The Sustainability of Mobility as a Service Solutions Evaluated through the Software Sustainability Assessment Method

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2018

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Vrije Universiteit Amsterdam, January 2018

Contents

1. Introduction

This research focuses on the sustainability of mobility. Lago et al. define sustainability as the “capacity to endure” and to “preserve the function of a system over an extended period of time” [1]. Therefore, in order to make mobility sustainable the way people move must not violate the conservation of our planet. The City of Amsterdam presented the following vision regarding mobility: “Mobility will be a custom-made service for everyone, with shared and emission-free cars that drive themselves. More room for pedestrians and bicycles (shared or otherwise), more greenery, and less room for parking spaces” [2]. However, before this vision can be realized multiple complications should be taken addressed. For instance, the population of Amsterdam is increasing [2]. On the one side, more houses are built in the city in order to house more people. On the other side, the number of tourists is increasing [2]. The overall growth of the population results in an increasing need for transportation.

With the increased use of big data, the possibility arises to reduce the stress on the current transportation infrastructure by reducing the number of cars on the road and create more space for pedestrians. For example, big data analytics enable mobility providers to adjust their supply to the demand of the end-users. A solution for the stress on the current transportation infrastructure could be offered thanks to the introduction of Mobility as a Service (MaaS), where end-users pay for the mobility they use instead of purchasing transportation means. For instance, the City of Amsterdam introduces the open MaaS framework [3] which is a data-driven solution for the mobility problems in Amsterdam. With this framework the City of Amsterdam is planning to adjust the supply of transportations means optimally to the demand of mobility within Amsterdam.

This trend towards MaaS is not only visible in Amsterdam. For example, in Sweden and Finland new mobility solutions arise. In Sweden, Drive Sweden, a Strategic Innovation Program, aims to introduce MaaS in Sweden [4] in Finland (specifically Helsinki) MaaS Global, introduces an app which provides people an alternative to owning a car [5]. The aim of this paper is to examine the sustainability of MaaS solutions by analyzing the economic, social, environmental, and technical effects of these mobility solutions.

In the project here reported, we have conducted research on the potential sustainability effect of MaaS solutions for society. To this aim, we used the Software Sustainability analysis (SoSA) method introduced by Lago [9]. This method and associated visual framework enables us to model the effects of MaaS solutions within and across the different dimensions, and show their interdependencies and necessary trade-offs.

The rest of this report is structured as followed. Firstly, we will describe our research method and explain the SoSA method. Thereafter, we will discuss the mobility framework of the City Amsterdam as an example of a MaaS solution. Subsequently, we will introduce our MaaS SoSA model. Based on the SoSA model we will draw our conclusions on the sustainability effect of the introduction of MaaS.

2. Research method

Lago et al. state that in order to analyse the sustainability of a specific software system four dimensions must be taken into account, namely, the economic, social, environmental and technical dimension [1]. Lago et al. introduce the Software Sustainability Assessment (SoSA) method where software solutions can be modelled within these dimensions in order to gather the sustainability implications of a software-solution in one picture and reason about its (potential) effects of the above-mentioned dimensions. Ongoing research aims to enrich the model with any predictions/estimations that have already occurred (if applicable) so that decision making can be based on better information, hence supported better. In our research, we applied the SoSA method on a MaaS software-related solution inspired by the Smart Mobility Framework introduced by The City of Amsterdam. The models we created during our research have the four dimensions (economic, social, environmental and technical) [1] and the SoSA method [9] as input.

In order to analyse the sustainability of the MaaS solution, we evaluated its effects in the above-mentioned dimensions. Firstly, they need to be defined. We are going to use the definitions from Lago et al. [1]:

- *Economic Sustainability* focuses on preserving capital and (economic) value.
- *Social Sustainability* focuses on supporting current and future generations to have the same or greater access to social resources by pursuing generational equity. For software-intensive systems, this dimension encompasses the direct support of social communities in any domain, as well as the support of activities or processes that indirectly create benefits for social communities.
- *Environmental Sustainability* aims at improving human welfare while protecting natural resources. For software-intensive systems, this dimension aims at addressing ecologic requirements, including energy efficiency and ecologic awareness creation.
- *Technical Sustainability* addresses the long-term use of software-intensive systems and their appropriate evolution in an execution environment that continuously changes.

In the SoSA method, the effects of the software solution are modelled within one of these four dimensions. Furthermore, the impact of an effect of the software solution can be immediate, enabling or systemic. *Immediate impacts* refer to changes which are immediately observable. *Enabling impacts* arise from use over time. This includes the opportunity to consume more (or less) resources, but also shorten their useful life by obsolescence (when we buy a new smart phone just because incompatible with newer applications) or substitution (when e-book readers replace printed books). *Systemic impacts* refer to persistent changes observable at the macro level. Systemic impacts include behavioral change and economic structural change. Systemic impacts may translate into (negative) rebound effects by converting efficiency improvements into additional consumption, or new risks - like our dependence on ICT networks that make a digital society also vulnerable. On a systemic level, the causes of unsustainability result from the deepest cultural structures within the modern world. These structures are required to change in order to create sustainability [6]. Modelling the MaaS software solution in the SoSA model enabled us to evaluate its sustainability impact by analyzing its drivers. The advantage of modelling a software solution in the SoSA Framework is the clarification of the trade-offs between the four different dimensions. Software quality is not solely a technical and economical matter, within these trade-offs it becomes clear that it is also important to take environmental and social effects into account.

3. Case Study: City of Amsterdam

The main goal of the City of Amsterdam is "to improve the safety, accessibility, air quality, quality of life, and attractiveness of Amsterdam" [2]. However, this is getting more problematic as the number of inhabitants of Amsterdam has increased by 9 per cent in the period from 2008 to 2014 and the number of hotel stays in Amsterdam has increased by 51 per cent over the same period [2]. As a result of the increasing number of inhabitants and visitors the need for mobility grows. In its mobility action plan, the City of Amsterdam states that using services becomes more important than owning them. Examples of this phenomenon are Netflix and Spotify. Previously, people used to own DVDs and CDs.
Nowadays, it is more common to pay for the service and always have the ability to listen to music and watch movies. The City of Amsterdam foresees that this could be the case in the mobility sector as well: instead of owning means of transport people will pay for the transport service. As a result, more services are provided through large internet platforms. In The Netherlands the digitalization is particularly high with respect to the European Union: the Internet access is widespread and the quality of the connectivity is excellent. Denmark, Finland, Sweden and the Netherlands have the most advanced digital economies in the EU [7]. This is illustrated by the Digital Economy and Society Index (DESI), which is a composite index that summarizes relevant indicators on Europe's digital performance and tracks the evolution of EU member states in digital competitiveness [7]. The indicators are Connectivity, Human Capital, Use of Internet, Integration of Digital Technology and Digital Public Services.

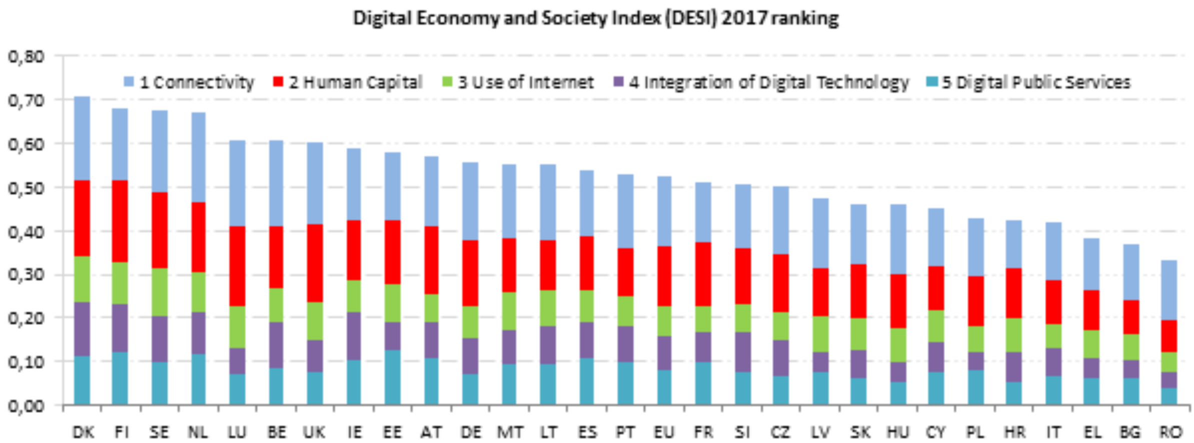

Figure 2. Digital Economy and Society Index (DESI) 2017 ranking [7].

The high DESI is a possible explanation of the fact that in Sweden [4] and Finland [5] there are already operational pilots of MaaS solutions, this is illustrated in figure 2. A digital infrastructure of high quality is required to design smart mobility frameworks. These frameworks bring supply and demand together in a smart way by efficiently using unused capacity. This results in the optimization of mobility as MaaS frameworks efficiently match the supply and demand of mobility.

In order to realize and integrate MaaS solutions in Amsterdam, the Smart Mobility Manager of the City of Amsterdam, Tijs Roelofs, introduced an Open MaaS Framework in the MaaS Meetup #3: "Data for Mobility" [3]. The Open MaaS Framework from the City of Amsterdam is illustrated in figure 3. We will introduce this MaaS Framework in order to create an understanding of the possibilities that MaaS solutions offer. Subsequently, we will model the effects of this MaaS solution using the SoSA method.

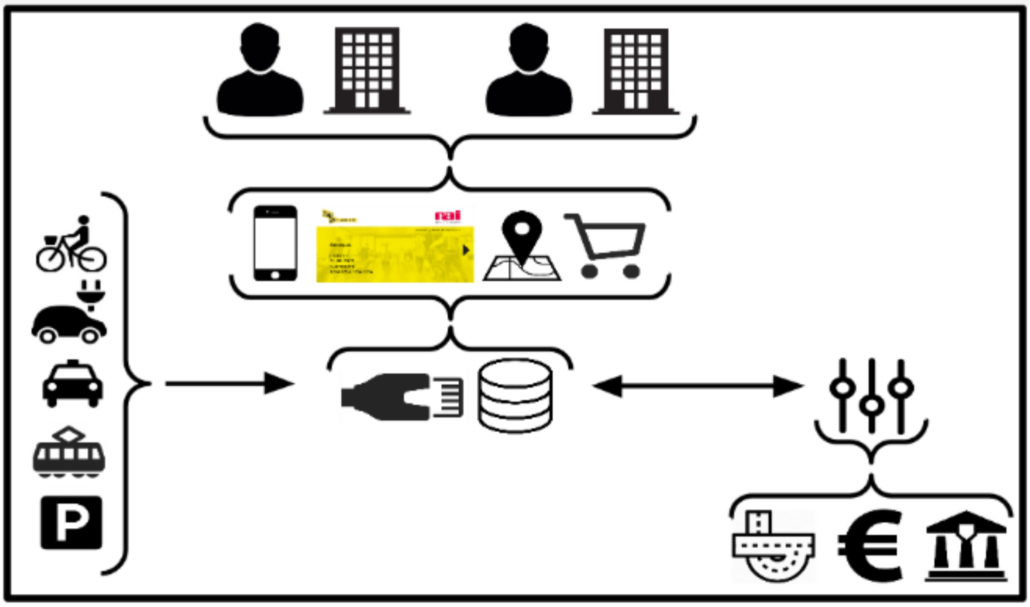

Figure 3: Smart Mobility Framework introduced by The City of Amsterdam [3]

The Open MaaS framework, which is shown in figure 3, is a framework where supply and demand of transportation are optimally adjusted to one another. End-users and mobility providers are connected in a database. The framework can be accessed through software applications executing on devices of end-users. The end-users are people that need to move from one place to another. The fact that a large part of the population can be considered as end-users can make the Open MaaS Framework successful. All the data of people who need to move is available and an algorithm can calculate the most efficient way of combining their mobility. Mobility suppliers can “plug in” their supply. This includes public transportation services, commercial taxi companies and even individuals making their bike available. If the database knows exactly who wants to travel at what time to a certain location and knows the available supply of mobility an optimal sustainable mobility plan can be generated by the MaaS framework. In the next section, we will evaluate the effects of such a framework.

4. SoSA Model(s)

In our work, we have modelled the effects of the MaaS Framework in the SoSA model in two different views: end-users and mobility providers. In figure 4 the view of the end-users is illustrated and in figure 5 the view of mobility providers. These two groups of people who will be using the framework are able to switch sides (users becoming providers). However, they generally have different interests. We will first discuss the framework from the view of an end-user's, subsequently, we will discuss the view of mobility providers. The model is based on the MaaS framework, which is represented as a circle in the center of the model. From this circle, arrows emerge which represents the chain of dependencies. Next to the arrows plus or minus symbols are referring to whether the effect is positive or negative. In the box after the arrows the effects are described in detail. In the section below, certain phrases are written in bold to represent the effects as modelled in the framework.

Using the framework, users will shift from using their own means of transportation **(possession of personal mobility means)** towards using mobility as a service, which will provide the user with an increased flexibility in its means of transportation. This entails that users will have access to a wide range of mobility (cars, bikes, public transportation) at all times **(flexibility of mobility means)**. Currently, a trip is usually executed by only one means of transportation. When MaaS Frameworks are realized, a trip can be carried out by using multiple means of transportation. Since a greater number of people will have access to cars, they will likely be used more often **(cars on road)** and in combination with other means of transport such as the use of public transport **(use of public transport)**. However, because a growing amount of these cars will be shared the number of cars needed will decline, thus, fewer cars will have to be produced **(cars produced)**. This change will have a positive effect on **emission** since a big part of emission from cars is the manufactory of them. Due to fewer cars on the road, as well as fewer **cars parked** since there will be fewer cars in total, there will be more free space available in the urban areas. The framework will allow mobility providers to operate in a more efficient manner **(efficiency of transport)** due to the amount of available data which allows supply and demand to be matched together optimally **(matchmaking quality between supply and demand)** leading to **faster travel** and **cheaper prices** for the users and a better competitive position for the mobility providers. The downside of the framework will be that users will be increasingly dependent on information technology (IT) **(software dependency)** and that IT failures will have an even larger impact on society in the future than what is already happening nowadays. In the case of IT failure, users will not be able to access the mobility they have grown accustomed to, and users will have reduced the number of private mobility means they will have trouble arriving at their destination **(impact of IT failure)**. Also, to be able to use the framework users will have to provide data regarding their location, destination, and budget, which will potentially negatively affect their **privacy**.

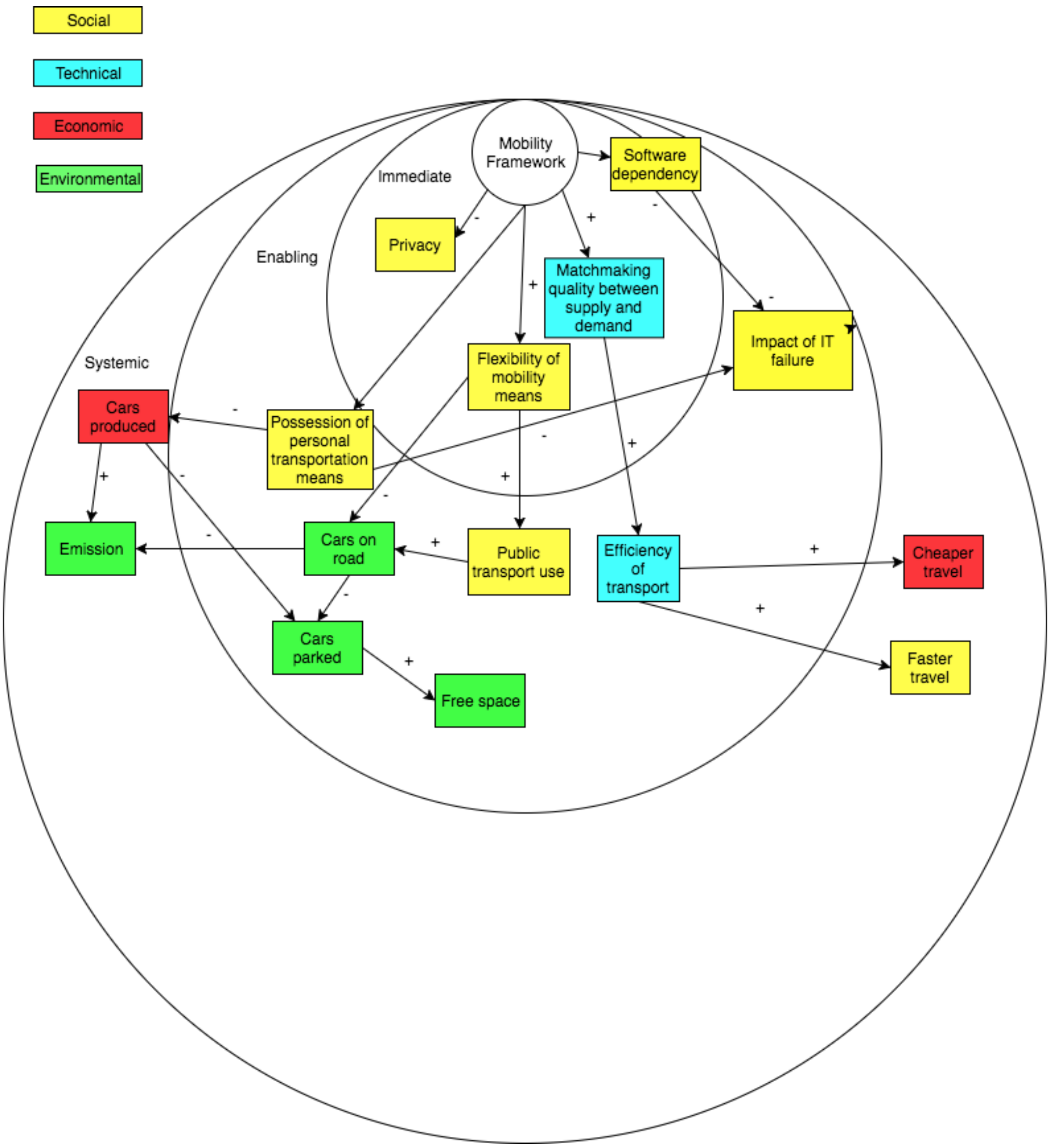

Figure 4. SoSA Model MaaS Framework from end-users' perspective.

We define a mobility provider as anyone who connects its mobility means to the platform, this can be users, but also public transport and companies like Uber or Greenwheels. For the provider to be able to use the framework they will have to provide data on their services and assets **(forced data sharing)** which can be problematic because data is essential for companies like Uber and probably do not wish to share it. As end-users, also the mobility providers will be **software dependent** since their services will (partially) be functioning through the framework. If the framework would fail a part of the customers would not be able to use their service and much revenue would be lost **(impact of IT failure)**. The increased efficiency of the transport previously mentioned will enable the providers to charge lower prices and travel faster giving them a **competitive advantage** over providers not connected to the framework leading to increased **provider profits**.

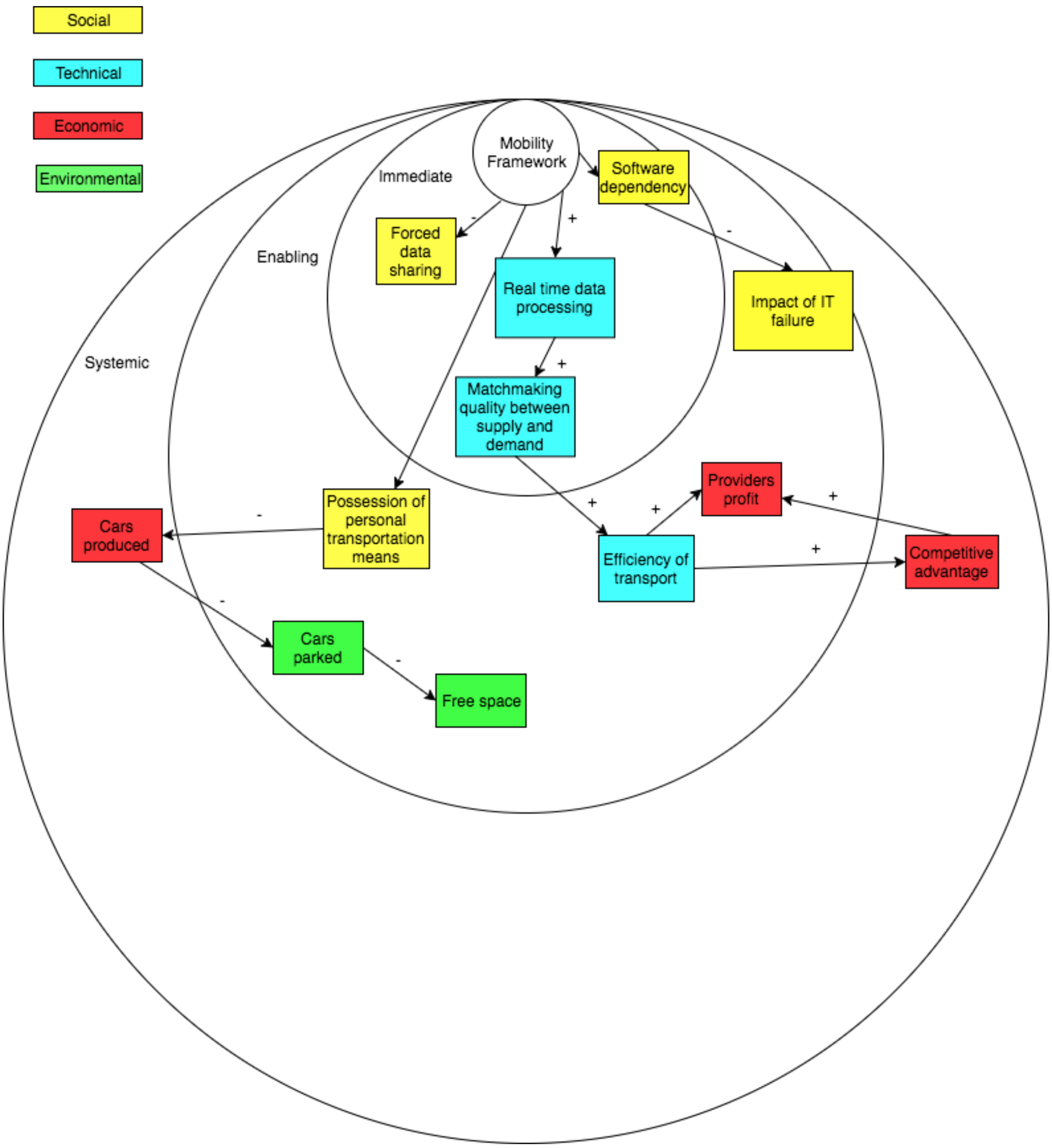

Figure 5. SoSA Model MaaS Framework from the mobility providers' perspective.

5. Network Effects

The MaaS framework can be implemented as a platform. If so, this would enable users to provide their own transportation means. However, to be successful in the long term, a mobility platform should be relisient to the so-called "network effects".
For a platform to create value for its users, it must create matches among these users and facilitate the exchange of services [8]. When the users are properly matched, they can provide a service of value for each other. An important aspect of the growth of a platform in general is *network effects*. A network effect is "the impact that the number of users of a platform has on the value created by each user". The success of a platform is dependent on

a number of users since an increased amount of users will enable improved matching among users. For example, the company like Uber is based on the **positive network effect** that more drivers cause faster pickups that, in turn, lead to more users, and more users lead to the need for more drivers. In order to optimize the impact of a MaaS Framework, it is important that the *positive* network effects are stimulated and the *negative* network effects are mitigated. An example of a **negative network effect** is when few users of a social media platform result in fewer interactions and input. This would lead to less value created on the platform, and this in turn would result in a further decrease in the number of users.
In the remaining of this section, we explore an example of important network effect that is present in MaaS frameworks. Furthermore, we propose actions meant to optimize the effects [8].

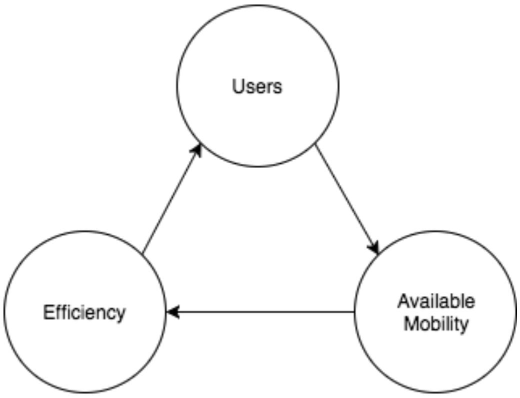

Figure 6: Positive network effect for a MaaS Framework.

As illustrated in figure 6, the main positive network effect of a MaaS framework is that an increase in the number of users of the framework would lead to an increase in the available means of transportation (Available Mobility). As such, the users would experience increased efficiency in mobility (due to the fact that the quality of matches is potentially higher as a result of the increased number of available mobility). This, in turn, draws more users to the platform. In this way, the cycle restarts.

At the beginning of the lifespan of a platform, there are no users yet, which makes the platform less attractive. A strategy to be followed in this situation is the follow-the-rabbit strategy. This strategy entails attracting an existing customer base [8]. In the case of the MaaS framework, users from the existing mobility providers can be attracted while slowly developing the platform side of the framework. To optimize the positive network effects a number of new users and their available mobility should be as high as possible. The monetization of the platform should therefore not be based on charging all users, however, it would be better to charge non-critical users such as users who do not provide mobility. This way of monetization will still encourage the positive network effects by encouraging users to make their mobility available to other users.

6. Discussion

Further research is needed to prove stated effects and discover new ones. In this exploratory work, we took as input the plans for MaaS in the City of Amsterdam and hypothesised the effects that would occur thanks to the introduction of a MaaS framework. Of course, further experiments and pilots are necessary to gather data and build experience with holistic MaaS solutions.

When users join the framework, the question arises whether the users are willing to give up their own means of transportation in exchange for a platform where they can use all means of transportation. However, people are often attached to their cars and bikes as this can give a feeling of freedom or be a status symbol.

Not only the possession of mobility means will become superfluous, sensitive data has to be shared inside the framework which could be problematic for some parties using the framework. An example of such a party is the mobility provider Uber. This is a data driven company and sharing its data with other parties could be unfavourable for its competitive advantage.

These disadvantages are accompanied with benefits for both end-users and transportation providers. An advantage for the end user would be faster travel, however, we wonder whether these advantages would actually cause users and providers to give up their means of transportation and sensitive data. We also question whether the framework could actually lead to lower prices for the end-user because the framework can become very expensive, especially when negative network effects occur.

On a systemic level, experiments and pilots need to show whether the MaaS framework will affect the number of cars on the road and passengers of public transport. The competitive advantage created by the increased efficiency of transport is still of unknown size, experiments and pilots will need to show whether this advantage is large enough to incentivise transportation providers to join the framework.

7. Conclusion

Mobility as a Service (MaaS) is a solution proposed for an upcoming transportation problem due to a growing amount of people in, for example, Amsterdam, where we analyzed the mobility situation as a case study. In our research, we examined the policy of the City of Amsterdam regarding the mobility problems in Amsterdam. The City of Amsterdam has plans to introduce an Open MaaS Framework in order to optimise the mobility in Amsterdam. This is a Framework where supply and demand are optimally adjusted to one another. We analyzed this framework with the Software Sustainability Assessment (SoSA) method developed by Lago et al. [1]. This is a method to model software solutions within four sustainability dimensions, namely, the economic, environmental, social and technical. All four dimensions should be taken into account in order to fully understand the balanced sustainability implications of a software-solution. In addition, it enables reasoning about its (potential) effects. In our research, we modelled the Open MaaS Framework, which is a software solution, with the SoSA method. This enabled us to gather all the sustainability implications and there trade-offs in one picture (see figures 4 and 5).

We foresee that the implementation of the MaaS framework would lead to a healthier distribution of traffic leading to environmental, economic and social benefits. Due to the reduction of car production, emissions can be positively impacted. Further, by gathering more data once the framework is in place more rides can be shared, this will result in less emission as well. Furthermore, busy places and peak hours can be taken into account and more transportation means can be used flexibly. Whenever there is less demand for mobility, for example, public transport buses can be replaced by only one car. Economic and social benefits arise from the fact that the user's' destination can be reached cheaper and faster as the MaaS framework is able to analyse all the transportation means and chose the optimal one.

However, these benefits are accompanied by disadvantages in the field of privacy and software dependency which are common problems in the current, modern society. Mobility providers and end-users are required to share their transport data in order for the MaaS framework to work properly and be able to optimize mobility. Regarding the software dependency, as the MaaS framework increases in popularity, an increasing number of companies and end-users will rely on this framework. In the case of a technical breakdown, the transportation will be disrupted. This will have a great impact on society as people are suddenly unable to move to their work, meetings, school and so on. These problems should be carefully considered and the negative effects are ought to be minimized. Moreover, a shift in behavior needs to be realized. The deeply embedded culture that transportation means need to be possessed in order to experience the freedom of mobility need to be changed. People need to realize that the MaaS framework will optimize their transportation experience and, eventually, will be necessary in order for mobility to be sustainable.

Acknowledgements
This work has received partial funding from the Netherlands Enterprise Agency (rvo.nl), project GreenServe on energy efficient software and green cloud.

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