediated networks encompass several distinct roles, including: (1) demand-side platform users, commonly called ’end users’; (2) supply-side platform users, who offer complements employed by demand-side users in tandem with the core platform; (3) platform providers, who serve as users’ primary point of contact with the platform; and (4) platform sponsors, who exercise property rights and are responsible for determining who may participate in a platform-mediated network and for developing its technology” [EPVA09, p. 131f.]
- ”platform-mediated markets comprise sets of rival platforms, each serving distinct platform-mediated networks” [EPVA09, p. 136]

- ”two platforms are rivals in the same platform-mediated market if they employ incompatible technologies and if changing the price that users pay to affiliate with one platform influences the other’s transaction volumes” [EPVA09, p. 136]
- ”Platforms are products, services or technologies that serve as foundations upon which other parties can build complementary products, services or technologies. A ’multi-sided’ platform or MSP (e.g. Sony’s PlayStation, Visa credit cards, Microsoft’s Windows, eBay) is both a platform and a market intermediary. Thus distinct groups of consumers and ’complementors’ interact through MSPs” [BH09, p. 188]

A.1.2. Platform Ecosystem

- ”the network of innovation to produce complements that make a platform more valuable” [Ce12, p. 263], based on [CG02]
- ”a platform-based ecosystem consists of two major elements - a platform and complementary apps - as Figure 1.1 illustrates. A software platform is a software-based product or service that serves as a foundation on which outside parties can build complementary products or services. A software platform is therefore an extensible software-based system that provides the core functionality shared by ’apps’ that interoperate with it, and the interfaces through which they interoperate [BW09, TKB10]. We refer to the lead firm primarily responsible for the platform as the platform owner, sometimes also called the ecosystem’s keystone firm [IL04] or the economic catalyst [ES05].” [Ti14, p. 5]
- ”the collection of the platform and the apps specific to it” [Ti14, p. 7]
- ”we refer to the collection of the platform and the modules specific to that platform as that platform’s ecosystem” [TKB10, p. 675]
- ”the platform ecosystem embraces (a) the platform provider, operating the platform and core platform offerings as well as mediating between service consumers and platform providers; (b) the service ecosystem of complementary product and service providers enabling the ’whole’ customized solution as offered to (c) the customers” [SS10, p. 2]
- ”the critical distinguishing feature of an industry platform and ecosystem is the creation of ’network effects’. These are positive feedback loops that can grow at geometrically increasing rates as adoption of the platform and the complements rise” [Cu10, p. 33]
- ”a two-sided Internet platform embodies a design, which defines the architecture of the services offered and the infrastructure that facilitates the interaction between the participating sides, and a set of rules, such as pricing terms and the rights and obligations of the participants” [BK08, p. 172]

- ”therefore, Salesforce.com and its users form a service ecosystem [...], in which service innovation is performed by the cooperation and interaction among the platform provider and users” [BKA14, p. 40]

- ”the ecosystem consists of a platform provider (Salesforce.com), and the platform users. A platform user is categorized into a developer (i.e., a user engaged in the application development) and a customer (i.e., a user consuming the application created by developers)” [BKA14, p. 40]

A.1.3. Complementary Software Application

- ”we define a module as an add-on software subsystem that connects to the platform to add functionality to it” [TKB10, p. 675]

- ”app: An add-on software subsystem or service that connects to the platform to add functionality to it. Also referred to as a module, extension, plug-in, or add-on” [Ti14, p. 7]

A.1.4. (Platform) User

Customer

- ”end-users are the collection of existing and prospective adopters of the platform” [Ti14, p. 6]

- ”demand-side platform users, commonly called ’end users’ [EPVA09, p. 131]

Secondary Developer

- ”external companies or entrepreneurs that build products and services to run on a platform, thus increasing the platform’s attractiveness” [SK12, p. 36]

- ”supply-side platform users, who offer complements employed by demand-side users in tandem with the core platform” [EPVA09, p. 131]

- ”we use the term ’complementor’ [...] as a shorthand for ’the developer of a complementary product’ where two products are complements if greater sales of one increase demand for the other” [GC14]

A.1.5. Platform Architecture

- ”a conceptual blueprint that describes how the ecosystem is partitioned into a relatively stable platform and a complementary set of apps that are encouraged to vary, and the design rules binding on both” [Ti14, p. 7]

- ”the architecture of a platform or an app is therefore a high-level description of its building blocks and how they are related to each other, not a working implementation” [Ti14, p. 38]

- ”Ecosystem architecture can be thought of as comprised of two levels: (1) the architecture of the platform itself (platform architecture) and (2) that of an app, which we refer to as that app’s microarchitecture” [Ti14, p. 84]

- ”both the high-level platform design and the interface designs that determine how subsystems work together”

- ”a two-sided Internet platform embodies a design, which defines the architecture of the services offered and the infrastructure that facilitates the interaction between the participating sides [...]” [BK08, p. 172]

- ”platform architectures are modularizations of complex systems in which certain components (the platform itself) remain stable, while others (the complements) are encouraged to vary in cross-section or over time” [BW09, p. [p. 23]

A.1.6. Platform (Ecosystem) Governance

- ”governance of a platform ecosystem broadly refers to the mechanisms through which a platform owner exerts influence over app developers participating in a platform’s ecosystem” [Ti14, p. 117]

- ”governance broadly refers to who decides what in a platform’s ecosystem. This encompasses three facets: (1) how decision rights are divvied up between the platform owner and app developers, (2) what types of formal and informal control mechanisms are used by the platform owner (e.g., gatekeeping, performance metrics, processes that app developers are expected to follow, and informal clannish pressure), and (3) pricing structures, including decisions about which side gets subsidized.” [Ti14, p. 39]

- ”platform governance encompasses three dimensions [...]: (1) the division of authority and responsibilities between the platform owner and app developers (decision rights partitioning), (2) the collection of mechanisms through which the platform owner exercises control over app developers (the control portfolio, which includes the authority to accept or reject apps), and (3) decisions about how proceeds will be divvied up between a platform owner and app developers (pricing policies)” [Ti14, p. 119]

- ”we define platform governance as who makes what decisions about a platform” [TKB10, p. 679]

- ”an effective platform governance enables providers to align the interests of all the stakeholders and is defined as the direction, control, and coordination of platform resources. It consists of formal and informal rules” [Ma12, p. 3]
- ”comparing the definitions shows that platform governance is a multi-dimensional concept, which firstly controls the decision-making process in a platform. Second, platform governance is the structure, power, processes, and control mechanisms that are applied by the platform owner to achieve his aims. We further conclude that governance has to be dynamically managed and implemented to flexibly react to changing conditions in the ecosystem. This includes control-concepts as a subset of platform governance. Hence, we argue that controls are vital elements of platform governance” [Ma12, p. 3]
- ”rules encompass information visible to network participants that is used to coordinate their activities. In particular, rules include standards that ensure compatibility between different components; protocols that govern information exchange; policies that constrain network user behavior; and contracts that specify terms of trade and the rights and responsibilities of network participants” [EPVA11, p. 3]
- ”a two-sided Internet platform embodies a design, [...], and a set of rules, such as pricing terms and the rights and obligations of the participants” [BK08, p. 172]

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