Imflow in Valby

A case of implementing an adaptive traffic control system

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Preface

This project report revolves around the adaptive traffic control system Imflow in Valby. The project aims to highlight issues that arose during the implementation and operation phase of the project, to map the actors involved in the project and to describe the future for the project. Imflow in Valby was implemented when the previous system, Motion, which was based on induction loops, produced results that were less than satisfactory. Further, the Municipality of Copenhagen's cooperation with the main traffic operator at the time, Swarco, was getting more strained as the operator made more demands and was simply too expensive to keep under contract. So Imtech, now Dynniq, signed an 8 year contract to implement their own and more cheap adaptive traffic control system; Imflow. But the implementation phase was not smooth and several issues contributed to the work being delayed. Once Imflow was finally operational too long time had passed since the reference points were made, to compare the efficiency of the new system with the older one and thus issues arose on how to then measure the effect of Imflow. How these issues arose and what they meant will be analyzed in this project with the help of the Actor-Network Theory.

The project was chosen because of my interest in ITS and adaptive traffic control and I wanted to gain knowledge about how the network behind a system such as Imflow is created. I was also interested in knowing how the various parties in such a project work together, how their hardware and software is compatible with one another and if such a system is successful. To gain the necessary background knowledge some very fruitful interviews were conducted with the involved parties and with experts on ITS and adaptive traffic control. These interviews provided invaluable data for the project and therefore I would like to express my deepest gratitude to, Anders Madsen from the Municipality of Copenhagen, Anil Sharma from Movia, Erik Damgaard from Imtech/Dynniq, Bo Westhausen from COWI and Per Homann from RUC. Without the input from these men this project could not have been written. I would further like to thank my supervisor Morten Elle for his very helpful guidance to me to reach my goals for this project.

Contents

1. Introduction

The Municipality of Copenhagen has visions of green growth, green mobility and lower CO2 emissions and by 2025 the aim is to be completely CO2 neutral (Københavns Kommune(a), 2012). Copenhagen has steadily been reducing CO2 emissions for decades now, e.g. from 2005 to 2011 the CO2 emissions in Copenhagen had dropped by 21 percent (Københavns Kommune(a), 2012). To reach their goals Copenhagen already has done and still must do various initiatives covering the energy, waste and transport sector. In the transport sector one of the key issues to lower CO2 emissions is the reduction of car traffic. To achieve this, more attractive alternatives need to be available to the car users. Those alternatives can be improved infrastructure for other transport modes such as walking, biking, buses and trains, and better incentives to try other transport modes than the car. The green mobility goals for Copenhagen for 2025 are (Københavns Kommune(a), 2012):

- 75 percent of all trips in Copenhagen to be done by walking, biking or public transport
- 50 percent of trips to work or school in Copenhagen to be by bike
- 20 percent increase in passengers on public transport compared to 2009
- The public transport is to be CO2 neutral
- 20-30 percent of all light vehicles to use newer and propulsion fuels such as electricity, hydrogen, biogas or bioethanol
- 30-40 percent of all heavy vehicles to use newer propulsion methods

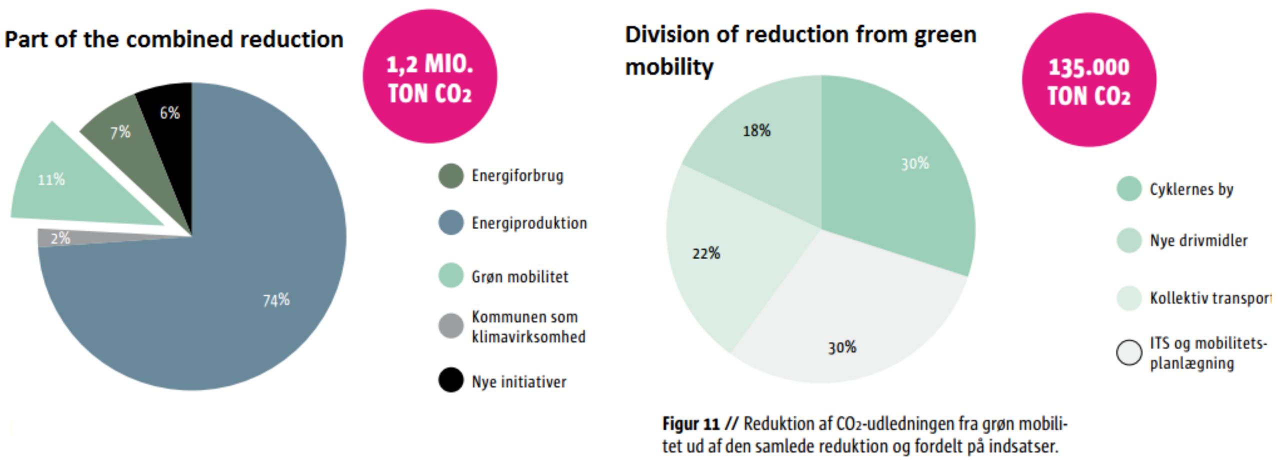


Figure 1: Two pie charts showing part of the combined reduction of CO2 and the division of reduction from green mobility (NOT DONE!)

In the municipal plan from 2011 Copenhagen shared its vision that transport in Copenhagen should be divided so at least 1/3 of all trips are to be made by bike, at least 1/3 by public transport and at most 1/3 by car (Københavns Kommune(a), 2012). To reach all of these goals by 2025 it requires massive investments in infrastructure, bicycles, electric and hybrid vehicles, biofuels for public transport and intelligent traffic management (Københavns Kommune(a), 2012).

As part of the decrease in CO2 emissions in the transport sector Copenhagen wishes to improve the infrastructure for and quality of public transport (Teknik- og Miljøforvaltningen(a), 2014). But to get people travel by public transport it is important that the public transport is running efficiently and travel time and punctuality are key success factors (ImTech, 2012). Thus, to implement a successful public transport strategy it is necessary that the public transport has a perceived high level of quality to the general public (ImTech, 2012). Investments in and implementation of *intelligent transport systems* (ITS) can contribute towards increased efficiency and reduced emissions from not only public transport but transport in general (Teknik- og Miljøforvaltningen(a), 2014). ITS is technological equipment that contributes to make traffic more efficient, safe and environmentally friendly (Københavns Kommune(b), 2014). By implementing ITS in traffic signals the municipality gets a wealth of new possibilities in relation to traffic management to systemic and prioritized management of traffic flow. This is being done primarily via traffic data from sensors, signs, etc. (Københavns Kommune(b), 2014). Further, ITS can contribute to a more optimal utilization of the existing infrastructure without major infrastructural changes (Københavns Kommune(b), 2014).

Thus, in 2013-2014, with a budget of more than DKK100 million allocated for new traffic signals and intelligent traffic management, Copenhagen implemented a number of pilot projects for ITS (Teknik- og Miljøforvaltningen(b), 2014). These projects span from bicycle projects to traffic light signals for buses. Buses are a big part of the public transport system in Copenhagen with about 160 million uses each year using MOVIA's buses in the metropolitan area of Copenhagen (Teknik- og Miljøforvaltningen(a), 2014). To properly service the bus commuters the bus traffic must be efficient and on time. This has been done via dedicated bus lanes and special traffic lights for buses (Teknik- og Miljøforvaltningen(a), 2014). But the bus traffic flow can be improved further. To ensure this, intelligent traffic light optimization (ITLO) could be prioritized to improve the flow of bus traffic (ImTech, 2012). Already in 2012 the Municipality of Copenhagen had signed an 8 year contract with Dutch transport technology provider Imtech (now Dynniq) to implement their traffic management stystem, Imflow. By 2015 Imflow was fully operational in Valby in the south-west of Copenhagen to test out the new system in 10 light crossings (ImTech, 2012)(Personal communication, Anders Madsen, 2016). The key policy objectives of the Imflow project are:

"… to establish a direct link between the municipality's policy objectives and signal timings at intersections. The main objective is to improve the travel time of the bus lines. Line 18 (now 8A) *has the highest priority in the network, together with lines 1A and 4A.*

In addition to this main objective there is a secondary objective to achieve green growth and green mobility by improving the waiting time for pedestrians and cyclists in the network." (ImTech, 2012, s. 3)

Further, there are objectives regarding maximum average waiting times at light crossings for pedestrians and cyclists and for the total network (ImTech, 2012). Below is a table listing the 10 intersection and a map showing them Valby where Imflow was to be implemented.

Number	Name
28.01	Vigerslev Allé - Sjælør Boulevard
28.03	Toftegårds Plads - Gl. Køge Landevej
28.04	Toftegårds Allé - Lyshøjgårdsvej
28.05	Valby Langgade - Toftegårds Allé
28.06	Toftegårds Alle - Rughavevej
28.07	Valby Langgade / Gl. Jernbanevej
28.08	Valby Langgade - Annexstræde - Ved Ovnhallen
28.11	Vigerslev Allé - Trekronergade
29.01	Vigerslev Allé – Ramsingsvej
29.02	Vigerslev Allé – Fengersvej

Figure 2: The ImFlow intersections in Valby

Before ImFlow was chosen as the new bus prioritization system an older system implemented at the start of the millennium had been used. It was based on induction loops in the roads that would detect the traffic and then a traffic calculator would calculate the runtimes and the "green-times"[1] in real time (Personal communication, Bo Westhausen, 2016). The system was known as Motion and was made by Siemens (Personal communication, Bo Westhausen; Anders Madsen, 2016). This system never functioned satisfactory. There were constant problems with loops breaking due to heavy traffic or road work and this made the whole system very fragile (Personal communication, Bo Westhausen, 2016). At some points as many as half of all the loops in Valby were not functioning (Personal communication, Anders Madsen, 2016). Thus the Municipality of Copenhagen wanted to implement a new and more reliable system and thus put it up for bidding so companies with expertise in the area could apply for a contract with the municipality to be a supplier and maker of a new system (Personal communication, Anders Madsen; Bo Westhausen, 2016). And so ImTech won the competition and the contract with the municipality and thus ImFlow was implemented in Valby (Personal communication, Anders Madsen; Bo Westhausen, 2016). Further elaboration of the ImFlow system, how it came to be in Copenhagen, its implementation and operation phases, the various parties involved, etc. will be done later in this project report.

[1] Green-time is the amount of time that a traffic light shows a green light

2. Problem Field

Behind the Imflow project there are several major actors, some of which have already been introduced. Imtech/Dynniq are the developers and suppliers, the Municipality of Copenhagen are the project leaders and then there is the public transport provider Movia, who owns the buses that are the target of Imflow. Further, there are several non-human, physical actors that play an important role in the ImFlow system, such as the cameras, the buses, the roads, etc. The significance of all these various human and non-human actors and the network they all make up will be explained in this project.

As mentioned before there were some problems with the previous traffic system, Motion, but Imflow has not been without its own share of implementation and operational problems. These phases will be presented more thoroughly through a case description later in the project. But what exactly caused the Municipality of Copenhagen to want a change in operators? Was it only the induction loops failing or were there other issues involved in the decision? And how would the new system be implemented? Through what methods would the implementation phase be realized and what parties would be involved in the process? And what is the future for Imflow?

In this project I will seek to answer those and more questions. I will do that partly by applying the main principles of the *Actor-Network Theory* (ANT). Through ANT I want to map the network of involved actors in the Imflow project and via the principles of the theory I want to illustrate the various relations and intricacies between the actors of the network, both the human but also the non-human actors. This process will be elaborated further later.

The bulk of the project's data will be provided through interviews with the main actors that have been and are involved in the Imflow project. This means input from representatives from Dynniq, the Municipality of Copenhagen and Movia. Further there will be input from people outside of the project but with expertise on the topic of ITS solutions for bus traffic.

This leads me to the following research question:

What constitutes the network of actors behind the Imflow in Valby project, what were the main issues during its implementation and operation phase and what does the future hold for Imflow?

3. Methodology

This chapter will provide a description of the methodology used to make this report. The research design of the report will be explained first, then the data collection and the methods of collection and lastly there will be a paragraph about the context and the structure of the analysis.

3.1 Research Design

This project report is a descriptive and analytical report based primarily on first hand data and the principles of the Actor-Network Theory (ANT). The purpose of this project is to explore why the old traffic management system in Valby was substituted, to describe the network surrounding the Imflow in Valby adaptive bus prioritization project, to map the actors involved and to describe the implementation and operation phase and all the issues that arose during those phases. Further, the future potential for the Imflow project will be explored.

The project report has started with a short introduction to the landscape of traffic management in Valby, Copenhagen from before the implementation of Imflow and up until the implementation phase of Imflow. After the short introduction the problem field was narrowed and the research question was presented. Following that chapter is this chapter; the methodology. Then comes the theory chapter. Here the theory of Actor-Network Theory will be introduced and explained. The main principles of ANT that will be the theoretical base of this project report will be explained. Following the theoretical framework chapter is the case of Imflow in Valby will. This chapter is a case description of the whole situation from before Imflow, Imflow's implementation and its operation phase. The various phases of Imflow in Valby will be explained in detail to give the reader an overview of the whole situation before Imflow and during its implementation and operation phase. When the case of Imflow in Valby has been explained the principles of ANT will be applied to the project in this report's analysis chapter. First the network around the previous traffic management system, Motion, will be mapped and the reasons for why it was discontinued will be explained, Then the whole network around Imflow in Valby will be illustrated and mapped and the relations and workings of the network will be analyzed and the issues that arose during the implementation and operation phases will be explained. After that the content and the findings of the analysis will be discussed in the discussion chapter. Finally I will conclude on the results of the project analysis and discussion and see to what extent the research question has been answered.

3.2 Data Collection

The data that this thesis is written from is mostly primary. This has been collected through interviews with the main actors behind the ImFlow project and other experts on ITS and ITLO. The research process along with the interviews took a great deal of time and work to gather the needed background information to construct some productive questions that would help with the writing of this project report. The interviews were conducted from an ANT perspective, so most of the questions were based on the principles of ANT. This was done to gain the required knowledge about all the actors in the network around Imflow to both map the network and to analyze it. The interviewees:

- Per Homann from RUC is a researcher in traffic and has also had a seat in Trængselskommissionen **(The Congestion Commission)**.
- Bo Westhausen is a consultant for COWI and is an expert on ITS and ITLO and has been working in the field for several years. He has previously been employed by Rambøll, Municipality of Herlev and Municipality of Frederiksberg among others.
- Anders Boye Torp Madsen is the project leader and contact person from the Municipality of Copenhagen on the ImFlow project in Valby.
- Anil Sharma is project leader at MOVIA and the lead person on Movia's part in the ImFlow project.
- Erik Damgaard, director of Dynniq, previously known as Imtech, and project leader representing Imtech in the Imflow project.

The interviews were semi-structured so there could be a line of questions to follow but also so the interviewees could deviate from the questions if necessary. Two interviews were conducted with Bo Westhausen from COWI, the second one after the other interviews were done to get some reflective thoughts on the information that I had gathered from the previous interviews.

Along with the first hand data much literature was used for the theoretical framework to be able to describe ANT most optimally with various sources contributing. Second hand data was also used in the more descriptive parts of the project report, such as the introduction and the case description. Most of the literature collected was collected via the internet or by referral from interviewees or professors from Aalborg University Copenhagen.

3.3 Context and Structure of Analysis

The analysis will be structured around the actor-world of Imflow in Valby. This will be the chapter where part of the research question will be answered. An illustration of the network before Imflow along with a description of the network and why it was discontinued will be provided before the Imflow in Valby network will be mapped and explained in depth. The principles of ANT explained in the theoretical framework will be applied to the material from the case description. That is, the main actors will be mapped, the intermediaries that link these actors to each other – directly or indirectly – will be described.

The extent of convergence and irreversibility of the actor-world will be explored and then the chapter will be concluded to lead up to the discussion chapter.

4. Actor-Network Theory

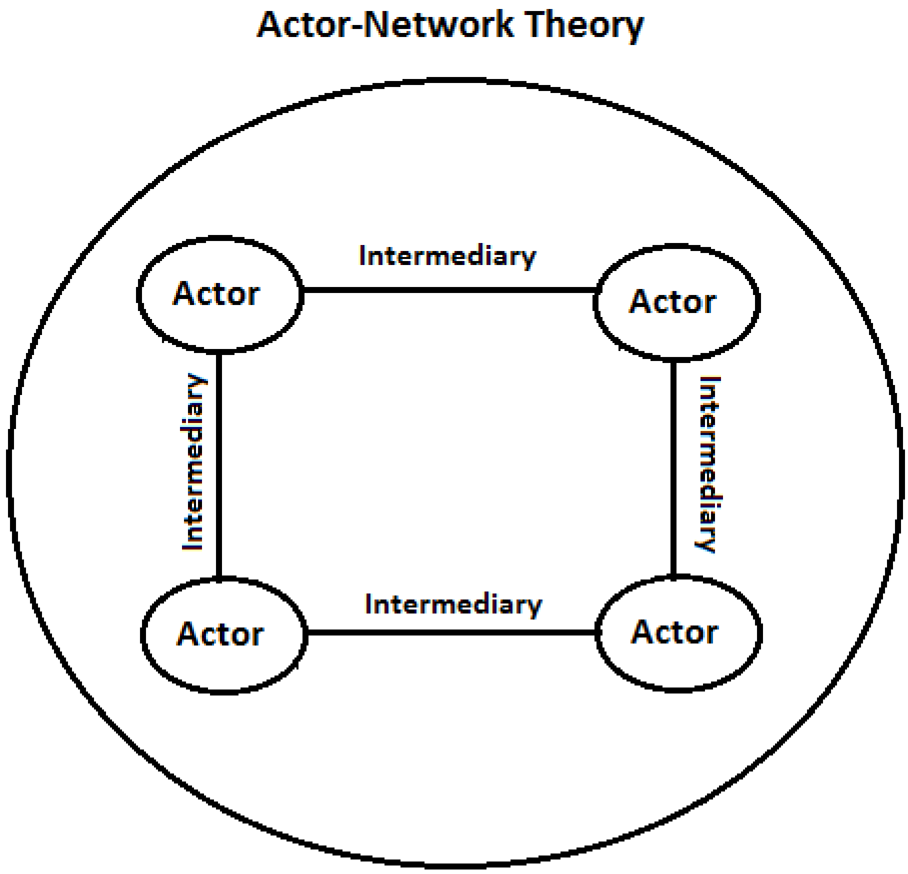


Figure 3: Actor-Network Theory

In this chapter the Actor-Network Theory (ANT) will be introduced and described, with the purpose of giving the reader an understanding of the theory before applying it to the data collected for the analysis. First will be a short introduction of ANT and its basic principles. Afterwards some of the main components of ANT will be explained and then the use and relations of them will be described.

ANT was created by Michel Callon in the early 1980's and since then has been developed and updated by him and his colleagues in the later 80's and 90's (Law (a), 2009; Latour, 1990). Since the theory was devised several papers have been written, both by Callon and by others such as John Law and Bruno Latour, both discussing ANT, developing and criticizing it (Callon(a), 1991; Latour, 1990; Law(a), 2009). The basic core of ANT can be described in these two ways:

"*ANT wanted not only to break with the division between technology and society, but also between human and non-human actors. It is not a given who can be actors in technological development and which characteristics they possess, ANTers argued. People, technology and natural phenomena can all be* *components in materially heterogeneous actor-networks and take on the role of actors.*" (Asdal, Brenna, & Moser, 2007, s. 23)

"(ANT) *…is distinctive because it insists that networks are materially heterogeneous and argues that society and organization would not exist if they were simply social. Agents, texts, devices, architectures are all generated, form part of, and are essential to, the networks of the social. And in the first instance, all should be analyzed in the same terms.*" (Law(b), 1992, s. 379).

So ANT works with more than just social networks, it works with networks in general. It does not only concern itself with the social relations and interactions of human actors – but it more aims to describe every actor, human or non-human, individual or non-individual, in a network (Latour, 1990). As Bruno Latour (1990) puts it:

"*Whereas social network adds information on the relations of humans in a social and natural world which is left untouched by the analysis, ANT aims at accounting for the very essence of societies and natures. It does not wish to add social networks to social theory but to rebuild social theory out of networks. It is as much an ontology or a metaphysics, as a sociology. Social networks will of course be included in the description but they will have no privilege nor prominence (and very few of their quantitative tools have been deemed reusable*" (Latour, 1990, s. 2-3)

So there will be no higher privilege for human actors over non-human actors, all things being equal. It is significant when trying to illustrate or describe a network, that leaving out non-human actors for human actors, in an ANT sense, will create more of a social network rather than a mixture of "*societies and natures*", a heterogeneous network (Latour, 1990; Law(b), 1992). This heterogeneity lies at the very core of ANT, it is; "*… a way of suggesting that society, organizations, agents and machines are all effects generated in patterned networks of diverse (not simply human) materials*" (Law(b), 1992). The diversity and heterogeneity is all-important in analyzing a network through an ANT perspective. But this also makes the networks dynamic, but this will be elaborated later in this chapter.

It is also important to point out early that despite its name ANT is not a theory. This has been pointed out by both Callon (2007) and Law (2009). Law (2009) explains that theories are mostly explanatory but ANT is more descriptive. He puts it that: "*… it is a disappointment for those seeking strong accounts.*" (Law(a), 2009, s. 142) ANT more describes how various relations in a network assemble, or do not, between the actors of the network (Law(a), 2009). As such, ANT will be used in this project to describe and illustrate the relations and interactions of the network behind the Imflow project.

4.1 Actors and Intermediaries

As mentioned in the previous section the notion of the *actor* can be many things. An actor can be both human and non-human, it can be an individual entity or a group or even a larger society. A given network can be comprised of actors that can be companies, scientists, money, texts, small and/or large physical objects, etc (Callon(a), 1991). An actor can also in one sense be an actor, or in another be a network, depending on the perspective, or it can be both; a hybrid (Callon(a), 1991). An example could be MOVIA. It can be a network of employees, secretaries, consultants, bus drivers, buses, offices, GPS systems, etc. But in terms of the Imflow project MOVIA is an actor in the network around the Imflow project. The actor, by default, without any explained purposes or intentions is neutral. It can be both a well-functioning unit or group or a one that fails like rusty machinery, failing mechanics, a group torn up by conflicting interests, etc (Callon(a), 1991). The actor, or actors, is also the so-called *authors* in a given network. It designs and defines the network, determines its contents and sets its boundaries (Callon(b), 1986).

"*… it* (the actor) *is any entity that more or less successfully defines and builds a world filled by other entities with histories, identities, and interrelationships of their own.*" (Callon(a), 1991, s. 140)

It creates relationships with other actors by way of passing intermediaries between itself and the other actors (Callon(a), 1991). It is those intermediaries that define the relationship between the actors of the network (Callon(a), 1991). Like actors the intermediaries can take many different forms and shapes, such as computer software, humans, technical artifacts, money, scientific papers, etc, and they can also be hybrids (Callon(a), 1991). Callon (1991) talks of four main types of intermediary:

"*First there are texts, or more generally, literary inscriptions. These include reports, books, articles, patents and notes.*

Second there are technical artifacts. These, which include, scientific instruments, machines, robots and consumer goods, are (relatively) stable and structured groups of non-human entities which together perform certain tasks.

Third and obviously, there are human beings, and the skills, the knowledge and the knowhow they incorporate.

And fourth there is money in all its different forms." (Callon(a), 1991, s. 135)

It might seem that actors and intermediaries are the same but there are distinctions between them. I mentioned that the actor is an author, it puts the intermediaries into circulation, it sets them in motion, it transforms them (Callon(a), 1991). Examples of this can be scientists transforming texts or grants into new texts or companies combining production machines and embodied skills into various goods and consumers (Callon(a), 1991).The intermediaries in that sense describe their networks. Callon (1991) elaborates: "*… they describe a collection of human and non-human, individual and collective entities. These are defined by their roles, their identities and their program – which all depend on the relationships into which they enter.*" (Callon(a), 1991, s. 139). So the intermediaries need the actors to put them into circulation and the actors need the intermediaries to describe the network. To summarize; the similarities between actors and intermediaries can be described as Callon (1991) does: "*An actor in an intermediary that puts other intermediaries into circulation*" (Callon(a), 1991, s. 141). And thus "*Actors define one another by means of the intermediaries which they put into circulation*" (Callon(a), 1991, s. 140)

Actors and intermediaries together describe a network. In the next section networks and the workings of the networks, and actor-networks, will be elaborated.

4.2 Networks

"*All groups, actors and intermediaries describe a network: they identify and define other groups, actors and intermediaries, together with the relationships that bring these together. When such descriptions include an imputation of authorship, then actors emerge in the stopping places, asymmetries, or folds.*" (Callon(a), 1991, s. 142)

Such is how Callon describes the networks that actors and intermediaries make up. The network of intermediaries that is accepted by an actor is transformed by that actor and is then carrying the signature of the actor. This is why Callon speaks of actor-networks, for "*an actor is also a network*" (Callon(a), 1991, s. 142). In order for the agreements to be made between actors and actor-networks some new terms will be introduced. Actors or actor-networks might have no a priori reason to be in agreement or compatible with each other. One might not accept another's definition. The three terms that can provide answers to the question of agreements between actors and actor-networks are *translation, convergence* and *irreversibilization* (Callon(a), 1991).

4.2.1 Translation

"*A translates B.*" (Callon(a), 1991, s. 143). Such is how one actor translates, or defines, the other. However, A is not at total liberty; it has itself been defined by past translations (Callon(a), 1991). The translation process is where the identity of actors, their possibilities for interaction and relations and their maneuverability are negotiated, defined and delimited (Callon(c), 2007). As Law (1992) puts it:

"*So "translation" is a verb which implies transformation and the possibility of equivalence, the possibility that one thing (for example an actor) may stand for another (for instance a network).*" (Law(b), 1992, s. 386)

The translation process is a core element of ANT, it concerns itself with how actors mobilize, are defined, how the boundaries are set and how they manage the various actors and intermediaries in the network, and how they:

"*… hold together the bits and pieces out of which they are composed; how they are sometimes able to prevent those bits and pieces from following their own inclinations and making off; and how they manage, as a result, to conceal for a time the process of translation itself and so turn a network from a heterogeneous set of bits and pieces each with its own inclinations, into something that passes as a punctualized actor.*" (Law(b), 1992, s. 386)

As mentioned, while actor A translates actor B, actor A is itself defined by past translations through definitions inscribed in the intermediaries between it and the translator (Callon(a), 1991). Since intermediaries can come in many forms it is necessary to define the medium into which the translation is inscribed. This means that there are almost endless possibilities, nevertheless the process of translation is triangular; "*It involves a translator, something that is translated, and a medium in which that translation is inscribed.*" (Callon(a), 1991, s. 143). It is also important to note that translations may change over time and this can alter the network (Callon(a), 1991).

The translation process can lead to convergence and irreversibilization.

4.2.2 Convergence

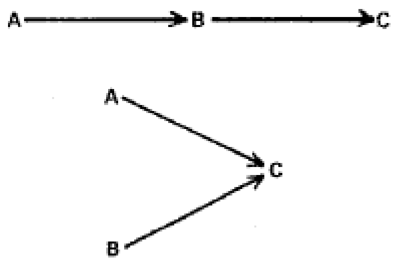
Convergence is when the translation process and its circulation of intermediaries leads to agreement (Callon(a), 1991). When speaking of convergence in ANT there are two dimensions to it; alignment and co-ordination.

Sometimes there are disagreements in the translation process between two actors or objects, the extent to which it is accepted and performed can vary (Callon(a), 1991). There might be unsuccessful translations that lead to consumers who are not satisfied with the quality of a product they have bought, scientists who disagree with the points of arguments from their peers, etc. And then there are translations that are accepted and performed, that become self-evident, they are perfect translations. Then there are the situations in between these two extremes (Callon(a), 1991). Callon (1991) describes it:

"*And between these two extremes lie all those situations so well described in game theory in which each player puts itself in the place of the other and they work through a series of iterations to a possibly stable conclusion. A successful process of translation thus generates a shared space, equivalence and commensurability. It aligns*" (Callon(a), 1991, s. 145)

So in summation; a network that is strongly aligned is one where the translations are successful and a network that has translations that are not successful is a weakly aligned network (Callon(a), 1991).

A network starts to form as soon as three actors are joined together by intermediaries. There are two basic possible configurations:



The first is one of complementarity in which the relationships are transitive. If A translates B which translates C, then A also translates C. The second is one of substitutability in which C is similarly translated by A and B. The level of alignment depends on the success of the translations – and in the case of substitutability on the extent to which they resemble one another.

Figure 4: Callon (1991) explains translation and alignment (Callon(a), 1991, s. 145)

Co-ordination has to do with the regulations in a network. A network where there are no specific rules is weakly co-ordinated while a network shaped by general and local rules is strongly co-ordinated (Callon(a), 1991). This also means that the possibilities for various translations in a network are limited in a strongly co-ordinated network and this makes the network more predictable (Callon(a), 1991). A network with a high degree of alignment and co-ordination is more convergent than a network where the situation is the opposite (Callon(a), 1991).

4.2.3 Irreversibilization

In a network the degree of irreversibilization depends on two things:

"*(a) the extent to which it is subsequently impossible to go back to a point where that translation was only one amongst others; and* *(b) the extent to which it shapes and determines subsequent translations.*" (Callon(a), 1991)

The irreversibility of a network comes down to the number of translations, where the translations cannot return to other translations (Callon(a), 1991). Then it becomes a normalized network. Sometimes networks become stabilized over long periods of time. An example can be the traffic lights; it is now generally known around the world that a red light means stop. It is so strongly inscribed in the network that it has now been rendered irreversible (Star, 2007).

"*In a strongly convergent and irreversibilized network, the actors are perfectly identifiable, and their behavior is known and predictable*" (Callon(a), 1991, s. 155)

The more irreversible and convergent a network is the more defined and limited the information of the network is and the less it tends to go beyond its borders (Callon(a), 1991). The actors of the network are more aligned and the translations are more successful (Callon(a), 1991). On the other hand, a less convergent network is more dynamic and unpredictable; it is more open to change and is less governed by rules (Callon(a), 1991). The actors in this network are more diverse and their motives and opinions differ more than in a convergent network (Callon(a), 1991).

4.3 Actor-worlds

The actor-worlds are constructed by the actors. These are worlds where the actors define the boundaries and the key actors and intermediaries that interact in the actor-worlds (Callon(b), 1986). An actor-world is a world created and thus the components of the world might not reflect the "real" world. Actors in the actor-world are defined by their roles in it (Callon(b), 1986). One actor might be a large and powerful entity in the real world but in a given actor-world its significance might be reduced to fit the actor-world. The components of the actor-world might also be limited. The actor-world is a more simplified version of the real world, which is infinitely complex (Callon(b), 1986). In the case of Imflow, the actor-world is set up around the actors and intermediaries that interact in the network. This means the actors and intermediaries - still human and non-human - that have significance to the Imflow project. Callon (1986) in his study "*The Sociology of an Actor-Network: The Case of the Electric Vehicle*" works with the case of the Electricité de France (EDF) and their plan for an electric vehicle and the social universe in which it would function (Callon(b), 1986). In their plan the EDF have defined the key actors and their roles through a simplification of the real world. He writes:

"*For example, towns consist of more than public transport, the wish to preserve town centres and the town councils that constitute their spokesmen. They differ from one another with respect to population, history and geographical location. They conceal a hidden life whose anonymous destinies interact. However, so far* *as the EDF is concerned, they may be reduced to a transport system that must avoid adding to the level of pollution and a town council that seeks to advance towards his goal*" (Callon(b), 1986, s. 29)

So the actor-world is designed according to the EDF's plan for their electric vehicle. In the same way I will set up the actor-world for the Imflow project in Valby. Such a procedure might pose some problems though as this simplification of the real world might be challenged if other entities are appearing to make the network more complex than intended (Callon(b), 1986).

ANT is chosen for this project because of the tools it provides for mapping a network and for analyzing the relations in that network, how it is constructed and what it is constructed from, etc. Since it not only concerns itself with the social relations it is a useful tool for explaining the non-human relations in a heterogeneous network. That is why ANT was chosen as the theoretical framework for this project report; It aides in the analysis of the various relations and translations in the Imflow network and in the network of the previous system. In this report I wish to highlight the issues that arose during the implementation and operation phase of Imflow, how they arose and why. I am applying ANT to both map the network and the relations but also to explore what the various issues in the network did to the rest of the network.

In the following chapters the Imflow project will be more thoroughly introduced and its actor-world will be illustrated and defined.

5. The case of Imflow in Valby

In this chapter Imflow in Valby will be presented as a case. The situation before it was implemented, why Imflow was the system chosen to be implemented, the implementation phase and the operation phase will be described. The Imflow system itself will be explained and the roles of the main parties involved in the planning and operation of Imflow will also be introduced and explained. This is to get the reader acquainted with the Imflow project before the analysis of its network.

5.1 The planning and implementation of Imflow

Figure 5: The intersection at Toftegårds Plads, with Movia's office buildings in the background

Before Imflow was implemented Copenhagen had been running an adaptive traffic control system (ACTS)[2] called Motion since the turn of the millennium (Personal communication, Anders Madsen; Bo Westhausen(b), 2016). Motion was made by Siemens but the Danish division of ITS and traffic solutions provider Swarco was the main traffic management operator for the municipality (Personal communication, Bo Westhausen(b), 2016). Motion was running with physical detectors in the roads, induction loops, that detects traffic via electric frequencies that are set to flag whenever a vehicle with a measurable frequency triggers the induction loop (Personal communication, Bo Westhausen(b), 2016). Motion measured the traffic flow into a grid of traffic signal networks and the data was then being sent to a traffic counter that would calculate the duration for green lights and the entire signal cycle[3] in real time (Personal communication, Bo Westhausen(a), 2016). However the system never worked optimally, neither in Valby nor in the other places it was implemented (Personal communication, Bo Westhausen(b), 2016). In most cases Motion had the opposite effect of what it was intended; it created chaos and queues at the light

[2] "*Adaptive Traffic Control Systems (ATCSs), also known as real-time traffic control systems, adjust, in real time, signal timings based on the current traffic conditions, demand, and system capacity*" (Transportation Research Board, 2010)
[3] The cycle is the period of time where a signal goes from a green light to green again (Personal communication, Bo Westhausen(b), 2016)

crossings (Personal communication, Bo Westhausen(b), 2016). One of the main issues with Motion was that the physical detectors, the induction loops, were failing. The whole system was fragile and when the loops were failing it would compromise the entire system because it would not get the necessary data input (Personal communication, Bo Westhausen(a), 2016). Fixing these loops was not an easy or cheap task however. Swarco were not contractually obliged to maintain the induction loops so the municipality had to either handle maintenance themselves or compensate Swarco financially to do it (Personal communication, Anders Madsen; Bo Westhausen(b), 2016). And then there are the troubles with the loops that you can only work on them one half of the year; you are obliged to use water when digging in asphalt because of the dust pollution but you cannot use water in the cold months because of the risk of the water freezing solid (Personal communication, Bo Westhausen(b), 2016). Anders Madsen, traffic engineer at the Municipality of Copenhagen and the project leader for the municipality in the Imflow project. He says:

"*When I started here there were about 200 induction loops in the roads and about half of them were broken from road works (…) imagine a system where only 50 percent of the sensors are providing data to it, then the system itself must calculate the missing input and then it is no surprise that the performance of the system suffere.*" (Personal communication, Anders Madsen, 2016, s. 1)

Figure 6: The intersection at Toftegårds Alle - Rughavevej

These issues with Motion meant that the municipality often had to roll back to backup programs that were not adaptive but rather were working from fixed time-managed systems (Personal communication, Anders Madsen, 2016). The municipality however was close striking a deal with Siemens where they would upgrade the Motion system to a newer version to improve performance and stability (Personal communication, Anders Madsen, 2016). But because the municipality was about to offer the whole operating contract for the traffic signals and because of the budget allocated for this the municipality instead opened up bidding for the contract for everyone (Personal communication, Anders Madsen, 2016). Part of the conditions for winning the contract were that new traffic detection systems must be above ground and not be induction loops as they are too fragile and require too much and too expensive maintenance work (Personal communication, Anders Madsen, 2016). It did not have to be a specific above ground system but it was important that the bidder could describe and put a price on an intelligent bus prioritization system to be implemented in Valby (Personal communication, Anders Madsen, 2016). So that, combined with Swarco wanting to implement their own DKK30 million traffic surveillance system meant that now the operating contract would be open for anyone to bid on (Personal communication, Bo Westhausen(b), 2016).

Movia were in on the idea from the beginning (Personal communication, Anders Madsen, 2016). Movia, like the Municipality of Copenhagen, were not satisfied with how Motion was working for their buses so they also had an interest in an optimized and more efficient ATCS to improve efficiency for their buses (Personal communication, Anil Sharma, 2016). This would make their product, the buses, more attractive. Movia had been using a GPS system in their buses along with the induction loops in the Motion system, but because the induction loops had a high rate of failure they did not work with the GPS system in the buses as well as intended (Personal communication, Bo Westhausen(b), 2016).

Figure 7: The intersection at Valby Langgade - Gl. Jernbanevej

Imtech Peek, as they were known as back then, won the contract and signed an 8 year deal with the Municipality of Copenhagen in 2012 (Personal communication, Anders Madsen, 2016). Imtech Peek brought in their own adaptive system, Imflow, to be implemented in Valby. Imtech did not exist in Denmark before the bid was made for the operating contract with Copenhagen, but winning the contract lead Imtech to set up a Danish division by bringing Peek Traffic under their banner (Personal communication, Erik Damgaard, 2016). Imtech Peek are now known as Dynniq and are a provider of traffic signals, adaptive systems, various surveillance systems and lighting and parking solutions. Dynniq is still a Dutch company that employees thousands of people around the world but in Denmark they employ approx. 25-30 people (Personal communication, Erik Damgaard, 2016). They are now Dynniq as Imtech went bankrupt but their traffic department was bought by an investment fund (Personal communication, Bo Westhausen(a), 2016). In the project I will continue to speak of them as Imtech when referring to them during the implementation phase and up until they changed name to Dynniq and then I will refer to them as Dynniq.

Figure 8: The intersection at Vigerslev Allé - Fengersvej

The plans for Imflow were to install 66 above ground cameras to detect vehicle traffic in 10 light crossings in Valby (Personal communication, Anders Madsen, 2016). The system would then detect and count the amounts of traffic and based on the data from the cameras the system would optimize the flow of traffic in the light crossings (Personal communication, Anders Madsen, 2016). In Valby the system was to prioritize the main bus lines that pass through the intersections to improve their travel time (Personal communication, Anders Madsen, 2016). After a test simulation phase where various technologies were put up against each other, the cameras were chosen as the preferred technology. The loops were used as a reference point and then they tested various radars and cameras and compared them to the reference point and to each other. The FLIR cameras gave the best results and thus they were picked for the system to work in conjunction with the GPS's installed in Movia's buses (Personal communication, Anders Madsen;

Erik Damgaard, 2016). A more detailed explanation of how the system works will come later, for now we will stick to the implementation phase of Imflow.

Figure 9: Intersection at Valby Langgade and Toftegårds Alle/Søndre Fasanvej

So Imtech won the contract and together with the Municipality of Copenhagen and Movia they started the work with the implementation of Imflow in Valby. It was rough sailings during the startup phase though, as Imtech who did nothave a Danish division before acquiring the contract had to bring in their Dutch experts to do the work on their behalf (Personal communication, Anders Madsen, 2016). It was a condition in the operating contract that the winning organization should be based in Denmark, but the people in Denmark working for Imtech were relatively inexperienced with ACTSs (Personal communication, Anders Madsen, 2016). This created some work and leadership issues on the side of Imtech; e.g. they had four different project leaders since they won the contract in 2012 because they were only there for about half a year before quitting or moving on (Personal communication, Anders Madsen, 2016). Some of the new project leaders had never worked within the area of ACTSs before so this dragged out the implementation process, as every time a new project leader was assigned to the project he had to learn the workings and the system all over again (Personal communication, Anders Madsen, 2016). Further, the Municipality of Copenhagen had to change the steering equipment from Siemens so the new Imflow equipment could be installed. This also created some problems as the Imflow steering equipment was made for a Dutch traffic environment so it had to be "translated" to the Danish traffic environment (Personal communication, Anders Madsen, 2016).

Imtech and the Municipality of Copenhagen then started the planning of the various light crossings and how Imflow and its components should be implemented in each of them. Erik Damgaard, CEO of the Danish division of Dynniq and current project leader of Imtech/Dynniq on the Imflow project, worked together with a Dutch Imflow expert for a few months on each light crossing and where every component for Imflow should be placed and just the general plans for each individual intersection (Personal communication, Erik Damgaard, 2016). He and Anders Madsen of the Municipality of Copenhagen then sat down and made agreements on the design and planning of the light crossings, and when that was done Erik Damgaard employed contractors for the digging work that had to be done in order to lay the wires and erect the stands for the cameras (Personal communication, Erik Damgaard, 2016). This took about 8 months but it was not without its own problems. The installation work related to the cameras was much more comprehensive than first expected (Personal communication, Anders Madsen, 2016). The digging and the laying of cables took a lot of time and took its toll the budget as well (Personal communication, Anders Madsen, 2016).

Figure 10: The intersection at Toftegårds Allé – Lyshøjgårdsvej, at Valby train station

As for Movia's role in the Imflow project, they were to implement virtual loops to be used along with the GPSs in their buses (Personal communication, Anil Sharma, 2016). Copenhagen and Movia got together and worked on where to place the virtual loops and activate them. Since then there has been some fine tuning and adjustment of the virtual loops and their locations but throughout the process the municipality has worked closely with Movia (Personal communication, Anil Sharma, 2016). Movia also had meetings with Imtech. Anil Sharma, traffic consultant from Movia and representative of Movia in the Imflow project, elaborates:

"*We had some introductory talks about how to set up the project, what opportunities we had and what we could deliver in terms of information. We provided some test data for Imtech to give them an overview of how our setup of data was, how they would get that data and how to use it going forward. So we had a close dialogue with them there.*" (Personal communication, Anil Sharma, 2016, s. 2)

When the cameras were installed and the physical work on the roads and intersections were done, then the Imflow system itself had to be configured (Personal communication, Erik Damgaard, 2016). It took 1-2 months to set the correct parameters in the software and hardware and around August and September 2014 Erik Damgaard and Imtech had the Imflow system ready for operation (Personal communication, Erik Damgaard, 2016). After the system was made operational there was still continual work on adjustments and system errors up until the spring of 2015 and since then Imflow has been fully operational (Personal communication, Erik Damgaard, 2016).

Figure 11: The intersections Valby Langgade - Ved Ovnhallen - Annexstræde

5.2 The operation phase

5.2.1 Imflow – what is it and how does it work?

Before going into how the operation phase has progressed since Imflow was launched up until now I will first explain how the Imflow system itself works. When Imflow was to be implemented in Copenhagen it was still a relatively new system. It had previously only been implemented at one location in Holland (Personal communication, Anders Madsen, 2016). The cameras chosen for Imflow in Valby, as previously mentioned, were FLIR cameras. The cameras work like this; the operator can put up 8 virtual detection fields which means that the camera can look at 8 different spots on the road from the same lens (Personal communication, Erik Damgaard, 2016). The software in the camera is made to make the camera detect objects, e.g. a bus that enters the detection field. One can then define the size of the objects to trigger the system so it only triggers when objects of a certain size enter the detection field (Personal communication, Erik Damgaard, 2016). When the cameras detect the traffic the Imflow module then calculates from the data from the cameras and thus it can control the traffic lights. Erik Damgaard explains:

"*… this is what the Imflow module handles and it starts calculating, it has this many vehicles from this direction, this many from that direction, it has bicycles over here, etc., and then based on the previous data it tries to predict what is going to happen during the next light cycle. So it adapts to the current traffic situation.*" (Personal communication, Erik Damgaard, 2016, s. 5)

Figure 12: The intersection at Vigerslev Allé - Trekronergade

In each of the 10 intersections a control module was installed. Into this control module the Imflow software has been installed (Personal communication, Anders Madsen, 2016). With Imflow being implemented in 10 light crossings it makes it a distributed system. This means that the 10 light crossings are communicating with each other, so the system takes into account how the flow is going in the neighboring crosses and in the others as well (Personal communication, Erik Damgaard, 2016). So, the light crossings are synchronized so one does not show red light when the other has just let traffic pass through it (Personal communication, Erik Damgaard, 2016). On top of the Imflow software a backup hardware of sorts has been installed in the control units in case the connection is lost to one of the control units or if the system breaks down. This hardware carries backup programs to fall back to. These programs contain predefined time schedules for the light cycles. These time schedules are individually based on the traffic conditions of each of the 10 individual intersections (Personal communication, Anders Madsen, 2016).

Various cameras from FLIR are being used in the Imflow system. They are being placed depending on their purpose. Some are narrow angled, some are wide angled based on where they are looking and how close or far they are looking (Personal communication, Erik Damgaard, 2016). The cameras are also dependent on which angle and height they are installed and thus they are put where they can work most satisfactory (Personal communication, Erik Damgaard, 2016).

Figure 13: The intersection at Vigerslev Allé - Ramsingsvej

In this system the cameras do not differentiate between the different road users. This means the cameras do not tell if a bus or a truck has entered the detection field, it only tells that an object of the defined size has entered the detection field (Personal communication, Anders Madsen, 2016). Imflow needs another source to tell it that a bus is arriving at one of the light crossings. That is what Movia's GPS and prioritization system does (Personal communication, Erik Damgaard; Anil Sharma, 2016). Movia's buses are equipped with a radio that has a GPS in it. The purpose of the radio is that the bus driver could communicate with the operating manager about delays, if the trains are not running and the buses then need to take on their passengers, etc (Personal communication, Anil Sharma, 2016). The GPS in the radio was so Movia would know where the individual buses are. Now Movia are putting in these virtual loops in Google Maps that trigger whenever a bus reaches them and this works along with the Imflow cameras.

So the buses tell the Imflow control modules that they are arriving at a light crossing, the cameras tell about the amount of traffic at a light crossing and with this data Imflow can control the light cycles to get the buses through the light crossings as fluently as possible (Personal communication, Erik Damgaard, 2016). So when a bus arrives it sends a message of arrival to the Imflow server. The server finds out which light crossing the bus is arriving at and then the module at that light crossing uses the data from the bus and cameras and then it calculates what it needs to do, e.g. prolong green-time, put one direction on green or the other, etc. (Personal communication, Erik Damgaard, 2016).

So now we know what Imflow is and how it works. Now we will get back to the operation phase of Imflow and how it has been running up until now.

Figure 14: The intersection at Vigerslev Allé - Sjælør Boulevard

5.2.2 Imflow up and running

Imflow has been running since 2014 but there has continuously been made adjustments and improvements to the system and so it was not fully operational at that point. The adjustments have been done by the municipality in cooperation with both Dynniq and Movia (Personal communication, Anders Madsen; Erik Damgaard, 2016). With Movia the Municipality of Copenhagen has been working with the placement of the virtual loops to ensure that they are utilized most optimally (Personal communication, Anil Sharma, 2016). Further the municipality is also working on analyses on the effects of the Imflow system on the bus flow, with data provided by both Movia and Dynniq. The problem however is that since the system was first made operational in 2014 a lot has happened in the traffic flow in Valby, the surrounding infrastructure, the various bus lines, etc. (Personal communication, Anders Madsen, 2016). This means that the base line and reference point might cause the results in to not reflect how the difference really is, if there is any at all (Personal communication, Anders Madsen, 2016).

The municipality added new protocols to be sent to the control modules. Movia have their own bus prioritization protocol where they have an interface to which they send various parameters based on the bus lines, their direction, prioritization, etc. (Personal communication, Anders Madsen, 2016). The municipality has now added parameters such as delays, ETA's, etc.

Previously, the data from Movia's buses were sent from Movia's server to a web interface which another server would then pick up and pass through to the control modules in the light crossings (as shown in figure 7) (Personal communication, Anil Sharma, 2016).

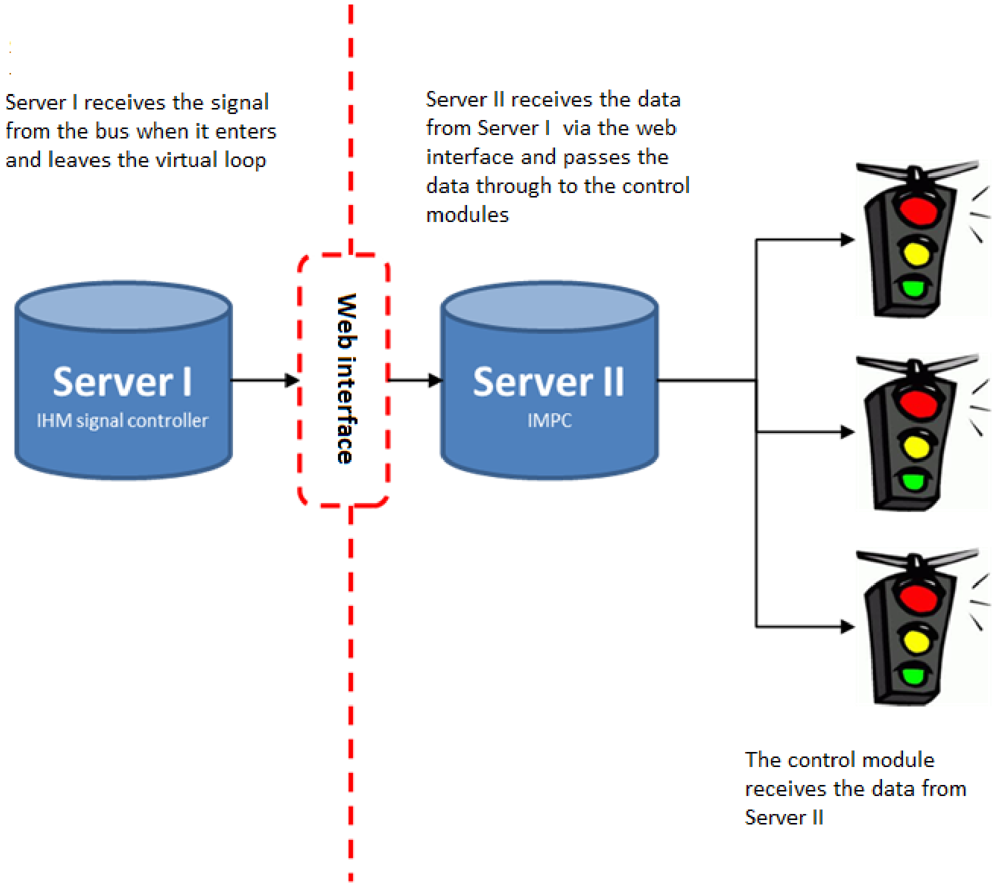


Figure 15: The previous data handling system with Movia and third party distributor

Previously the municipality and Movia had used IMPC (Server II in figure 10), a Jutland based company, as a middle man where Movia's data was sent to and then IMPC passed the data through to the control modules. This was done via a 3G connection and it took a few seconds before the data from Movia reached the control modules, and in traffic prioritization those few seconds matter (Personal communication, Anders Madsen, 2016). So the municipality and Dynniq have together developed a new communication system so they now can use the same lines of communication to the surveillance modules and the prioritization requests (Personal communication, Anders Madsen, 2016). So now they have a server that pulls Movia's data and then the municipality can use their own communication system to pass the data on to the control modules for bus prioritization (Personal communication, Anders Madsen, 2016). This means that the system is running more efficiently and the second-loss that happened when the data was sent to IMPC has been eliminated (Personal communication, Anders Madsen, 2016).

As of yet it is not known what exactly the effects of Imflow have been, if the effects on bus traffic have been positive or negative or if Imflow has made an impact at all (Personal communication, Anders Madsen, 2016). As mentioned earlier, the Municipality of Copenhagen are working on analyzing the traffic situation in Valby now and comparing it to before Imflow was implemented, but as also mentioned there are some issues with in regards to that procedure. This along with the future of Imflow will be discussed later in the project. In the following chapter the network relations in the Imflow project will be analyzed and the actor-world will be illustrated and analyzed.

6. The actor-network of Imflow in Valby

In this chapter I will go deeper into the relations and interactions between the actors of Imflow in Valby. I will also define the actor-world of the project and illustrate the actor-world. This will be the chapter where the concepts of ANT will be applied. First I will present the actor-world of Motion, to shortly describe the situation before Imflow in ANT terms.

6.1 The Motion actor-world

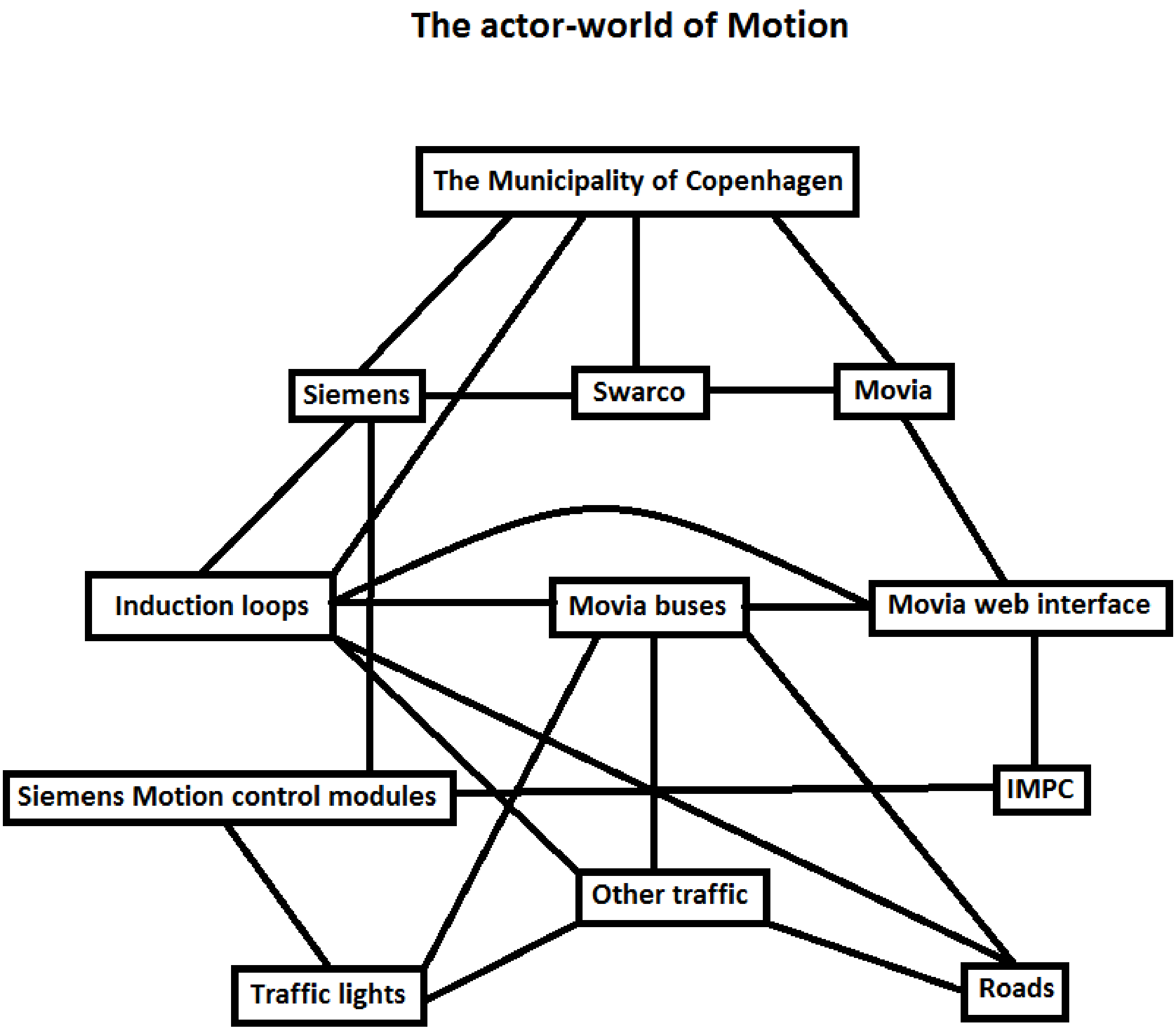


Figure 16: The actor-world of Motion

Above is an illustration of the actor-world of Motion in Valby. The actors are shown linked to each other via the intermediaries they have put in motion in the network. As mentioned earlier the Motion system never really functioned satisfactory. The system was too fragile and Swarco proved to be a too demanding and expensive traffic operator (Personal communication, Bo Westhausen(a+b), 2016). The induction loops failed too often and required too much maintenance to really keep the system functional and financially sustainable (Personal communication, Anders Madsen; Bo Westhausen(a), 2016). In ANT terms, certain actors were too inconsistent and the intermediaries put in circulation were sometimes more disruptive to the network than beneficial. The data was often either lacking or inaccurate, mostly because of the failing induction loops (Personal communication, Bo Westhausen(a+b); Anders Madsen, 2016). The translations in the network between several of the actors were also unsuccessful. Siemens translated the induction loops, defined them, but according to Anders Madsen the loops failed approx. half the time (Personal communication, Anders Madsen, 2016). This led the intermediaries that were put into circulation from the loops, to Movia's interface, IMPC, the control modules to the traffic lights to be inaccurate. It did not help neither that the traffic of data between Movia's web interface, IMPC and the control modules was slowed down because of the distance between the 3 parties. The results were almost physically visible; from the offices of Movia the employees could look down at the intersection at Toftegårds Plads and see the lines of cars build up when there should be a flow of traffic instead (Personal communication, Bo Westhausen(b), 2016).

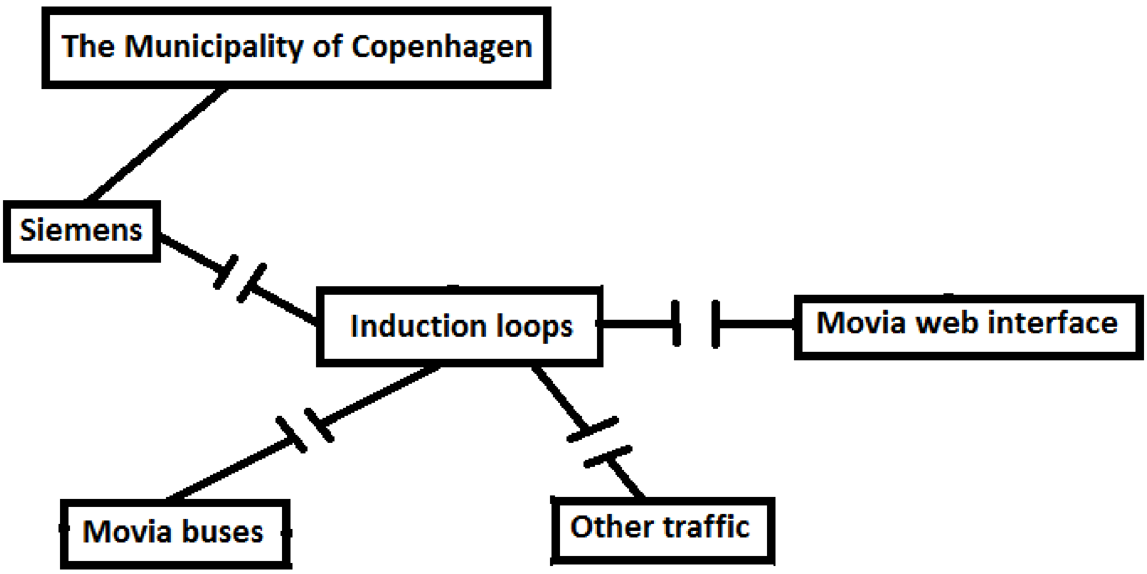


Figure 17: The broken links from the dysfunctional induction loops

Among the main human actors there were also issues. The municipality was tasked with the maintenance of the loops since it was not in the contract with Siemens and this further strained the Motion network and its budget (Personal communication, Anders Madsen, 2016). The relationship with Swarco in many ways was not satisfactory either. Bo Westhausen explains:

"*Swarco started turning the screw and said that if they were to get in and optimize the traffic light signals then they need to improve the existing cable network and implement their own surveillance system called Omniview, which cost a fortune; Around DKK20-30 million, and that was when the Municipality of Copenhagen had enough and put the new contract for the operation and maintenance of traffic signals in Copenhagen up for bidding*" (Personal communication, Bo Westhausen(b), 2016, s. 1)

From his seat as a Rambøll consultant for the municipality Bo Westhausen several times saw examples of the municipality possibly spending more money on Swarco projects and initiatives than needed (Personal communication, Bo Westhausen(b), 2016). Here they had a distributor who profits from providing expensive solutions and who can set the prices on hardware and man hours as they like since they have little to no competition (Personal communication, Bo Westhausen(b), 2016). The rebuilding and restructuring of intersections and signals was just tasked to Swarco (Personal communication, Bo Westhausen(b), 2016). But in the end the municipality said enough and stopped the cooperation with Swarco and Siemens (Personal communication, Bo Westhausen(b); Anders Madsen, 2016).

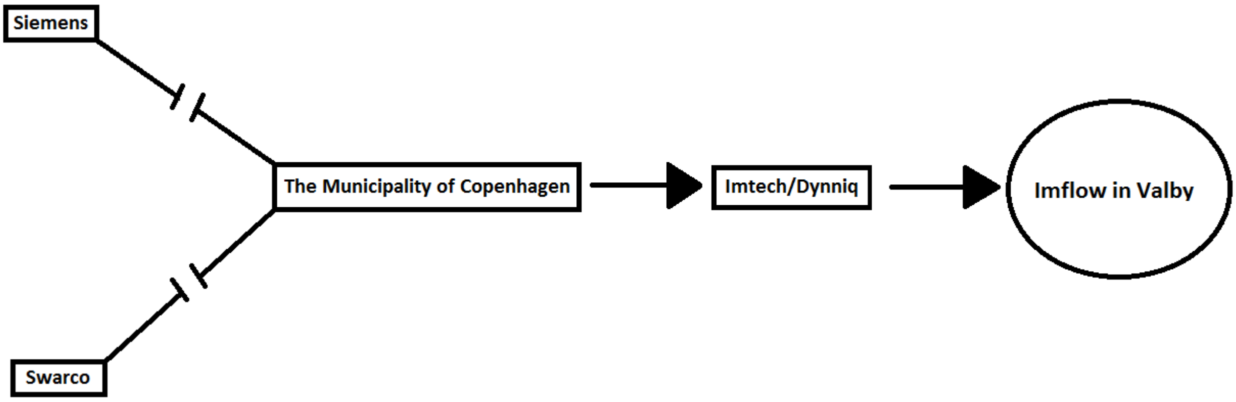


Figure 18: The municipality ended the cooperation with Swarco and Siemens and instead moved forward with Imtech to deliver Imflow in Valby

So the actor-world was discontinued. There was little convergence to speak of, some of the actors aligned but many of them did not and the co-ordination of the network failed as well. I will now look into the Imflow in Valby network and see if the situation is different there and if the network will prove itself more successful.

6.2 The Imflow actor-world

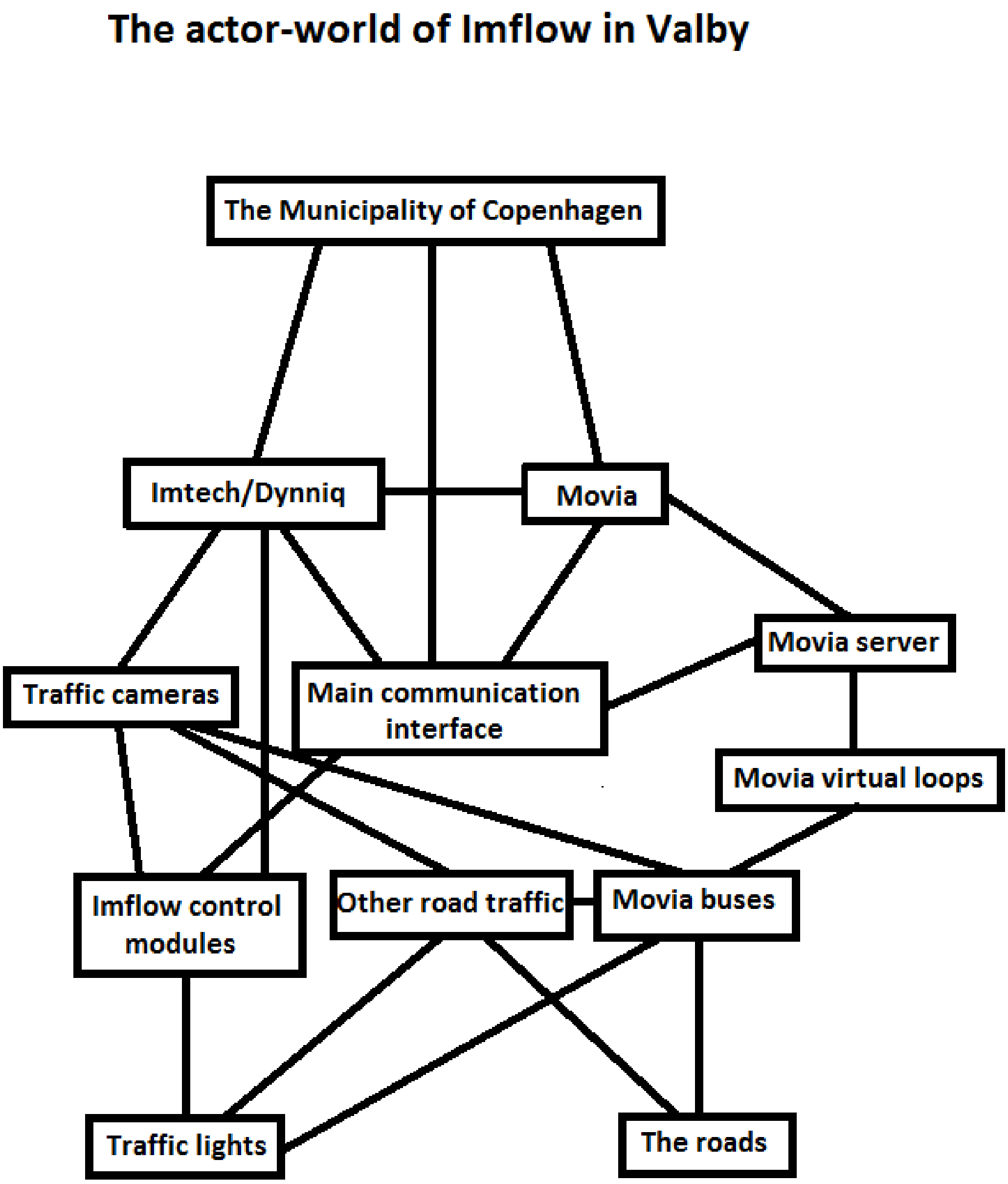


Figure 19: Actor-world of Imflow in Valby

Above is an illustration of the actor-world of Imflow in Valby with all the actors and how they are linked together. How some the actors are connected to each other has already been explained but here it will be elaborated more in ANT terms. The actors are chosen from their significance to the implementation and operation of Imflow in Valby and thus this actor-world is limited to the 12 actors in this actor-world and their intermediaries.

As aforementioned the case of Imflow in Valby was spawned by the Municipality of Copenhagen's will to implement a new and more reliable adaptive traffic control system in Valby using above ground detection rather than induction loops (Personal communication, Anders Madsen; Bo Westhausen(a), 2016). After an open bidding period Imtech won the contract to implement a new traffic control system. Movia were also part of the process at an early stage. Together the three parties defined the project that would end up with being Imflow in Valby and they also defined the other actors in the network. To start off this chapter I will describe how the actors are linked together by various intermediaries.

6.2.1 The actor-world explained

Let us start from the top of the network and work our way to the bottom. The Municipality of Copenhagen is linked to Imtech/Dynniq via the 8 year contract that both parties signed in 2012 (Personal communication, Anders Madsen, 2016). The municipality and Imtech/Dynniq since went on work together with placing the traffic cameras and with analyses of the data from the Imflow system (Personal communication, Anders Madsen; Erik Damgaard, 2016).

The municipality and Movia worked together from the beginning of the Imflow project and before that as well, with bus prioritization for Movia's buses (Personal communication, Anders Madsen; Anil Sharma, 2016). For Imflow Movia implemented their virtual loops and have continuously adjusted the loops' locations. Movia and Dynniq are linked by exchanges of data and knowledge before and during the implementation phase (Personal communication, Anil Sharma, 2016). But from then on and during the operation phase when Dynniq and Movia have communicated it has been through the municipality (Personal communication, Anil Sharma, 2016).

Moving down the actor-world "tower" – so to speak – Imtech/Dynniq installed the cameras and control modules in the 10 intersections where their use would be most optimal and adjusted their software so they would fulfill their purpose (Personal communication, Erik Damgaard, 2016). Dynniq still maintains the traffic cameras and the control modules. Together with the municipality Imtech/Dynniq also set up the new communication interface that would handle all the data distribution more efficiently than the previously used third party interface (Personal communication, Anders Madsen, 2016). This main communication interface is then linked to the municipality, Imtech/Dynniq and Movia via the data that it handles. Data is fed to the communication interface from Movia's server and this is then sent to the Imflow control modules. Movia's server receives notifications from the virtual loops whenever a bus passes over them. It is this data that Movia's server passes through to the communication interface to be fed to the control modules (Personal communication, Anders Madsen; Anil Sharma, 2016. The traffic cameras are counting the traffic via object detection; they do not distinguish between the various road users so they are affected by both the buses and the other road traffic (Personal communication, Erik Damgaard, 2016). The data collected in this way is sent to the Imflow control modules.

Moving further down the “tower, we have the Imflow control modules who calculate the light cycles and green times for their respective intersections based on the data fed to them by the traffic cameras and the main communication interface (Personal communication, Anders Madsen; Anil Sharma; Erik Damgaard, 2016). The other road traffic affects the general traffic conditions in the 10 intersections. The more of it there is the less fluently the traffic flow is which in turn means that the bus travel time is longer (Personal communication, Erik Damgaard, 2016). The traffic cameras and the control modules are there to prevent congestion as much as possible. The buses in turn also affect the other road traffic and the cameras, even though the cameras cannot distinguish between buses and trucks. But the cameras can tell the difference between small and large vehicles. When a bus passes a virtual loop it sends a trigger of data that goes through the system. The cameras can then see a large vehicle approaching and this combined with the data from Movia lets the control modules know that a bus is now arriving at an intersection (Personal communication, Erik Damgaard; Anil Sharma, 2016). It is a sort of combined translation process.

All the data that is sent to the Imflow control modules is used to calculate the light cycles of the traffic lights. These light cycles then affect the road traffic and the buses. The roads are affected by the road traffic and the buses and the roads also affect them. As seen in some of the pictures from the intersections in Valby, there is regularly road works going on and this has a significant effect on traffic (Personal communication, Bo Westhausen(b), 2016). The traffic’s effects on the roads are wear and tear from continuous use.

6.2.2 The intermediaries of the actor-world

The most prominent intermediaries in the actor-world are forms of data. This various data that is passed around the network and transformed in many various ways is what describes the whole network. There are various other forms of intermediaries in the network too. I will now elaborate on the intermediaries in the network.

There are many kinds of data that connect the actors, human and non-human, to each other. In most of the cases the data needed optimization before it was fully functional. I have already mentioned the virtual loops and how they were continually adjusted so their data is most precise (Personal communication, Anil Sharma, 2016). There were many little adjustments like that where the data just needed to be optimized a little bit to make the system work more fluently. However there were also some larger issues with the data management. One of them was getting the Imflow system to understand the data sent from Movia (Personal communication, Anders Madsen, 2016). Movia already had their own system that was up and running with their own server and interface (Personal communication, Anders Madsen; Anil Sharma, 2016). Imflow is a Dutch system that is built up differently with different protocols. So there needed to be made adjustments to the Imflow system since it was the outsider, so to speak; Movia already had their system set up in Copenhagen while Imflow was to be implemented, so they had to adapt to Movia and not the other way around (Personal communication, Anders Madsen, 2016).

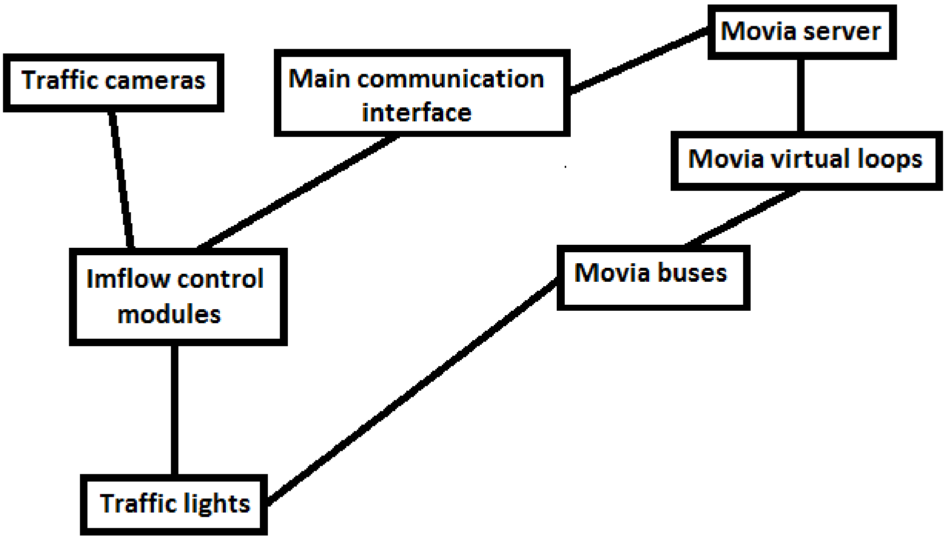


Figure 20: The data life cycle, from the Movia buses to the traffic lights.

The data that circulates in the Imflow network gets transformed several times throughout the cycle. If we stick to the virtual loops; they trigger when a bus enters their detection field, data is then sent to the Movia server. From there it goes through to the main communication interface and then to the Imflow control modules who then combines that data with the data they get from the cameras and then control the traffic lights (Personal communication, Anders Madsen; Erik Damgaard; Anil Sharma, 2016). During that process the data is transformed and translated to be compatible with the receiver. The main communication interface translates the input from the Movia server to the Imflow control modules. However, while the data might be transformed in a way the message that the data from the virtual loops carry is the same although expressed in a different language (Personal communication, Anders Madsen; Erik Damgaard, 2016). The same is the case with the data from the traffic cameras.

The contract between Imtech/Dynniq and the Municipality of Copenhagen is one of the most significant intermediaries in the network, as it is this intermediary that in some way allowed the rest of the network to unfold. It is a limited intermediary though, as the contract is only for 8 years, so the municipality and Imtech/Dynniq have as this report is being written gone through half of the contract period (Personal communication, Anders Madsen, 2016).

As mentioned in chapter 4, 4.1 the intermediaries are what describe a network. This is evident in the Imflow network. The contract and the data that is in circulation in the network are what makes Imflow. Alone, the traffic cameras are just cameras, the virtual loops are just that, the main communication interface is just an interface with no data to handle. But with the intermediaries the actors have a purpose and the network is alive and dynamic. It is not only the intermediaries that define the network though, the other actors do it too, most significantly the municipality, Imtech/Dynniq and Movia. These actors define the other actors in the network through translations. These translations will be elaborated in the following paragraph.

6.2.3 Translations

"*A translates B.*" (Callon(a), 1991, s. 143). So it was written in chapter 4, 4.2.1. This means that one actor defines the other in an actor-world. In the actor-world of Imflow in Valby the main actor, or author, is the Municipality of Copenhagen. It was the municipality who created the network. It has defined the roles of the two other major actors in the network; Imtech/Dynniq and Movia. Outside of the network Imtech was a large international company dealing with major projects across Europe but in this network they are the supplier and installer of the Imflow components, that is the software, the cameras and the control modules. Movia were also defined; in this project they are not a provider of public transport to other municipalities. They are a provider of buses to the project area and they also provide services like the virtual loops and their web interface. This pattern continues through the system. E.g. the cameras are defined by Imtech/Dynniq. As was mentioned in chapter 4, 4.2.1, even though actor A translates actor B it does not mean that actor A has free roam, it has itself been translated. There is a case of A translates B which translates C (see figure 4). In this particular case the municipality translates Imtech/Dynniq which translates the traffic cameras.

The Municipality of Copenhagen $\xrightarrow{\textbf{Contract}}$ **Imtech/Dynniq** $\xrightarrow{\textbf{Imflow}}$ **Traffic cameras**

Figure 21: The translation progression with the intermediaries linking together the actors

There were some issues in the implementation process as was mentioned in chapter 5, 5.1. The cooperation with Imtech was problematic in the beginning because Imtech had several different project leaders quit the project which caused the implementation process to be slower than anticipated (Personal communication, Anders Madsen; Erik Damgaard, 2016). Also many of the Imtech people were very green on the area of adaptive traffic management so this combined with the many changes in project leadership from Imtech caused the installation work to stretch over 2,5-3 years (Personal communication, Anders Madsen, 2016). When Erik Damgaard, the current project leader from Dynniq, entered the project none of the installation work had been done. But from then on the cooperation went smoother. Erik Damgaard explains the working relationship:

"*I had very good dialogue with Anders Madsen from the Municipality of Copenhagen. We got along really well. The cooperation with Movia also worked well. We mostly communicated only about the interface, if it worked or not. I would say it was unproblematic. When they were called to action they came, and same for us. There was a solution-oriented spirit where the problems that came up were solved. There were not many disagreements. Only thing I remember, and I also understand this, is that the municipality were not too satisfied with the long delay of the project. But then I got the impression that now that things were moving forward they became more satisfied. So when they had overcome their dissatisfaction with me being the fourth project leader and when they saw that I could contribute here then we had a great working relationship*" (Personal communication, Erik Damgaard, 2016, s. 4.)

So once the implementation and installation of Imflow was finally up and running the working relationship between the Municipality of Copenhagen and Imtech/Dynniq became much improved. The working relationship between Imtech/Dynniq and Movia was nearly all based on sharing data and preliminary meetings in the implementation phase about how to set up the system and what the two parts would deliver (Personal communication, Erik Damgaard; Anil Sharma, 2016). Since then there has not been much communication between Imtech/Dynniq and Movia, it has mostly been through the municipality.

Movia and Copenhagen worked together from the beginning of Imflow and even before that. They worked together on placing the virtual loops and then Movia shall continually deliver the data from the virtual loops to the main communication interface. That has been Movia's main role, to provide the bus data to the Imflow system (Personal communication, Anil Sharma, 2016). Since the placing of the virtual loops they have adjusted their location continually based on information given to them by the municipality (Personal communication, Anil Sharma, 2016).

Movia has further had to inform the bus drivers about this new system that was to be implemented (Personal communication, Anil Sharma, 2016). Movia informed the drivers how to react to the new changes to the intersections in Valby and that even though the old loops will not be used anymore there is still detection for the buses, via the virtual loops (Personal communication, Anil Sharma, 2016). This did not seem to create any issues and the buses and virtual loops did not produce any complications either.

The control modules are reliant on the setup of hardware and software from Imtech/Dynniq and the data that is delivered to them by the traffic cameras and the main communication interface. As mentioned earlier the cameras do not distinguish between buses and trucks when large vehicles enter the detection fields so the Imflow control modules need the necessary data from the buses via the communication interface to know if a bus or a truck is arriving at an intersection (Personal communication, Erik Damgaard, 2016).

In regards to the main communication interface we have a case of substitutability, as was described in figure 4. Here both the municipality and Imtech/Dynniq define the actor as they together developed this new communication interface to optimize the efficiency of the handling of data in the Imflow system (Personal communication, Anders Madsen, 2016).

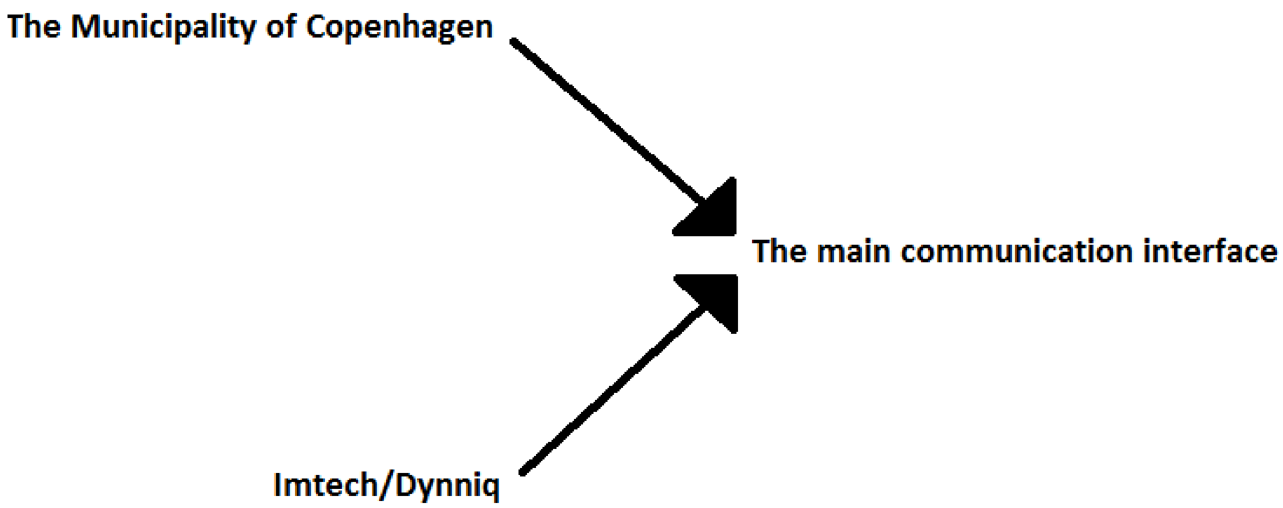


Figure 22: The translation process in the case of the main communication interface

6.2.3.1 Convergence

The level of convergence in the network has varied since the beginning. There was not much alignment between the municipality and Imtech/Dynniq in the early phases, as has been explained. It took a fourth project leader from Imtech to finally get the project rolling as it should. There were also some troubles with getting the various data systems to be compatible, i.e. Movia's system and Imtech/Dynniq's system, but those issues were also solved. The level of alignment between the actors and intermediaries has been improving since the beginning of the project. The co-ordination in the network has also reached a relatively high level with the actors finding their roles within the regulations of the network that have been defined top down. The actors now have their defined roles although some of the actors are less predictable; the network is not completely irreversible.

6.2.3.2 Irreversibilization

By now the Imflow network seems like a network with a high level of convergence. Many of the inconsistencies between the actors seem to have been eradicated. It will always be hard to fully control the other road traffic and the buses as there are many outside influences that can affect them (Personal communication, Anil Sharma, 2016). There can be an increase of traffic due to other traffic veins being cut off by e.g. road works and thus the traffic from there can be redirected to the roads in the Imflow area. Extreme fluctuations in traffic can affect the whole network directly and indirectly. More traffic can mean that Movia have to move the virtual loops around to adjust to the increase in traffic (Personal communication, Anil Sharma, 2016). This can affect the traffic in and about an intersection and with the whole Imflow system being distributary this means that the other intersections will be affected as well. This means all the actors that operate in the intersections; the traffic lights, the control modules, the cameras, the buses and the other road traffic. These influences on traffic might not only be from the outside but also from within the network. E.g. road works inside the network can change the flow of traffic. The weather can affect the apparatus that is installed in the intersections; massive snow fall can affect the cameras' ability to detect vehicles if snow is on the camera lens (Personal communication, Bo Westhausen(a+b), 2016). One part or the whole system can fail which means that the backup protocols will be set in effect (Personal communication, Anders Madsen, 2016).

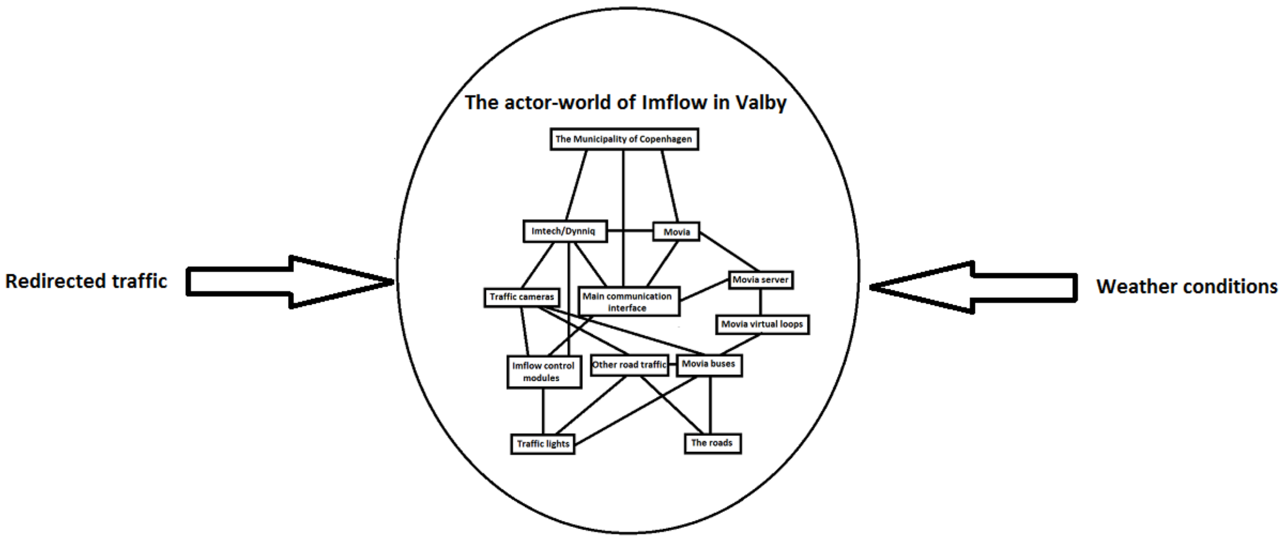


Figure 23: Outside influences on Imflow in Valby

System errors are always a big threat when working with large computer based systems (Personal communication, Bo Westhausen(a), 2016). From the beginning of the project there have been little errors that have needed adjusting but yet there have not been major system failures (Personal communication, Anders Madsen; Erik Damgaard, 2016).

While the network at present might seem to have a high degree of convergence, good alignment and coordination there are still various potential threats to the network both from the outside and from within. There are solutions to some of the issues. The municipality already has some backup plans ready, such as the backup protocols in case there are system breakdowns or errors (Personal communication, Anders Madsen, 2016). The weather's influence on the cameras is limited but should it become a problem that needs a solution there are other technologies that do not suffer from hard rain; radars for example (Personal communication, Bo Westhausen(a), 2016). But this will be elaborated further in the next chapter. Still, even though there are some uncertainties about some of the actors in the network these uncertainties could be removed in the future. As mentioned in chapter 4, 4.2.3 some networks become stabilized and normalized over a period, like light crossings. Imflow has stabilized since its inception but still not to the point where it is completely irreversible. But what does the future hold for Imflow in Valby? Will the network continue to stabilize? How will we know if Imflow in Valby has had the expected effect? Will a new system be implemented? In the following chapter I will discuss this, what methods that could be used to measure the effect of Imflow, the findings from the analysis and if something could have been done differently.

7. Discussion

The actor-network of Imflow in Valby has been introduced and explained and now it is time to discuss the findings. I finished the previous chapter with a few questions that I will look to answer in this one. However, I will first discuss the findings from the analysis before answering those questions.

7.1 The actor-world of Imflow in Valby

In total 12 actors were defined for the actor-world of Imflow in Valby. These were defined because of their significance in the network and how they directly and indirectly influence and relate to each other. The municipality is the main author of the network that defined the other major actors who then defined "lesser" actors. I put 'lesser' in quotations because even though they are smaller they are still very significant to the success of the network; e.g. without the roads there would be no problem for Imflow to solve. The relations and linkages between the actors in the network were illustrated in figure 11. Only direct links were put into the model. So even though the bus traffic influences the control modules they only do so indirectly through the traffic cameras. Likewise, the Imflow control modules only affect the bus traffic indirectly via the traffic lights. That is partly what ANT can illustrate; one might think that the control modules directly influences the bus traffic, but put in ANT terms and in this particular network, it is only and indirect influence. These principles are consistent throughout the network.

Getting back to the 12 actors, could more or less actors have been included in the network? For instance, the commuters who travel by bus? Maybe even the bus drivers could have been an actor group by themselves or the GPS technology in the bus. These are not included in the network as they are represented by the Movia buses. They are seen as part of the actor-world that is a bus. In chapter 4, 4.1 it is mentioned that an actor can also be an actor-world, a hybrid, and that is what the bus in this case is. It is a network in itself, comprised of the driver, passengers, the GPS technology, the seats, the wheels, the engine parts, etc. But in the Imflow actor-world the buses constitute people carriers equipped with GPS technology who are prioritized in the flow of traffic. The passengers and drivers were not part of the planning and implementation of the Imflow system. They are always there indirectly but not directly and because they are represented by the buses they are not included in the actor-world as individual actor groups (Personal communication, Anil Sharma, 2016).

As mentioned in chapter 6, 6.1.3.2 redirected traffic in the Imflow area in Valby and the weather could be outside influences on the network. These are not actors included in the actor-world as they are both not constantly influencing the network significantly. They are intermediate influences on some of the actors of the network rather than actual actors.

But could there have been fewer actors in the actor-world? Maybe the roads did not have to be included as it is a given that if there is road traffic and intersections and traffic signals then of course there are roads. But the roads should not be taken for granted in that sense. They affect the traffic in various ways. E.g. road works greatly influences the flow of traffic. Road works might be done because of maintenance due to wear and tear from the traffic the roads carry, inflicted by the buses and other traffic. This in turn influences the whole system as it can lead to increased or decreased traffic, redirection of traffic flows, etc (Personal communication, Bo Westhausen(b); Anil Sharma, 2016). So the roads have been deemed too significant to leave out of the actor-world.

The actor-world did not start out being convergent although it has been moving towards a higher degree of convergence as Dynniq's situations stabilized. Here we again are talking about a hybrid which was influenced by the turmoil among the actors within it; the shift in project leadership, the bankruptcy, the new owners, etc. (Personal communication, Anders Madsen; Bo Westhausen(a), 2016). But the Imflow network stabilized along with the stabilization of Dynniq and the successful adaptations of the Imflow software language with Movia's data. Perhaps some of the issues with Imtech/Dynniq could have been avoided if a foreign operator had been signed rather than insisting on a employing a Danish company. But it was required by policy from the municipality that a Danish company should be signed (Personal communication, Anders Madsen, 2016). Danish contractors will likely know about the Danish traffic landscape and the Danish transport system. But back when Imtech won the contract most of the qualified people were located primarily in Holland and Poland so the many of the Danish people employed to the Imflow project did not have much of a traffic background on their resume (Personal communication, Erik Damgaard, 2016). So the project took longer time than expected because the Imtech/Dynniq project leaders had to get acquainted with how the whole project should work and with ACTSs in general. Perhaps the delay could have been avoided with foreign employees, however perhaps in their case they would have to get acquainted with the Danish protocols, etc. and then there would have been a delay anyway.

So the relations between the human relations in the Imflow project were a bit problematic in the beginning, specifically between the municipality and Imtech. However those issues have more or less been resolved. The relations in the Motion network were problematic in different ways. While there may not have been problems with the competences of the people at Swarco their solutions were often way over the municipality's allocated budget and with the failing induction loops Swarco could keep putting pressure on the municipality to install Swarco's new own traffic surveillance system (Personal communication, Bo Westhausen(b), 2016). The experiences with Swarco and the Motion system led the new contract to have some conditions in it that would prevent situations like the aforementioned to happen again. The costs for the new system to be implemented were defined and some benchmarks were made that the winner of the contract would have to live up to (Personal communication, Bo Westhausen(b), 2016). The benchmarks consisted of maximum time before a system error is fixed, how much uptime the system is going to have, etc., and based on these benchmarks and whether or not the contract winner is able to fulfill the conditions the winner will either get a bonus or a "*slap with a stick*" (Personal communication, Bo Westhausen(b), 2016, s. 2) as Bo Westhausen puts it.

Overall it seems that there are differing opinions on how Imflow has progressed and how the working relations have been. Erik Damgaard's experiences have been good but he also was not at Imtech/Dynniq when they were just starting up and so he did not experience all the problems of the beginning of the project. Anders Madsen from the Municipality of Copenhagen however was there from the start so his impressions from the whole process are different (Personal communication, Anders Madsen, 2016). Movia's interactions with Imtech/Dynniq have mostly been in the preliminary stages where they shared data with each other (Personal communication, Anil Sharma; Erik Damgaard, 2016). In the operation phase there was very little contact. So Movia did not experience the same issues with Imtech/Dynniq that the municipality did. And the work between the municipality and Movia did not seem to create any big problems (Personal communication, Anil Sharma; Anders Madsen, 2016).

Another delay to the project was the installation work of the cameras and control modules. Wires had to be laid and this meant digging up the roads (Personal communication, Anders Madsen, 2016). This not only caused delays but also put a strain on the budget of the project (Personal communication, Anders Madsen, 2016). At that time it was not possible to run these cameras wirelessly, but perhaps if Imflow is to be expanded to other parts of Copenhagen the technology will have progressed enough to allow for wireless operation of the cameras (Personal communication, Anders Madsen, 2016). This brings us to the irreversibility of the actor-world. Should newer technology be made available for a price that is within the budget of the municipality perhaps they could upgrade the system and thus affect the actors, intermediaries and translations within the actor-world. The irreversibility of the actor-world and its future will be elaborated more in the following paragraph.

7.2 The future of Imflow in Valby and ATCSs in Copenhagen

Dynniq are now halfway through with their contract with the municipality (Personal communication, Anders Madsen, 2016). The effects of Imflow are still relatively unknown. Tests and simulations were made to predict the impact of Imflow on the bus traffic and they showed good results (Personal communication, Anders Madsen; Anil Sharma, 2016; Imtech, 2012). But as of yet there have not been any conclusive evidence to show that there has been a positive effect on the bus traffic from Imflow. It is difficult to measure the effects too because the reference point has shifted so much since Imflow was first being worked on (Personal communication, Anders Madsen, 2016). It is up and fully functional now and an analysis report of the results from Imflow is expected for the summer of 2016 (Personal communication, Anders Madsen, 2016). But that is still dependent on the methods of measuring the impact of Imflow on the bus traffic. So in the immediate future for Imflow in Valby it is about finding out if the system has had an impact on the bus traffic in the area. Maybe because of this the future for ACTSs in Copenhagen is quite unknown. The municipality is working on optimizing the whole traffic signal system in the city through a new traffic management plan and various projects around the city (Personal communication, Anders Madsen; Anil Sharma; Bo Westhausen(a), 2016). But let us start with Imflow first.

7.2.1 The future of Imflow

At the moment the detection methods in Valby are relatively simple; there are the GPSs in the buses, the virtual loops in Google Maps and the FLIR detection cameras. The cameras are pretty simple; they detect only objects and depending on the size of those objects they can tell if it is a small vehicle or a large one (Personal communication, Erik Damgaard, 2016). More cameras or cameras with more advanced technology could improve Imflow in various ways. There is already detection for pedestrians at the intersections via the buttons on the light poles that the pedestrians can press to let the light signals know that they are waiting to cross the road (Personal communication, Anders Madsen, 2016). But cyclists do not have any way of "signing on" so to speak. Cameras who can detect the soft transport modes – walking and bicycling – could help improve the flow of the soft transport modes (Personal communication, Anders Madsen, 2016). In Copenhagen they now have a policy that it is not acceptable that pedestrians have to press a button to get green light, it should happen automatically (Personal communication, Anders Madsen, 2016). Therefore infrared cameras could be installed to detect the pedestrians but at the time the costs of implementing the traffic cameras in Valby were too high for further detection devices for pedestrians (Personal communication, Anders Madsen, 2016). But the incorporation of thermal cameras for detection of pedestrians could be done in the future (Personal communication, Anders Madsen, 2016). The data from the cameras could then be implemented in the Imflow system to further improve the flow, and perhaps not only for buses. That is one of the smart things about Imflow; the system itself can receive any type of detector input so the Imflow system can be kept even though more advanced detection methods should be put in use (Personal communication, Erik Damgaard, 2016). So should the detection methods need an upgrade the system can be kept the same. And there are many different methods for detection that could prove to be more efficient than the cameras currently in use in Imflow. Preliminary tests were done before implementing Imflow to see which detection methods were to be picked. The cameras were picked based on performance and price (Personal communication, Anders Madsen, 2016). They do the job of detecting and counting vehicles to the extent that is needed for Imflow (Personal communication, Anders Madsen, 2016). But the cameras are limited to just that, there are various tasks they are not able to carry out that other detection methods can. Take radars; some of the newer ones can detect and measure everything, they can count, they can separate bicycles and cars from each other, they can account for all vehicles in their detection field and measure the vehicles' speed and distance to the stop line, etc. (Personal communication, Anders Madsen; Bo Westhausen(b), 2016). This means the radars can help reduce the amount of rear end collisions, they can prolong the green time if a vehicle is a certain distance from the traffic signals and travelling at a speed that makes it impossible for it to stop before the stop line. In such cases the vehicles are caught in the dilemma zone where they cannot break if the signal should change to a red light and that causes accidents (Personal communication, Bo Westhausen(b), 2016). This technology is going to be implemented at various locations in Copenhagen via a separate contractor called ITS-teknik, a Danish ITS developer (Personal communication, Anders Madsen, 2016). So these radars have a lot more to offer than the cameras and thus offer a wider range of prioritization opportunities than just bus prioritization (Personal communication, Anders Madsen, 2016).

Implementation of this technology would introduce more actors to the Imflow actor-world; ITS-teknik and the radars for starters. And perhaps some actors would be lost, e.g. the cameras might be sacrificed to make way for the more advanced radars. This would affect the relations in the network in some ways but if properly implemented, it would just be a substitution of the old data to the new data from the radars and pedestrians and bicycles could be introduced as actors in the network. If Imflow was kept as the control system then Dynniq would still be an actor in the network, but if a new operator would be hired – perhaps when Dynniq's contract expires and if it is not renewed – then a new operator actor would also be introduced to the network. This is still just speculation, partly because there is still 4 years left on Dynniq's contract and it is still not known what effects Imflow has had on the bus flow in Valby. But for now, let us assume that Dynniq will be kept on as the operator, how would the network look if ITS-teknik's radars were implemented? On the next page is a mapping of the network with ITS-teknik entering the fray.

The actor-world of Imflow with radars instead of cameras

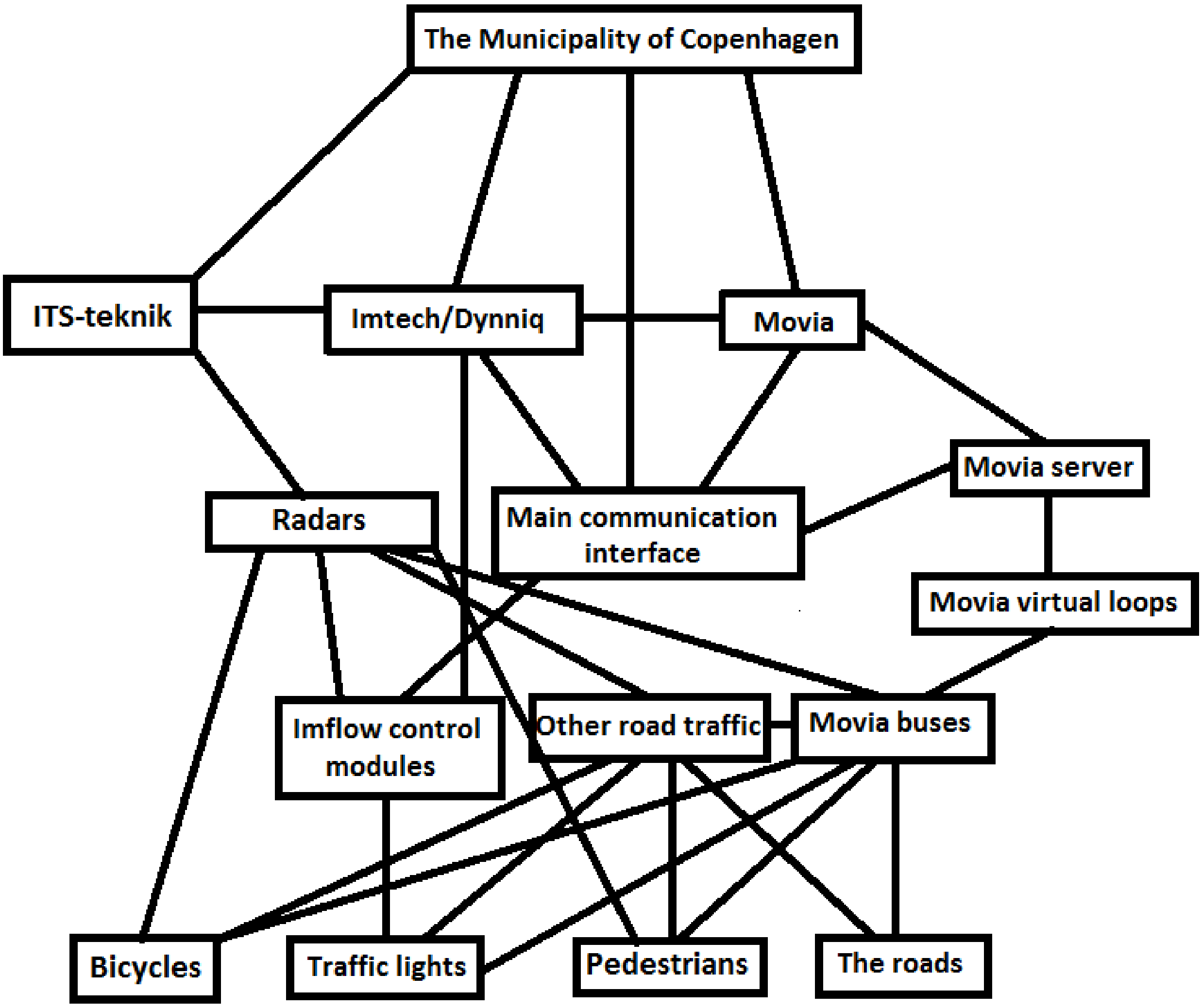


Figure 24: The actor-world of Imflow with radars instead of cameras

This network is slightly more complex than the one with only the cameras. One of the most notable differences is that the radars bring in three more actors; ITS-teknik, the radar operators, and the pedestrians and bicycles. The last two are added to the network because the radars can detect these while the cameras cannot (Personal communication, Bo Westhausen(b); Anders Madsen, 2016). This is just a potential network should ITS-teknik implement their radars in Imflow too, but as of yet they are just implementing them in 14 corridors in Copenhagen (Personal communication, Anders Madsen, 2016). But should these radars prove to be successful and should more funds be allocated to the Imflow budget then perhaps the radars could be implemented there too (Personal communication, Anders Madsen, 2016). But that also depends on the success of Imflow, which brings us back to the analyses to measure the effects of Imflow on the bus flow.

One way to test if Imflow has had an effect could be to simply shut down the system for a period of time and then measure the effects during the down period and then compare them to the effects when Imflow is turned back on (Personal communication, Anders Madsen, 2016). However, this could still raise some issues. Traffic in Copenhagen varies and fluctuates on an almost daily basis. This could be due to weather, the seasons, road works, redirection of traffic, signal failures, etc. (Personal communication, Bo Westhausen(b), 2016). All these affect how the flow of traffic is in the various areas of Copenhagen and this provides some challenges when trying to put a reference point with which to compare the effects of Imflow on the bus flow. Because how long should Imflow then be shut down? And when should it be shut down? Should it be over a long continuous period or should it be in intervals throughout a year to see account for the changes of weather and the seasons and how that affects the overall traffic? Still, shutting down Imflow for a period of time might be the best way to get a proper and valid reference point. The old reference points and baselines are too outdated to be used now (Personal communication, Anders Madsen, 2016). So while there might be certain challenges with the proposed method of shutting down Imflow it will still bring a more current reference point than the ones from back in 2012-2014.

The findings from the analysis and the future of Imflow have now been discussed. The relations in the network are very complex, counting the human and non-human actors. The relations resulted in both success and problems. Some of the problems have been overcome and some still persist and the future for Imflow is still uncertain. In the next chapter I will conclude on the results of this project.

8. Conclusion

Imflow in Valby has had a rough implementation phase. The system was to be an improvement on an old detection system, Motion, that when it worked was very precise, but all too often the detectors failed and affected the whole of the system. The costs of having the system operational and the maintenance work were too high so the Municpality of Copenhagen offered up the whole traffic signals operations contract for bidding to anyone who could provide a more sustainable system that was also not based on induction loops as detectors but rather above-ground detection. This contract was won by then Imtech Peek who proposed their Imflow system; 66 traffic cameras were to be installed in 10 intersections in Valby, Copenhagen to detect the vehicle traffic. Public transport provider Movia set up several virtual loops on the roads via Google Maps that would trigger when one of their buses equipped with GPS technology would enter the loops' detection field. The data from the virtual loops and the cameras is then processed by control modules in the 10 intersections to be used to control the traffic signals. This is meant to secure the best flow of traffic for the buses in those 10 intersections.

So when Imflow was chosen to be the next ACTS the Municipality of Copenhagen thought they had found a valid substitute for the previous system. But the implementation brought a lot of issues with inexperienced project leaders from the contractor, Dynniq, and a slow installation process and a tight budget that was further strained by the delays and complications. But when the issues with the project leadership from Dynniq's side were fixed the implementation was finally carried out. However when the system was finally up and running new issues arose; how could the effects of the system be measured? When Imflow was finally operational the reference point to compare with was too old and outdated to be used in a valid analysis. Further, new detection technologies are making their way onto the ACTS market, new technologies that could perhaps replace the current detectors in the Imflow network, if the municipality sees a need for more than just bus prioritization in the 10 intersections in Valby.

The purpose of this project report has been to map the actors that have been and are involved with Imflow in Valby, both the human and non-human and to explore the issues that arose during the implementation and operation phase. Actor-Network Theory has been chosen as the tool to analyze and map the network around Imflow in Valby. The main human and non-human actors were identified and then by applying the principles of ANT their relations and interactions were described and explained and the actor-world they make up was illustrated. By applying the principles of ANT the intricacies of the network could be elaborated, the relations, the inconsistencies, the alignment of actors, the agreements within the network, the issues that arose during the implementation and operation, why they arose, and what that meant.

Further, the future of Imflow in Valby was looked into, what is the potential for Imflow and what changes could happen in the future. All this was done to answer the research question which was:

What constitutes the network of actors behind the Imflow in Valby project, what were the main issues during its implementation and operation phase and what does the future hold for Imflow?

So let us start with the first part of the question; what constitutes the network of human and non-human actors involved with Imflow in Valby? In figure 17 all the actors involved in the network are mapped in the actor-world they make up. These actors were chosen from their significance to the implementation and operation of Imflow in Valby. The intermediaries that link these actors to each other and that describe the network are illustrated via the links between the actors and are elaborated in that chapter. The issues that arose during the implementation and operation phase were varied. The implementation phase brought along a lot of issues with the newly contracted operator, Imtech. Their lack of experience delayed the project significantly as they had a change of project leadership 4 times during the implementation. The installation of the cameras also proved to be time consuming and more expensive than expected. There were also issues with the compatibility data and software of Imtech and Movia. Imtech had to translate their data and software to be able to "talk" with the software and data of Movia. The municipality and Imtech/Dynniq together developed a communication interface to get the data transferred as fast as possible from one end to the other, instead of using the middle man the municipality had used before. The use of a middle man, in the shape of IMPC in Jutland, caused the data to be circulated with a few seconds of delay as the data was sent from Movia in Copenhagen, then to IMPC and then to the control modules in the intersections in Valby. This delay was cut out with the implementation of the new communication interface. Apart from the larger issues there were smaller issues with adjusting the virtual loops' locations to be used most optimally, adjustments of the cameras, the control modules, etc.

One of the largest issues in the operation phase is also linked to the future of Imflow; whether Imflow has had a positive impact on bus flow or not. Measuring the impact cannot be done via comparison with the old reference points as that data is outdated now, because of the delays during the implementation phase. So one possible solution is to shut down Imflow for a period of time and then compare the results of that period to when Imflow is turned back on again. But the results might not be accurate enough because there are many factors at play; shutting down the system during summer might show different results from shutting it down in winter, there might be excessive road works during the shutdown period which changes the flow of traffic. This can be both road works within Valby or outside in which case the system might be dealing with redirected traffic. So if the municipality decides to shut down the Imflow system for a test period it might be wise to have several shutdown periods or a prolonged period to account for the different variables that might affect the general traffic flow.

Depending on the results of the analysis of the effects of Imflow new technology could also be implemented in the system, should additional funds be allocated to the Imflow project. These additional technologies could be thermal cameras for detection of pedestrians or radars for detection of both pedestrians and cyclists and the road traffic, and for more advanced data on travel speeds of the vehicles, distance from vehicle to vehicle and vehicles' distances to the intersections. This would make Imflow about more than just bus prioritization but again, this is dependent on the budget for the Imflow project and the success of both Imflow and the other technologies in other parts of Copenhagen.

So as of yet it is still relatively unknown if Imflow is making a positive impact on bus traffic or not. There were tests and simulations that showed that there definitely was potential for improvement in the bus flow. But since then the situation has changed and there have been infrastructural changes in Copenhagen, traffic flow changes, etc., so it is still up in the air whether or not Imflow works. But once, and if, it is known then it is a question of what the future of Imflow in Valby will be. Perhaps it will be expanded to other intersections in Copenhagen or perhaps it will be optimized and have newer detection methods implemented into the system. It all depends on how the performance of the system turns out to be.

9. Reflections on the project report

The results of the project report have raised some questions that might need reflection. First, was ANT necessary to write the report? ANT is a very useful tool for analyzing the intricacies and relations in a heterogeneous network. What differentiates ANT from regular sociology is that it not only is interested in the human and social relations but also in the non-human, physical relations and how a non-human entity can be an actant in a network. With ANT it was made easier to analyze the non-human relations and also to map the network and to see what the various translations in the network meant. But ANT also has its limitations. Since ANT is not a theory it does not provide any explanations to why something happens. It is more descriptive in nature. Basically it is used to describe and analyze a network. So it cannot be used to give an explanation to why the issues in Imflow happened, it can only explain how.

In the network of Motion the data was gathered through interviews with the Imflow actors and Bo Westhausen from COWI. A more thorough description of the network would have been possible with interviews with Swarco and SIEMENS, to get their point of view as well. However this project focuses on Imflow and since no interviews were conducted with Swarco and SIEMENS the Motion network was not going to be part of the research question or play as big a role in the discussion as Imflow did. It was more part of a background story for Imflow.

About the next step for Imflow, it is difficult to know what will happen. The analysis that is planned for this summer might need to be postponed if it is not possible to find a valid reference point to use to compare the current situation with the situation before Imflow. It might turn out that adaptive systems do not improve the flow of traffic in Copenhagen and that the default light signal programs are the most efficient manage the traffic.

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10.1 Figures

Frontpage picture 1: Google Maps

Frontpage picture 2:

https://da.wikipedia.org/wiki/A-bus#/media/File:Movia_bus_line_4A_on_Lygten.JPG

Figure 1: Københavns Kommune, 2012, p. 42

Figure 2: ImTech, 2012, p. 2

Figure 3: MS Paint

Figure 4: Callon(a), M. (1991). Techno-economic networks and irreversibility. In J. Law, *A sociology of monsters: essays on power, technology, and domination* (pp. 132-165). London: Routledge.

Figure 5: Google Earth

Figure 6: Google Earth

Figure 7: Google Earth

Figure 8: Google Earth

Figure 9: Google Earth

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Figure 15: Sharma, A., 2013, *TDRprio*, p. 2

Figure 16: MS Paint

10.2 Appendices