CHALMERS
UNIVERSITY OF TECHNOLOGY

Monetisation of vehicle sensor data for road asset maintenance purposes

A exploratory & abductive case study in the automotive industry

Master's thesis in the Master's Program
Entrepreneurship and Business design

JOHN CARLUND

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENTREPRENEURSHIP AND STRATEGY

CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se
Report No. E2021:138

REPORT NO. E 2021:138

Monetisation of Vehicle Sensor Data for Road Asset Maintenance Purposes

An Exploratory & Abductive Case Study in the Automotive Industry

JOHN CARLUND

Department of Technology Management and Economics
Division of Entrepreneurship And Strategy
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021

Monetisation of vehicle sensor data for road asset maintenance purposes
An exploratory case study in the automotive industry
JOHN CARLUND

Report no. E2021:138
Department of Technology Management and Economics
Chalmers University of Technology
SE-412 96 Göteborg
Sweden
Telephone + 46 (0)31-772 1000

Gothenburg, Sweden 2021

Monetisation of Vehicle Sensor Data for Road Asset Maintenance Purposes

JOHN CARLUND

Department of Technology Management and Economics
Chalmers University of Technology

Abstract

The transition towards connected and spatially aware automobiles presents a plethora of opportunities for new data-driven services. This thesis investigated the relatively unexplored area of vehicle sensor data monetisation for road asset maintenance purposes. The study adopted an abductive methodology that incorporated theory, empirical observations and analysis in an iterative manner to enable recontextualisation of findings from adjacent research fields and a pragmatic orientation towards research inquiry. In the aspiration to create pragmatic and actionable advice for practitioners and researchers alike, this thesis has elucidated concerns and opportunities in four areas: key variations between incumbent and new entrants by value chain analysis; relevant regulations and possible implications of these; challenges inhibiting the realisation of the use case, and factors associated with success in the actualisation of data-driven service utilizing vehicle sensor data for road asset maintenance purposes

Table of contents

1 Introduction

1.1 Background

Importance of road asset maintenance
Road infrastructure constitutes the backbone of national and international socio-economic development and as such it is considered among - if not the - most important public asset (Nicodème, 2015, as cited in Klopfenstein et al., 2019). In Europe, 49% of goods are transported exclusively on road infrastructure and 72% of all inland passenger transport relies on private vehicles (EU road federation, 2017). The importance of road infrastructure's role in empowering economic activities, driving commerce and enabling transport of passengers and freight cannot be understated.

State of road asset maintenance
Road infrastructure constitutes a significant and expensive investment even for economically advanced EU countries, with transport infrastructure accounting for 1.1% of GDP in the 19 Member States part of Euroconstruct (Funk, 2017). Maintenance efforts have however plunged since the 2008 economic crisis - illustrated by the 38% decrease in road maintenance expenditure between 2006 (€31 b) and 2012 (€19 b) (European Commision 2019). The lack of funding has led to considerable backlogs that keep piling up. Badly maintained roads result in higher fuel consumption, wear & tear and travel time as well as worsened safety and travel comfort. The consequences are not only expansive but significant. Studies show that more than half of U.S highway fatalities are due to bad road conditions (Miller, 2009). Greenhouse emissions by vehicles increase around 10% on badly maintained roads and an estimate by the European Parliament shows that an upgrade of one-third of the entire network could lead to yearly savings of 14 million tonnes in CO_2 emissions (IRMD 2018). Both the European construction Industry Federation and the European Road Federation (ERF) have warned about the threats of the ageing infrastructure (European Commision, 2019). The longer maintenance needs are delayed the more expensive they become. It has been reported by the South African National Road Agency that maintenance costs multiply by six after three years and 18 times by 5 years (Magadzi, 2016). Indeed, the state of the European road networks are in a detrimental state and the effects are significant.

Current widely adopted solutions
To make the best of scarce funds, road authorities need to adopt a preventative maintenance strategy and strategically prioritise their efforts (European commission, 2019). This requires a data-driven approach. Besides manual reports, the most commonly adopted solution is to use vehicles equipped with specialized sensors able to measure road roughness or enable off-site inspection of assets such as traffic signs. This method is however expensive which leads to only a few prioritised roads being surveyed and with limited frequency. (Li et al., 2020)

A more novel approach to collecting road asset data is using crowdsourced data from smartphones. Over the last few years, this topic has become increasingly popular with many new organisations and initiatives taking form. While the solution has demonstrated its value, challenges in regards to data quality and user engagement persist and wide scale adoption has yet to occur (Klopfenstein et al., 2019).

Vehicle sensor data as a potential solution and state

An even more recent approach is to collect data from modern automobiles. These are increasingly equipped with sensors, processors and communication systems. Sensors are now able to gather information about the environment outside and inside of the car. The processors enable the refinement of this data into valuable insights and communication systems make these insights accessible. In comparison to an approach using smartphones, modern vehicles offer data of higher granularity, of a larger variety, in real-time and on a superior scale. While some initiatives to use vehicle sensor data for this purpose exist - the use of vehicle sensor data for road maintenance use is still in an exploratory stage with next to no previous cases demonstrating its applicability.

OEMs perspective

On the OEMs side, a large shift is occurring in the industry. Cars are transitioning from being manually operated to autonomously driven, from private to shared ownership, from offline to connected and from gas-driven to electrified. This transition has given rise to increased competition, which in turn puts pressure on OEMs to identify and realise new revenue sources, such as data monetisation. Some use cases for car data such as fleet management, usage-based insurance and insurance conquesting have reached a rather high level of market maturity and proven very profitable. While other use cases – such as smart city application, urban planning, parking and mapping – which require additional sensors in the form of cameras and lidars, are still in their infancy (KPMG, 2020).

Concluding remarks

Using vehicle sensors for road infrastructure maintenance has enormous potential to save lives, reduce emissions and create savings for individuals, organisations and road authorities. Realising this opportunity requires active participation from both the private and public sectors. In the private sector, OEMs are trying to navigate the transition from hardware to software-as-a-service and find ways to compensate for falling margins and rising investments. So far, additional revenue sources have been realised in the context of data monetisation for insurance and fleet management purposes. The use case of road asset maintenance is however still very exploratory and the research field is next to non-existent.

1.2 Research question

The purpose of the study is to investigate the use case of utilizing vehicle sensor data for road asset maintenance purposes. The use case is studied as a business opportunity for OEMs. As such the study intends to first investigate which competing solutions exist and how value-creating activities differ amongst actors employing different solutions. Secondly, the investigation aims to highlight and interpret the most relevant European regulations for the OEM to consider in the specific context of this use case. Thirdly, the study aims to identify what challenges practitioners face in realising the use case and, fourthly, identify which potential factors might be associated with success.

Leading RQ	**How do OEMs best monetise data for road asset maintenance use?**
Sub-RQ 1	What are the different solutions employed and how do they differ in terms of value creation?
Sub-RQ 2	What are the key European regulations for OEMs to consider in this use case and what is their implication?
Sub-RQ 3	What are the challenges OEMs must overcome to realise this use case?
Sub-RQ 4	What are the critical success factors for OEMs in realising this use case?

1.2.1 Delimitations

The research questions are subject to limitations in terms of scope. These are described below. Delimitations in terms of data collection, as well as limitations in terms of validity, are included in the Methodology chapter.

Sub-RQ 1

The analysis regarding the first sub-research question is limited to value chain analysis. Analysis falling outside the scope of the value chain concept is thus excluded from the research. Value chain analysis was deemed appropriate due to the exploratory nature of the investigation and the relatively advanced research field of data value chain frameworks.

The value chain concept was applied to data for road asset maintenance as opposed to vehicle sensor data for maintenance use. Reason being that it was considered relevant to identify and compare competing solutions to a potential solution using vehicle sensors.

As such, the study made a limitation to only include similar methods of data generation. These similar methods are defined as methods incorporating mobile traffic speed surveys which are fully or partly automatised. For the sake of clarification, this excludes the following methods from the investigation: traditional, on-site visual traffic speed survey; methods using stationary devices, drones or satellites and methods using data other than that based on recordings of road assets, such as weather data used to estimate deterioration.

The study is not limited to - but aspires to - include only European companies and solutions. The delimitation is not made explicit due to the limited amount of information available and some references to companies in the US are made.

Sub-RQ 2

The second sub-research question regarding the regulatory environment is limited to analysis from the OEM's perspective. Other data generation methods are not considered during this part of the analysis.

It is also limited to only include analysis of European regulation on a European level. Meaning that it excludes regulations in the US or regulation in Europe on a national level. The limitation is made due to the complexity of the regulatory environment and the abundance of information and relevant regulations. The limitation could be perceived as further motivated by the Brussel effect, meaning the effect in which the more stringent regulation in vital markets gain global effects (Bradford, 2021).

The analysis is further limited in regards to the number of regulations analysed. The choosing of which regulation to analyse was made based on relevancy to the case, the relevancy was determined by the researcher in cooperation with a legal subject matter expert.

Sub-RQ 3

Sub-research question three in regards to challenges was limited to identification and contextualisation. No effort to prioritise, compare, validate or suggest solutions for identified factors were made. This is considered a consequence of the exploratory nature and breadth of the research which is further discussed in the Methodology chapter.

It furthermore excludes any meta-analysis of challenges in terms of temporal properties or other measures of abstraction such as hierarchy level in terms of industry, organisation or project level. Challenges are however subject to an interpretative and subjective analysis in regards to similarity, which is used to illustrate identified challenges and make the analysis section coherent.

Sub-RQ 4

The analysis in which success factors are constructed draws on a wide range of literature. The study makes no explicit delimitation in regards to information assimilation but is limited due to time constraints. The justification and reasoning behind this can be found in the Methodology chapter as well in the Critical Success Factors (CSF) Concept chapter.

The analysis is limited to proposals of success factors – meaning that no prioritisation, comparison of importance or verifications are made.

2 Literature review

The current research and initiatives in regard to vehicle sensor data for road infrastructure maintenance can be described as fragmented and nascent. Maintenance needs that could be described as urgent and which pose a direct safety hazard – such as temporary slippery roads or debris on the road – have, understandably, gained significantly more interest than less urgent needs, such as vandalised signs or potholes. In regards to urgent and safety-related traffic data initiatives such as Data For Road Safety have formed a large network of data providers, established data standards and conducted pilot tests on a European level. Less urgent road maintenance have however gained significantly less attention from the automotive sector and no similar international initiatives exist for these purposes.

The maturity in which member countries manage road asset data displays considerable discrepancies (Luiten et al., 2018). The problem is further complicated by a fragmented responsibility structure and lack of harmonisation between national guidelines (European Commission, 2019). On a national scale, three major pilot projects were identified. The Swedish road authority in collaboration with Nira Dynamics and Volvo initiated the “Digital Winter” project in 2018: a pilot project which involved sourcing data from individually owned vehicles and using said data to plan pavement maintenance (Asp et al., 2021). In May 2019, Mobileye in collaboration with Great Britain's national mapping agency (Ordnance Survey) began a joint project called RIACT, Roadside infrastructure Asset Capture Trail. A project which in the initial phases aimed to map road assets such as lightning infrastructure, street signs, manholes and highway status information for maintenance purposes (Mobileye, 2020). In June 2021 Tactile Mobility announced the launch of a nationwide survey project in Israel. The company aims to provide the government with road surface data gathered from Union Motor vehicles equipped with Tactile Mobility software (Tactile Mobility 2021).

The lack of realised use cases for vehicle sensor data for maintenance purposes might explain the lack of research conducted in the context of this specific use case. The current research was perceived to adopt a wider perspective encompassing areas such as Business-to-government (B2G) data sharing - or data monetisation by the automotive sector. The former lacks context to vehicle sensor data and the latter to road maintenance or public sector use. Some exceptions do however exist.

Graham (2020) interviewed road asset management experts in the UK to better understand what the gaps are for realising the use case. Graham concludes that while most gaps are at the authority user end, they are unlikely to be interested until it has demonstrated actual value. Thus, it creates a chicken and egg situation in that the data providers do not have the incentive to invest in the required capabilities without demand from users.

Much of the research within data monetisation by the automotive sector focuses on the technical feasibility (in terms of transmission and processing) as well as best practices and challenges in regards to both direct monetisation or by use of third parties (McKinsey, 2018) (Gorkas 2020) (Mckinsey 2020) (Lindgrens et al., 2017) (Fridolin 2019) (McHardy et al 2018). Current research does, however, lack context to specific use cases. The extensive discrepancies in regards to the business maturity, regulatory environment and technical specifications of various use cases make the surrounding research fields applicability to the investigated use case questionable.

3 Theoretical Concepts and Frameworks

In this chapter, frequently mentioned terms and the two major concepts applied in the investigation are discussed. Due to the exploratory and theoretical nature of the thesis, most of the theoretical concepts utilized are subject to analysis and interpretation - as such, the introduction of these resides in the “Result & Analysis” chapter. This is further motivated and detailed in the Methodology chapter.

3.1 Definitions

In this chapter, some frequently mentioned terms are discussed and defined. These terms are “data monetisation”, “road maintenance” as well as “road assets” and “road infrastructure”. These were considered relevant to discuss as they are frequently mentioned and open for interpretation.

Data monetisation

Data is increasingly regarded as a valuable asset and as a source of competitive advantage. Leveraging data for economic benefits fall within the domain of data monetisation. A term defined as “converting the intangible value of data into real value” by Najjar and Kettinger or referred to as “using data for quantifiable economic benefit” by Gartner (as cited in Baecker et al., 2020). It is important to emphasise however that economic benefits can be realised in a number of different ways. Baecker et al (2020) research in data monetisation strategies illustrates this by identifying 12 distinct strategies for data monetisation. These include realising economic benefits by optimising internal business processes or existing products with data. Exchanging data for cash or other resources such as software, services or data. Strategically opening data for co-creation activities or leveraging data to create lasting relationships. Even *not* transacting or using data can be included as a monetisation strategy in cases where data privacy and control guarantees result in realised economic benefits.

Road assets & infrastructure

Road assets is a frequently used term in the thesis and refer to road infrastructures such as pavement, lighting, traffic signs, road markings, boundary fencing and other roadside assets. If other road assets such as bridges, tunnels, earthworks and housing structures are referred to the thesis does so explicitly.

Road infrastructure refers to infrastructure which is used to transport goods and passengers via road.

Road maintenance

American Association of State Highway and Transportation Officials (as cited in Karimzadeh & Shoghli, 2020) categorises road asset maintenance into two different areas; reactive or proactive. Reactive maintenance strategies refer to unplanned maintenance that occurs after failure. Such a strategy often relies on manual and voluntary reports or manual traffic speed surveys. Most member states have some sort of mechanism to handle such reports, in

Sweden, there is for example LiveTraffic: an app that allows for anyone to report road infrastructure damage. Another common way to identify maintenance needs is through manual traffic speed surveys, which relies on professional drivers visually inspecting the road at traffic speed.

To some degree, reactive maintenance is always going to be required. Road assets can be damaged due to for example accidents or vandalization. Neglecting assets and prolonging maintenance until failure is however another question and can lead to great costs, both for road authorities and to society as a whole.

A proactive maintenance strategy aims to prevent or postpone failures. This strategy could be further categorised into preventive and predictive. A preventive maintenance strategy refers to conducting maintenance on set internals, the duration of which can be determined by the supplier of the road asset. This strategy leads to inefficient use of resources as the deterioration of assets is heavily influenced by environmental factors. Adopting a preventive strategy might thus result in unnecessary repairs or repairs long after failure.

A predictive maintenance strategy relies on inspection analysis and prediction models to forecast the time of failure. Inspection analysis is traditionally conducted by using specified mapping vehicles. As these are expensive to procure and operate, only a few prioritised roads (usually around 20% of the total road network) can be mapped with limited frequency (usually around every 5 years). As such, there has been a shortage of data to develop predictive analysis models, especially models that could be used for rural road networks.

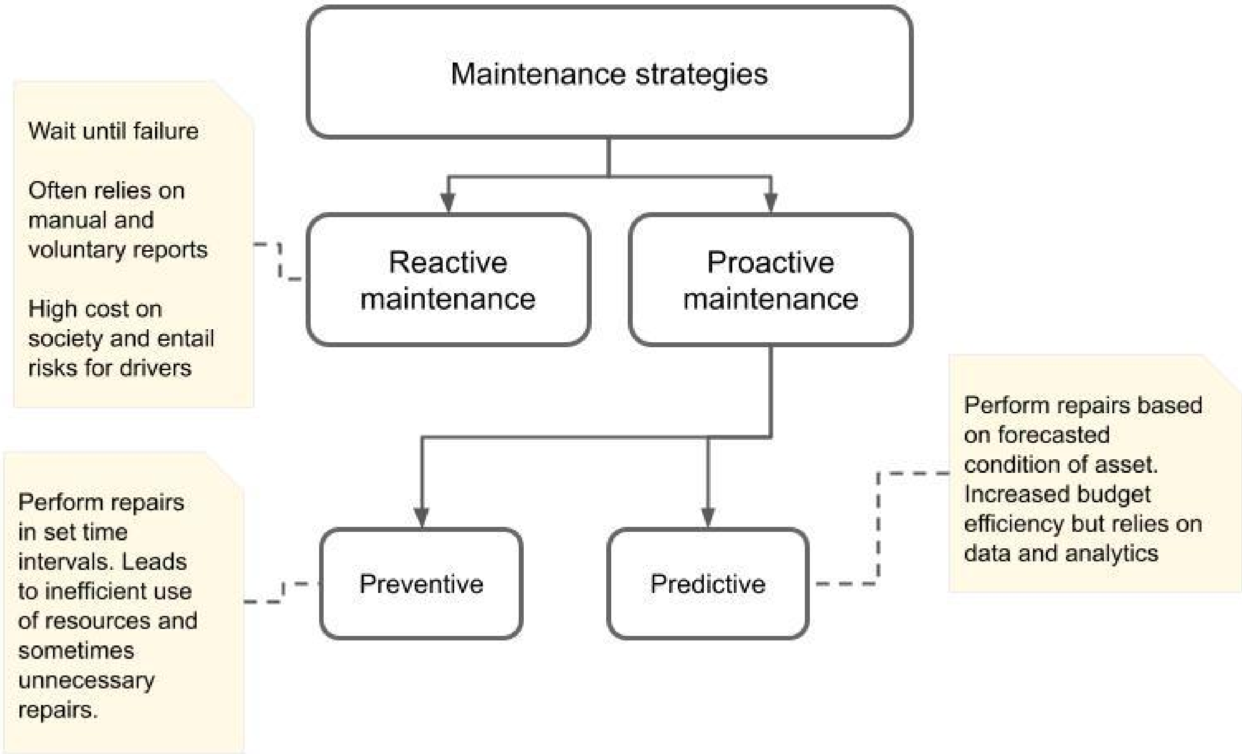

Figure 1, Maintenance strategies

3.2 Theory

In this chapter, the two overarching theoretical concepts applied in the study are presented. They are first discussed in terms of origin, then usability and practicality are discussed which is followed by a short description of their application in this study. The two concepts discussed are “value chains” and “critical success factors”. As mentioned previously, further theory, empirical observations and analysis are introduced collectively in the “Result & Analysis” chapter, this is motivated in the “Methodology” chapter.

3.2.1 Value chain concept

The value chain concept was introduced by Porter in 1985 within the research field of business management. “Value chain” refers to a set of activities a firm performs in order to deliver a valuable product. The concept is based on a process view in which activities are deconstructed into essential activities, i.e primary activities, and supportive activities.

Since its introduction, the concept has gained popularity and been applied in a variety of industries and scenarios. The first data value chain was introduced by Ackoff in 1988, since then other researchers have contributed to the field and additionally refined the concept. Gorka (2020) conducted a literature review within the field data value chain, some of the more influential of which is illustrated in the image below.

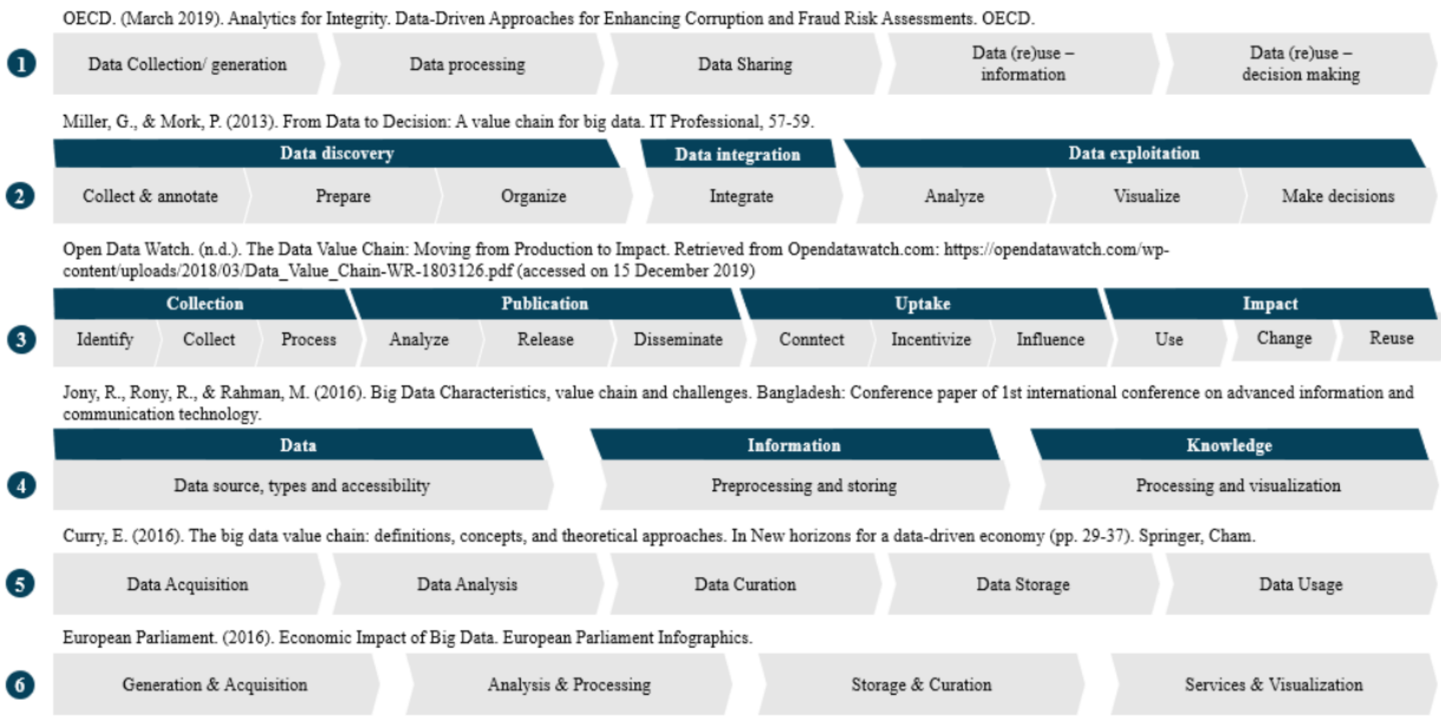

Figure 2, Data value chain overview by Gorka (2020)

Value chain analysis deconstructs the major value-creating activities and facilitates both the understanding of **why** a company exists and **what** it does. The advantage of this analysis are that actors can within the context of their firm identify beneficial strategic positions. It can for example help answer questions such as “Is this a beneficial market for us to enter considering our current capabilities?" or "How can we further optimise or add value to our services?".

In the context of this study value chain analysis was deemed appropriate as it allowed for more focused information assimilation, especially considering the exploratory nature of the investigation and abundance of existing data value chain frameworks. The value chain concept was applied to data for road asset maintenance as opposed to vehicle sensor data for maintenance use. Reason being that it was considered relevant to identify and compare competing solutions to a potential solution using vehicle sensors.

3.2.2 Critical success factors (CSF) concept

Critical success factors are the key factors that have to be performed well in order to be competitive in a specific industry. CSF was first introduced as a concept by McKinsey consultant J.Ronald Daniel in his article "management information crisis". CSF was introduced as a concept which bridges the gap between the volume of information available to managers and the capacity to which said manager could make efficient use of that information. The concept of critical success factors was later popularised by Rockart who had considerable influence on future literature within CSF. Rockart (1979) defined critical success factor as "*...the limited number of areas in which results, if they are satisfactory, will ensure successful competitive performance for the organisation*". As the research field grew in popularity more refined definitions were created, one of which that gained traction is Bruno and Leideckers (1984) definition - "*Critical Success Factors (CSF's) are those characteristics, conditions, or variables that when properly sustained, maintained, or managed can have a significant impact on the success of a firm competing in a particular industry. A CSF can be a characteristic such as price advantage, it can also be a condition such as capital structure or advantageous customer mix; or an industry structural characteristic such as vertical integration.*".

The popularity and rather ambiguous definitions have made CSF subject to wide interpretation. Previous researchers have tried to provide more clarity by classifying CSF according to some measure of particular abstraction (Amberg et al., 2005) (Williams & Ramaprasad, 1996). The most common of which might be an organisational hierarchy as defined by Rockart (1979) who differentiate between CSF on an industry, corporate or sub-organisational level. Because of the many levels of abstractions discussed by previous researchers, it is possible to relate other concepts such as best practices, principles and learnings to the concept of CSF.

This investigation has chosen a practical orientation in that other concepts, such as best practices, are included in the analysis without regard to any particular measure of abstraction between the various concepts. This enables for the investigation to consider a wide range of elements that are associated with success. Identified elements are deconstructed and categorised based on intuitive and interpretive analysis of factors, the purpose of which is to create practical advice for practitioners and formulate conjectures for further empirical research.

4 Methodology

The methodology chapter contains a description of the philosophical position of the thesis and the method of investigation employed. As to help the reader understand the stance taken by the researcher, each sub-chapter begins with a short description of the terminology. This is followed by a description of the stance taken by the researcher.

4.1 Theoretical perspective

What is meant by theoretical perspective?

Theoretical perspective, also referred to as Grand Theories (Bryman & Bell, 2011), Philosophical Perspective or Paradigm Perspective (Moon & Blackman 2014), is the concept characterized by a higher level of abstraction than research specific research methods. They are in fact, so abstract as to not provide much aid in guiding social research but rather represent a set of values or assumptions to which the researcher adheres (Moon & Blackman 2014) (Bryman & Bell, 2011). The theoretical perspective was considered important to make explicit in order to motivate the assumptions that lead to the design and methodology of the research. Examples of theoretical perspectives are; Positivism, structuralism, constructivism (*following the distinction to constructionism made by Patton (2002) as cited in Moon & Blackman (2014)*)), interpretivism, critical theory and pragmatism (Moon & Blackman 2014).

Theoretical perspectives are underpinned by epistemological and ontological leanings and can in some cases be viewed as, and interchangeable with, epistemological or ontological positions (Moon & Blackman 2014). Just as with epistemological or ontological positions, theoretical perspectives are characterized by pluralism in the sense that researchers need not commit to one theoretical perspective and that this perspective might change over the course of the research (Moon & Blackman 2014).

What is the theoretical perspective in this thesis?

This thesis has adopted a pragmatic theoretical perspective. This is coherent with the research emphasis on actionable knowledge as well as with the purpose which is to aspire for practical research outcomes rather than the development or testing of theory in itself. The pragmatic approach inherent flexibility and reflexiveness was also perceived as suitable to the complex and exploratory nature of the investigation.

While it could be argued that the thesis takes a constructivist oriented theoretical perspective, the rather agnostic view towards ontological issues made apparent by application of models without consideration of the truthfulness of said model but rather considering the utility of said model, argues for a pragmatic theoretical perspective.

The pragmatic perspective is furthermore made apparent in the assimilation of information. A constructivist or interpretivist orientation values the particular perspective or context in which an argument was constructed (Patton, 2002), while a pragmatic view values the utility of said argument (Kaushik & Walsh, 2019). This line of reasoning is evident throughout the thesis. A concept that has been developed in another research field might be interpreted as useful within the investigated context and is thus used without appreciation of the context in which that concept was constructed.

4.4 Ontology

What is meant by ontology?

Ontology, the study of being, concerns how the researcher relates to what is true and real. Ontological perspectives can be divided into realism and relativism. In simplified terms realism argues that truth and reality exist independently of human experience and as such only one truth and reality exist. While realism in contrast argues that reality is a construct of the human mind and as such is relative to individual and time. Examples of realism ontologies are naive realism, structural realism and critical realism. Examples of relative ontologies are bounded relativism and relativism (Moon & Blackman 2014).

What is this thesis ontological stance?

This thesis has adopted an ontology of relativism. Despite the open-ended and subjective nature of the research question both a realism or relativism ontological orientation is possible. The former, realism, would argue that the research question is possible to answer truthfully to a reality independent of human cognition. While the latter, relativism, would argue that it is possible to answer truthfully to a reality resulting from human cognition. The exploratory context of the research purpose and the abductive research logic applied was however considered determinant factors for adopting a relativistic ontology during the research progress.

It could be argued that a bounded relativism is suitable for the research purpose - this thesis does however hold to a relativism ontology since the researcher perceives that multiple answers could be considered true to reality in the same time, organisation, or geographic location. This was considered congruent with the pragmatic theoretical perspective in that it adopts an agnostic view towards what is true but rather emphasises what might work in practise - and what might work is perceived as pluralistic.

4.5 Epistemology

What is meant by epistemology?

Epistemology, the study of knowledge, is concerned with how knowledge is created. For the sake of simplification, it can be stated that while ontology regards the existence of reality epistemology regards the degree to which that reality is knowable. Examples of epistemological stances are objectivism, constructionism and subjectivism (Moon & Blackman 2014). Objectivism assumes truth and reality exist independently from human experiences but is rather dependent or inherent in the object, as such truth and reality can be discovered by rigorous research. While subjectivism assumes truth and reality is pluralistic and that truth and reality is imposed by the individual's thoughts independently from the object. Constructionism rejects both of these concepts and means that truth and reality is a construct derived from the engagement between subject and object - between mind and world. Constructionism in a similar manner as to subjectivism is pluralistic, equally meaningful realities and truths in relation to the same phenomena can exist, the difference lies in whether truth is created by the interplay of subject and object or purely by the subject.

What is this thesis epistemological stance?

This thesis adopts a constructionism oriented epistemology. Since the purpose is to research a business opportunity for pragmatic reasons it was considered reasonable that meaning emerges from the interplay between the world and individuals. Accordingly, the thesis aspires to assimilate meaning from individuals with experience within the investigated context. Or from secondary sources doing so.

It could be argued that the thesis stance is subjectivist in that the study investigates individuals' perception of an object, in the form of a problem, solution or activity. But since the focus of the investigation is on the interaction between OEMs (subject) and a certain data monetisation activity (object) the study is considered using a constructionist oriented approach. If the study emphasised the subjects' perception of the object and how widely held those perceptions were it would be considered subjectivistic. As is, the study emphasises the meaning and knowledge arising from the interaction between subject and object for the purpose of generating contextual understanding of a particular phenomenon. These features are mentioned as characterizing a constructionism oriented epistemology by Moon & Blackman (2014).

4.2 Research Strategy

What is meant by research strategy?

This thesis adopts Bryman and Bells (2011) definition of research strategy which refers to the "*general orientation of the conduct of business research*" and can be said to either be quantitative or qualitative. The former, quantitative, is said to refer to a research strategy characterised by;

- Emphasises the quantification in the analysis and collection of data.
- A deductive approach to the relationship between research and theory
- Adopts the norms and practises associated with natural scientific models, in particular: positivism and a view of social reality as external

Qualitative research is said to contrast quantitative research and as such refer to a research strategy that is characterized by;

- Emphasis on words in the analysis and collection of data
- An inductive approach to the relationship between research and theory
- Rejects the norms and practises associated with natural scientific models, in particular positivism and a view of social reality as external. Meaning that it embodies a view that social reality is an emergent property of individuals creation.

As argued by Brymann and Bell (2011) it should be noted that the distinction is not as straightforward as this and variations occur in which these distinctions don't hold true. The simplified contrast was however considered useful to provide a fundamental grasp of the concepts.

What research strategy is employed in this thesis?

This thesis incorporates a qualitative research strategy. This was considered a natural choice as the thesis deals with the generation of theory within an exploratory and complex context. The subjective and open-ended nature of the research questions is well reflected in the choice of a qualitative strategic approach. Furthermore, the exploratory nature of the research would make it challenging to adopt a quantitative approach as there are no models perceived to be suitable for testing in a way that would be coherent to the purpose of the research. A qualitative approach in this regard instead allows for an in-depth analysis based on interpretive analysis focused on the exploring of ideas - which is perceived as to conform to the purpose of the thesis.

4.3 Research Design

What is meant by research design?

Research design refers to the framework which guides the execution of the research method and the collection and analysis of data (Brymann & Bell 2011). As such the choice of research design is guided by the purpose of the research and enables the researcher to narrow down what research methods are suitable for the purpose. Examples of research design are experimental, cross-sectional, longitudinal, case study and comparative (Bryman & Bell, 2011).

What research design is employed in this thesis?

This thesis conducts a case study research in which the case is bound to the business opportunity of investigation. As such the investigation isn't a case study of an organisation, event or group of people but rather a phenomenon defined as a business opportunity. This approach was considered congruent with the research questions as they too are bound to this specific case. This design was perceived to be suitable to generate an in-depth, multifaceted understanding of a complex issue as well as being consistent with the pragmatic theoretical perspective and qualitative research strategy. The case study approach was perceived as a more viable method of investigation in comparison to the above-mentioned designs due to resource constraints in terms of time, research participants with knowledge of the case and researchers conducting the study.

The case study can be described as exploratory rather than descriptive or comparative. The emphasis of the research is to explore the problem situation and discover new ideas. The outcome of the investigation aspires to enable subsequent research to attain more conclusive results. The findings are thus not to be interpreted as aspiring to constitute a definite answer to the research questions.

The pragmatic theoretical perspective has been identified by previous researcher Steenhuis (2015) as forming an inductively oriented case study design, closely related to a constructivist and interpretivist approach. This is coherent with the approach adopted in this thesis as a predominant part of the investigation uses inductive reasoning - and as is discussed later, has an epistemological and ontological stance that could, at most times, be considered constructivist and interpretivist.

It could be argued that the research design is that of an comparative or multiple case study design. Indeed, the thesis does study multiple companies and make comparisons. While this is acknowledged, the researcher chooses to define the research design as a case study in which the case is framed by the investigated business oppportunity. This was considered preferable to distinguishing each sub-question to a seperate design as to faciliate the structure and narriation of the thesis.

4.6 Research logic

What is meant by research logic?

Research logic refers to the reasoning the researcher employs to construct or identify truth and reality. Research logic can in simplified terms be explained as either inductive, deductive or abductive. Deductive oriented research can be said to concern the testing of theory while inductively oriented research is concerned with the development of theory. Abductive oriented research on the other hand is concerned with the suggestion of new theory (Kovacs and Spens 2005).

A deductive research approach generally starts with existing theory, derives a logical hypothesis and collects data to test said hypothesis, while an inductive approach may start with observations which are then analyzed to develop a theory. Deductive reasoning thus moves from the general to the specific, while inductive reasoning moves from the specific to the general. An abductive research approach on the other hand is concerned with the particulars of a specific phenomena and the deviation of said phenomena to general structures. As such abductive reasoning, like induction, can start with observation, but unlike induction, abduction investigates the observed phenomena by theory matching. Meaning the empirical observations are made in an iterative manner combined with re-contextualising and interpretation within new contextual frameworks. Abductive reasoning can also, like deduction, start with a theory, but unlike deduction - creatively apply it to an existing phenomenon and investigate in an iterative cycle of empirical observations and theory assimilation (Kovacs and Spens 2005). The illustration below explains the variations in progression for the three research logics, image is an adapted illustration from Kovacs and Spens (2005) study with added description of respective research logic.

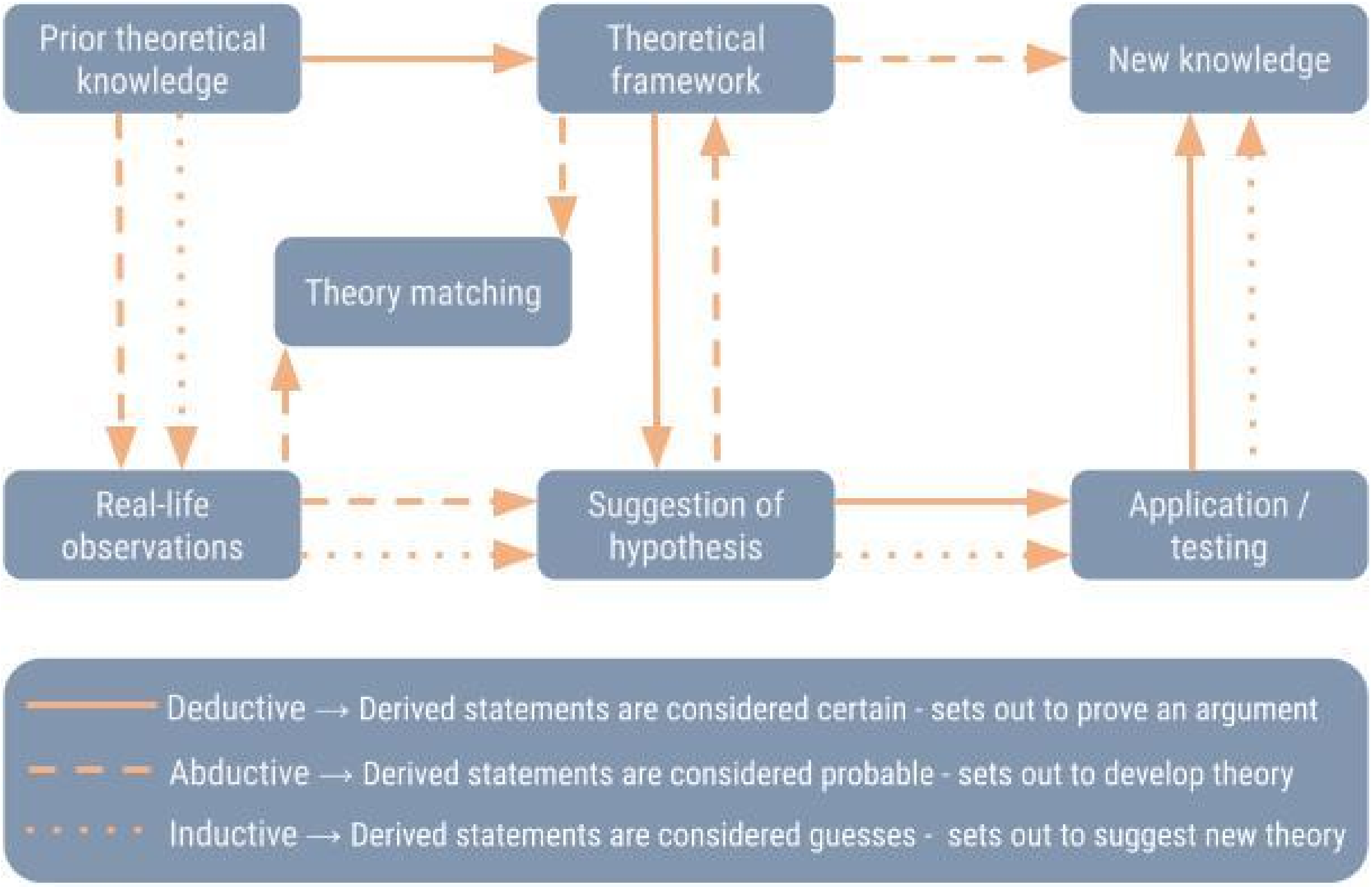

Figure 3, research logic illustration by Kovacs and Spens (2005)

What research logic is incorporated in the thesis?

This thesis incorporates an abductive research logic. The primary reason for this is the exploratory nature of the investigated phenomena, that is, vehicle sensor data monetisation for road asset maintenance purposes. As such, abductive reasoning enabled a pragmatic relationship to inquiry. Meaning that empirical data collection in the form of semi-structured interviews, as well as data collected from companies websites, was collected and analysed iteratively while reviewing theory found in closely related research fields.

Because the abductively influenced inquiry, theory utilized in the development of theory and arguments is presented in the Result & Analysis chapter as opposed in the Theoretical Concepts and Frameworks chapter. The reason being the iterative utilization, and tight integration, of theory, empirical result and analysis. This choice of presentation also has a pragmatic reason in that a wide range of research fields are discussed and a theory section in each of these demands an unproportionate effort in relation to the utility.

The abductive nature of the research is furthermore evident in the application and development of the models constructed in the thesis. Consider the image below illustrating model and analysis in respective sub-question.

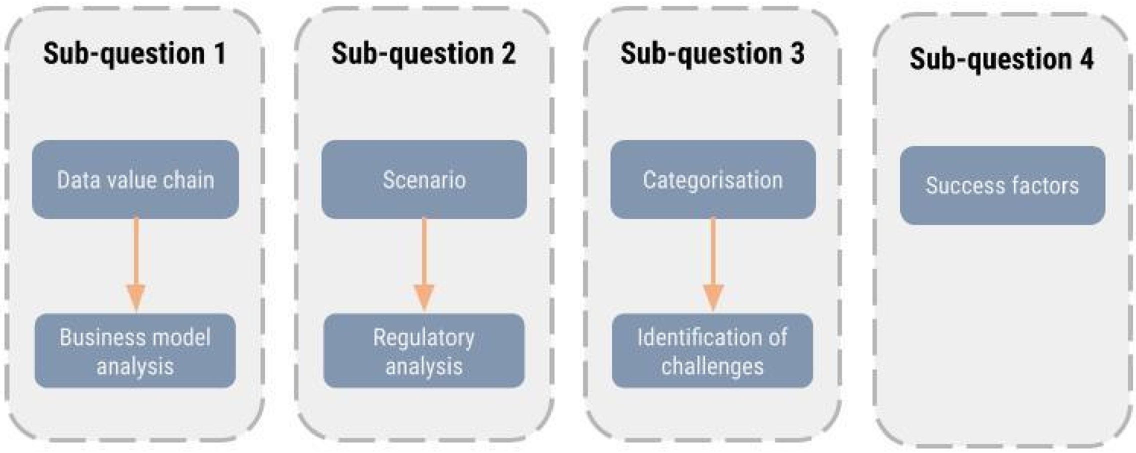

Figure 4, sub-question with associated model

In sub-question one and four, the models (i.e the developed data value chain artefact and the conjectured success factors) are considered new knowledge which aspires to answer the sub-question. In sub-question two and three, the models (scenario and categorisation) does not directly contribute to the answer of the sub-question but does so indirectly by providing a structure to the analysis.

In sub-question 1 - the data value chain is developed abductily, meaning that theory, empirical observation and analysis was done iteratively and as such was presented collectively in the Result & Analysis chapter. Due to the limited amount of prior models within the specific context, a deductive approach was considered infeasible. An Inductive approach was, however, considered. An inductive approach might for example use grounded theory and gather empirical observations by semi-structured interviews to answer the sub-questions of what solutions exist and how other firms generate value. The abducted approach was chosen due to pragmatic reasons. Due to the study lacking participants with knowledge of the investigated case and due to time limitation combined with the breadth of the leading research question, the study had severe resource constraints. As such an abductive approach offered more flexibility and a less resource-demanding approach as it allowed for the researcher to incorporate both theories from related research fields and empirical observation in the form of marketing on company websites.

In sub-question 1 during the next phase, the business model analysis, one might argue for a deductive approach utilizing data either from interviews or websites to determine the probability or utility of the constructed data value chain artefact. This approach would, however, be a time demanding endeavour and as such limit the extent to which the other sub-questions could be answered. This thesis instead chose a more pragmatic approach in the sense that the following business model analysis aimed towards furthering the sub-question 1 and the leading research question. As such only three companies were investigated and the comparison considered the implications for how monetisation activities within the context could be constructed rather than determining the extent to which the constructed value chain artefact is true or useful. As such the following analysis of business models is considered abductive in the sense that it concerns educated guesswork based on empirical observation investigated in a model which in itself is also educated guesswork.

In sub-question 2, which concerns a regulatory analysis, a scenario in the form of a transaction chain was constructed and used as a foundation from which the regulatory analysis originated. The scenario was constructed abductively in the sense that is it guesswork and based only on a handful of conversations with subject matter experts and the prior knowledge of the researchers gained from the investigation.

In sub-question 2, during the next phase of analysing regulation, an abductive approach was utilized due to the pragmatic inquiry method it enabled. Meaning that literature in closely related fields was interpreted and contextualised to the specific phenomena investigated. An inductive or deductive approach was discarded for both phases discussed in relation to sub-question 2 with similar pragmatic reasoning communicated in relation to the sub-question 1.

In sub-question 3, the aim was to identify relevant challenges for the realisation of vehicle sensor data for road asset maintenance. As such the thesis takes a rather agnostic view towards the measure of abstraction adopted in categorising the identified challenges. The emphasis is rather on the identification and contextualisation of previously identified factors hindering vehicle sensor data monetisation. In a similar line of pragmatic reasoning mentioned in relation to sub-question 1, the researcher discards the idea of using an inductive or deductive approach to sub-question 3.

In sub-question 4, the aspiration is to propose success factors for the investigated phenomena. No model was constructed for the construction of success factors, meaning that no measure of abstraction was used to categorise factors or determine their relevance to the context. The thesis does however present the identified factors (chapter 5.4.1-5.4.3) depending on which context the factors originated from. This is however due to the aspiration to create a structured narration rather than for utility reasons. As such the thesis does not consider this a model used for investigation but rather a byproduct of storytelling. It might be argued that an inductive research logic is employed during the investigation of sub-question 4 due to the similarities between grounded theory and the method employed. But due to the incomplete set of information on which theories are constructed, and due to the interpretation and recontextualisation involved in the analysis - the researcher holds the position that it is of abducted nature. As with previous sub-questions, the researchers discards an inductive or deductive approach with a reasoning congruent with the reasoning in sub-question 1.

4.7 Specific research methods & Data collection

This section describes the specific research methods used in the assessment of data as well as how data was collected. The assessment models and data collection varies from respective sub-question, the following paragraphs detail these in order of question.

Sub-question 1 - *What are the different solutions employed and how do they differ in terms of value creation?*

This question is investigated by using value chain analysis. Some previous data value chains were investigated and the thesis adopted Gorka's (2020) value chain as a starting point and adapted the artefact as required. A value chain analysis was considered appropriate to the purpose of the thesis and the exploratory context of the investigated phenomena.

After the data value chain was constructed it was applied to compare three companies in order to gain additional insight and further the answer to sub-question 1 and the leading question.

Both theory and empirical observation were utilized for the construction of the value chain artefact. The theory was primarily found in academic studies but also in white papers and reports. Empirical observations were exclusively from corporate websites, press releases, blogs and financial statements. Meaning no interviews were for the purpose of constructing the value chain artefact.

Sub-question 2 - What are the key European regulations for OEMs to consider in this use case and what is their implication?

To identify the key regulation a scenario in the form of a transaction chain was constructed. The motivation of which came from - and was constructed in collaboration with - a legal subject matter expert within the automotive industry. The transaction chain facilitated the identification of relevant regulations as it provided a basis to originate from.

The relevancy of regulations was investigated in an iterative manner in which regulations were identified, discussed with a legal expert and then additional searches were made and discussed. The regulations that were deemed the most relevant were analysed in regards to opportunity and threat to the OEMs. This was later translated into implications, which are summarised at the end of each sub-chapter in the regulatory analysis.

In the context of interpretation and implications, the investigation aspired to triangulate as extensively as possible. Due to limitations in time allocation and legal expert interviewees, this section of the analysis relies on the researcher's interpretation of regulations and, when possible, on secondary sources such as opinion papers and research studies.

Sub-question 3 - What are the challenges OEMs must overcome to realise this use case?

The investigation of challenges is framed by Fridolin's (2019) study of barriers to realising an API economy in the automotive sector. Challenges are categorised into legal, technical and business. This categorisation is a loose adaption from Fridolin's (2019) categories of; social acceptance, economic, technology and legal. The reasoning behind the merge of social acceptance and economy was purely pragmatic. As reasoned in the Research logic sub-chapter the thesis takes an agnostic view of any measure of abstraction between the identified challenges.

Additional research studies besides Friodlin's (2019) as well as information from semi-structured interviews are then reviewed and incorporated into the study, either to endorse the actuality of the challenge, to put it into the context of this investigation or to complement the already identified challenges.

11 semi-structured interviews were conducted in relation to challenges. The interviewees were all working in the automotive sector and had to some degree experience in data sharing initiatives. The interviewees chosen had a wide degree of diversification both in the context of area (legal, technical & business) and level (activity to c-level) which allowed for a multifaceted perspective on current challenges. The described group of 11 interviewees are commonly referred to as group B in the thesis, further detail is communicated at the end of the subchapter Specific research methods & Data collection.

Sub-question 4 - What are the critical success factors for OEMs in realising this use case?

The critical success factors are identified by using an adapted method based on Leidecker and Bruno's (1984) identification techniques. The learnings from previous research questions provide a knowledge base from which the researcher interprets the applicability of findings in adjacent research fields. As motivated in sub-chapter 3.2.2 Critical success factors (CSF) concept - the investigation has adopted pragmatic orientation in that other concepts, such as best practises, are included in the analysis without regards to any particular measure of abstraction between the various concepts. This enables the investigation to consider a wide range of elements that are associated with success. Identified elements are deconstructed and categorised based on intuitive and interpretive analysis of factors, the purpose of which is to create practical advice for practitioners and formulate conjectures for further empirical research. An overview of the deconstructed factors and their perceived similarity can be found in appendix A.

Information is collected from both literature reviews and semi-structured interviews with 15 subject matter experts - 4 of which had experience from realising the discussed use case and 11 of which were considered subject matter experts in data sharing by automotive sector actors. The described group of 4 interviewees are commonly referred to as group A in the thesis, further detail is communicated at the end of the subchapter Specific research methods & Data collection.

Leading question - How do OEMs best monetize data for road asset maintenance use?

The leading research question is answered by the sub-questions, the image below illustrates a summary of the method employed and the data collected in the respective sub-question. This is followed by a description of the order in which activities were conducted and questions answered.

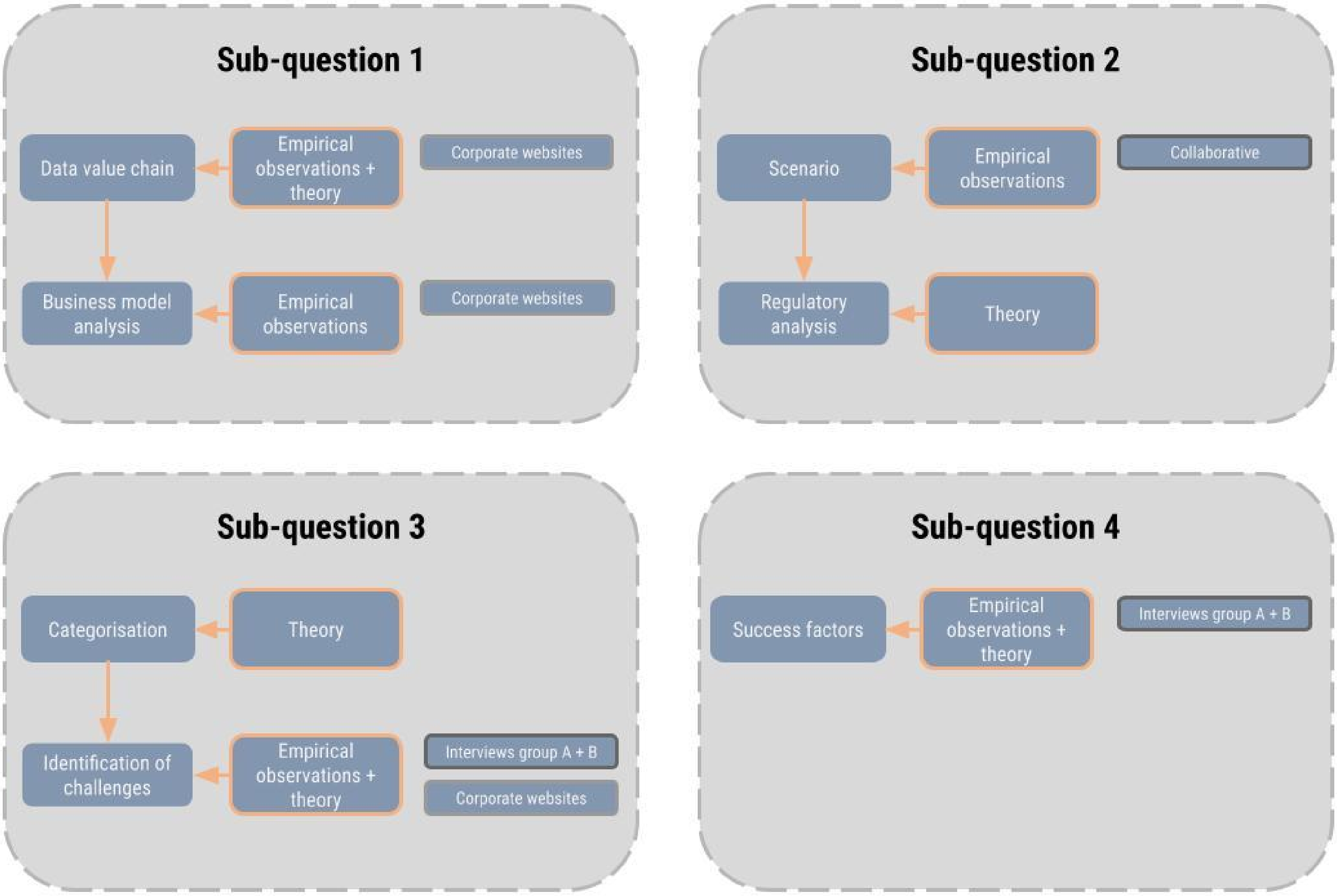

Figure 5, sub-question with associated model and data collection

The study aspired to answer each sub-question in order of 1 first and 4 last. At times, however, information was found that could contribute to a previous question and as such the process was at times overlapping or iterative.

The investigation started with a prior art literature review in conjunction with interviews with participants in group B. The early onset of the interviewing phase was considered to be motivated by the exploratory nature of the investigation. This gave increased focus of direction and purpose of the thesis. Interviews with participants in group B were ongoing until the conclusion of sub-question 2. Interviews with group A were conducted in parallel with literature review and analysis aimed at answering sub-question 3 and 4.

Besides the interviewees in groups A and B a subject matter expert within the business domain was consulted in regards to the findings of the study. These consultation sessions were conducted during the whole progression of the thesis and aided in directing the study and to some extent verification of results.

Interviews - when, how and who?

The interviews were held between 10 of January and 25 of May. A total of 15 interviews with 15 interviewees were completed. Each interview is around one hour. The interviewees chosen had a wide degree of diversification both in the context of area (legal, technical & business) and level (activity to c-level) which allowed for a multifaceted perspective.

The interviewees were divided into two groups, those that had experience in realising the investigated use case and those that did not. In total 4 interviewees had this experience, hereafter referred to as group A, while the remaining 11 did not - hereafter referred to as group B.

Interviews with subject matter experts in group A were framed by Thompson, Gamble & Strickland strategies for identifying success factors. For interviewees in group A the context and purpose of the investigation were described in detail in the initial phase of the interview. As motivated in this theory the following sub-questions will be asked to identify key success factors;

- On what basis do buyers choose between services?
- Given the nature of the competitive forces, what capabilities does a firm require to be a competitive success?
- What limitations or shortcomings among services are almost certain to put a firm at a significant competitive disadvantage?

Follow-up questions were asked freely and the answers were recorded and interpreted by the researcher.

Interviews with subject matter experts in group B adopted another approach. Formulation of questions as well as a selection of participants was made in cooperation with a subject matter expert. Questions were evaluated during the progress. Only minor adjustments were made after five interviews as the result was deemed satisfactory. For interviewees in group B the context and purpose were put in the context of data sharing with third parties, as this was what the interviewees had experience in and was thought to provide better discussions. Interviewees in group B was asked the following questions;

- What do you believe are the most urgent challenges/issues that need to be addressed in regards to partnerships with 3rd parties?
- How do you think [you company] might address them?
- Are there less important challenges/issues that should be addressed? Or less urgent challenges or issues?
- What would you say are the three most important learnings in relation to collaborations that entails data sharing? Could be from experiences from inside or outside of [your company]. Specific or general.

- What were some recent challenges or issues in relation to third parties that [your company] have addressed and solved?
- What have been the three greatest challenges in relation to involving [a partner company] in these collaborations? How were these addressed? Who was happy about it?
- Have you thought of or identified any low hanging fruit in regards to third-party actors that should be addressed?
- Is there anything you think I have missed to ask or is there something else you think I should have asked?

4.8 Trustworthiness

This thesis incorporates Guba's (1985) and Guba and Lincoln (1994) (as cited in Bryman & Bell 2011) quality criteria concerning trustworthiness. These criterias consist of; credibility, transferability, dependability and confirmability.

The credibility of the study is primarily limited by the "respondent validation" and triangulation of information assimilation. The former refers to the extent to which research findings are confirmed by subject matter experts and the latter refers to the utilization of a multitude of information sources, such as interviews or academic studies. Respondent validation is limited to three participants who have helped in verifying findings. One of which only regarded the findings concerning regulations. While triangulation was aspired to, the limitation of available time and interviewees put constraints to the extent triangulation was possible. This is very evident in the value chain analysis and regulatory analysis which are lacking data gathered from semi-structured interviews. Another limitation in regards to credibility is the structural validity of the value chain and scenario used for further analysis. While this is motivated in the subchapter Research logic it should be acknowledged as a limitation in regards to credibility.

Transferability can be described as limited in regards to multiple levels, such as: which other kinds of monetisation activities the findings are transferable to; to which actors - such as OEMs vs service providers in the automotive industry, to time - in the sense that findings might not be applicable in 1 year, and in geographical scope. The study aspires to combat these limitations by providing a rich description of the context and how observations and theories are interpreted. The aim of which is to allow for transferability by researchers and practitioners to another context. Due to the volatile environment inherent in a nascent market - the quality criteria of transferability can be questionable from a temporal perspective. While this limitation is acknowledged, the research makes some effort towards mitigating this limitation by adopting a forward-looking perspective. This is for example evident in the regulatory analysis in which regulations not yet enacted are analyzed.

Demonstrating dependability, as referred to by Bryman and Bell (2011), entails the keeping of records and auditing of research by peers. Due to the exploratory and abductive nature of this research, dependability has been disregarded in preference for flexibility and time management. The effort of keeping detailed records of the progress of the research was considered unproportionate to the trustworthiness it might induce, this is further motivated by the lack of motivation to engage peers to audit the enormous data set a detailed record-keeping would produce.

Conformability concerns the objectivity of the researchers. Due to the inherently creative nature of abductive research, the study could be described as displaying low conformability. While the study aspires towards conformability by adopting a prosaic language and awareness of sentiment - the researcher considers this a tradeoff for displaying erudition and utilizing creativity. As such the limitation of conformability is acknowledged but considered motivated.

5 Result & Analysis

The Result & Analysis chapter is divided into four parts; Data Value Chain, Regulatory Analysis, Challenges and Success Factors. Each of these four parts aspires to answer each of the four sub-research questions respectively.

Each part concludes with a discussion on the findings which aims to interpret the result and contribute to the main research question of “How do OEMs best monetize data for road asset maintenance use?”

5.1 Data value chain

A value chain analysis was conducted to better understand how different organisations compete. The information used to conduct the value chain analysis was collected exclusively from secondary sources such as research studies, whitepapers, newspapers and companies websites. The focus of the analysis was to identify variations within the primary activities; the purpose of which is to facilitate understanding of how different actors are, or can be, positioned in the industry.

Since the purpose of the analysis was to study the variations in which companies create value, the order in which these activities occur has not been of great focus. Previous researchers have observed that the order in which value-adding activities occur in a data value chain isn’t necessarily linear (Attard 2016). The constructed value chain should thus not be interpreted as a linear model but rather as activities that have been identified as to be critical in creating value within the industry. The model does however aim to adhere to the order and definitions established in previously established data value chains to allow for further research and benchmarking.

5.1.1 Data access

Despite different namings such as data acquisition, data sourcing, data collection, data generation and data discovery - the first phase often refers to identifying the purpose of the data acquisition and gaining access to said data (Gorkas, 2020). In Gorkas’ (2020) constructed data value chain for carmakers the first phase is called data access which is then subcategorised into data generation and collection. Gorkas' approach to the first phase was deemed to be the most appropriate framework within the context of this thesis since this facilitated the distinction of what sensors are used to generate data and what mechanisms and methods are used to collect data to a centralized data portal.

During this investigation, three different methods for generating data have been observed. These methods are; mapping vehicles, vehicle sensors and dashcams. What method is employed determines what sensor data is available as well as the data quality in terms of granularity and reliability. Data acquisition cost and the data collection method are greatly influenced by the choice of data generation method.

Data Generation	Variations		
Data source	Mapping vehicles	Dashcams	Vehicle sensors

Table 1, Data generation variations

In terms of data collection, five distinctions were made. The first relates to whether or not the operator of the vehicle is employed by an organisation. This distinction is made since it influences to what extent the operator is accountable and responsible for data uploads. In scenarios where individuals are involved, data contributions have been observed to be voluntary and without accountability. When employees are operating the vehicle it is however possible to contractually regulate accountability in terms of both quantity and quality.

The second distinction is between active vs passive collection. Active collection in this context refers to when the route is chosen for the purpose of collecting data while passive collection refers to when it is not. For example, the active collection could refer to a scenario in which a company is contracted to conduct a survey while passive collection could be a logistic company collecting road asset data along logistic routes.

The third distinction relates to how the data aggregator identifies what data to collect, which can be either based on static parameters or on requests. This distinction is based on prior research within crowdsensing which distinguishes between personalized and public crowdsensing (Maheswaran et al., 2018). Public crowdsensing refers to generalized and large-scale monitoring, while personalized sensing refers to data collection focused on a specific user-defined need. Public crowdsensing has been interpreted as fixed acquisition, meaning that the parameters which determine collection are static (Maheswaran et al., 2018). Such parameters could for example be the region in which data is collected or what data is collected, such as road surface data. Personalized sensing on the other hand refers to when data is requested for a contingent and specific user need. In this scenario, the query requesting data is both location and time-specific (Maheswaran et al., 2018). An example could be a road authority requesting imagery of a certain stretch of road.

A fourth distinction is made between edge and cloud computing in relation to preprocessing. Road asset data is acquired by processing road imagery data or other sensor data by use of automated image recognition programs or other analytical software. In this thesis, this process is referred to as preprocessing. The preprocessing could either be done on the device that generated the data, in which case preprocessed data is uploaded to a data portal, i.e edge computing. Or raw data could be transferred to a local or cloud storage and processed there i.e cloud computing.

The fifth distinction relates to how the data is uploaded to the data portal, which can be done either in batches or continues. Continuous data uploads postulate a cellular or some other kind of communication technology that enables continuous connection to a data portal, such as the suggested Dedicated Short-Range Communications (DSRC) technology. The limited bandwidth of these technologies makes uploading data in bathes preferable when data volume is large, as this allows for direct data transmission via cable. The distinction in regards to data transmission is thus closely intertwined with the distinction in regards to preprocessing because edge computing enables greater data minimization and thus continues data transmission.

Data collection	**Variation**	
Operation of vehicle	Organisation	Individual
Route selection	Active	Passive
Data identification	Static parameters	Request based
Uploading of data	Batches	Continues
Preprocessing	Cloud computing	Edge computing

Table 2, data collections variations

5.1.1.1 Mapping vehicles

Data generation
Mapping vehicles refers to vehicles equipped with high precision GPS and specialized sensors. In the context of traffic signs, such specialized sensors could be omnidirectional HD cameras and Lidar scanners. The specialized sensors enable the generation of highly defined data. Specialized lidar sensors can for example provide data on the retro-reflectivity of signs (Soilán et al., 2016). Other road assets such as pavement do however require other specialized sensors such as Laser Road Surface Tester or GMR Profilometers that provide detailed information about the surface of the road (Du et al., 2014). The specialized equipment leads to higher investment costs compared to other data generation methods. But has the benefit of being highly precise and being able to provide data compatible with various standards, such as the IS EN 1436 standard in regards to retro-reflectivity for traffic signs (RetroTek, 2020)(Soilán et al., 2016).

Data collection
Due to the density of the data generated by mapping vehicles, transferring data via a cellular connection or processing the data within the mapping vehicle isn't feasible (Seif & Hu, 2016). Companies utilizing mapping vehicles thus transfer data via direct connection to a local or cloud storage for computing, i.e extracting road features and insights (Cyclomedia, 2021). The transferring of data in batches, as opposed to continuous transfer, makes this method of generating data less beneficial to more urgent maintenance needs such as vandalized traffic signs or oil spills.

The specialized sensors used by mapping vehicles are expensive and often require professionals for the operation of the vehicle. The actors using this method for data generation often own or rent the required equipment and operate the vehicle themselves. A benefit of having a "closed" (internal as opposed to crowdsourced) data collection is increased reliability in terms of what roads are being mapped. The drawback is a higher cost in the collection of data compared to other data generation methods that allow for crowdsourcing of data. The higher cost results in limited frequency and coverage for road authorities mapping efforts.

5.1.1.2 Dashcams

Data generation

Dashcams is a more recent method of collecting data on road assets compared to mapping vehicles. In the context of this thesis, dashcams can be smartphones, consumer-grade omnidirectional cameras or any other consumer-grade recording devices equipped with a GPS - such as GoPro - that could be mounted on the dashboard of a vehicle.

In the context of traffic sign data, the quality depends on both the specifications of the recording devices and the operator of the camera. In terms of device characteristics, factors such as resolution and frame rate are of importance (Yoong, 2017). In relation to the operator of the camera quality factors include the mounting or positions of the camera since this affects the camera angle, and the speed of the vehicle since this affects how many images are collected for a given length of road.

In the context of pavement distress data from a smartphone camera, gyroscope and accelerometer sensor have been used by previous researchers. While this method has - in some cases - been able to indicate pavement distress to some extent the method poses several challenges and is as of yet not reliable enough for large scale implementation (Sattar et al., 2018)(Exner et al., 2020).

The data generated from dashcams are lower quality compared to data generated from mapping vehicles or vehicle sensors. in the context of traffic signs, the lower GPS precision and image resolution is however often good enough for recognising assets such as signs and determining their coordinates with a tolerance of meters, which is often good enough for maintenance purposes. (ESRI, 2017) (Arnesdotter, 2018)

Data collection

Companies relying on this form of data generation have been observed to utilize a crowdsourcing approach to data collection. Meaning the dashcam is owned and operated by an external actor such as individuals, partner companies or the end-user themselves.

What data is collected varies. In most cases - as with Mapillary and Transconomy - raw data in the form of georeferenced video is uploaded to a data portal then processed. In some cases, as with Univrses, data is processed within the recording device - in their case a smartphone, and georeferenced insights are uploaded via the cellular network. (Mapillary, 2020) (Transconomy, 2021) (Univrses, 2021)

Crowdsourcing road asset data can greatly decrease the cost of gaining access to data as the data collection is handled by external actors. The reliance on external actors can however create challenges in fulfilling the data users need for timeliness and coverage. Connecting the right data contributors to data users is thus a focal point for companies using the crowdsourcing approach.

5.1.1.3 Vehicle sensors

Data generation

Vehicle sensor data refers to data being generated by onboard vehicle sensors from modern automobiles. Using vehicle sensors data for road asset maintenance is the most recent and more novel compared to the above-mentioned methods of generating data.

Modern automobiles are often equipped with a wide range of sensors - including cameras, lidar, wheel pressure sensors, accelerometers and high precision GPS - this enables the vehicle to generate detailed data on road assets such as pavement and traffic signs (HERE Technologies, 2018).

The sensors might not provide as precise data when compared to data generated by specialized sensors on mapping vehicles but they have the benefit of having a lower investment cost. Vehicle sensors are for example very well adapted to identify traffic signs, but it's still highly uncertain if the lidar onboard consumer vehicles will be able to measure retroreflectivity in a reliable manner (Ai, 2013). In regards to measuring pavement distress precise enough to be compatible with standards such as IRI (international roughness index), there are companies claiming this functionality such as Nira (Nira Dynamics, 2021) as well as companies suggesting its feasibility in proof of concept projects (HERE Technologies, 2018).

Data collection

Due to the advanced image recognition capabilities and communication systems within the vehicle, it's possible to either process data within the vehicle and upload georeferenced insights via cellular, ITS infrastructure or store raw data and upload data in batches through wifi/ethernet as is the case when making highly defined 3D maps using vehicle sensors (Nvidia, 2021).

The vehicle can be operated by a wide range of actors, from partners such as ride-sharing companies - to individuals owning the vehicle - to manufacturers of vehicles themselves. The former two can be defined as crowdsourcing. While latter is a closed model and often is the case in research and development projects.

5.1.2 Data curation

Data curation has been referred to as "*the active management of data over its life cycle to ensure it meets the necessary data quality requirements for its effective usage*" (Curry 2016, as cited in Gorka 2019). In Currys (2016) definition data curation includes activities such as content validation, transformation, selection and preservation. The purpose of which is to make the data accessible, reusable, trustworthy, compliant and discoverable. In Gorka's definition, the data curation is subcategorised into data storage and structure and includes activities that aim to make the data interoperable and easily assessed. Within the context of this thesis, data curation is primarily discussed in terms of cleaning and interoperability.

Examples of cleaning activities are anonymization, deduplicating and removing data of unsatisfactory quality in terms of reliability or timeliness. Interoperability refers to activities promoting reuse or accessibility, such as making data interoperable with third parties.

5.1.2.1 Data cleaning

To what degree companies engage in cleaning activities varies greatly depending on what method is used to access said data. Companies using mapping vehicles for example have professional drivers operating the vehicle for the specific purpose of gathering data. This means that the need for deduplication, anonymization and quality assurance activities are greatly decreased compared to other options.

Dashcams on the other hand are primarily used in crowdsourcing models which means that large amounts of duplicate data of varying quality and sources is provided. Quality assurance can thus present a great challenge. Mapillary has for example approached this problem by constructing an AI which estimates image quality (Ertler & Quack, 2020). Anonymization is also more burdensome compared to mapping vehicles. Anonymization efforts such as blurring of faces become costlier as the volume of data increases. In models where individuals contribute their privacy must be handled as well, this can be done by either anonymization or pseudonymization (Alkharashi & Renaud, 2018).

Data from vehicle sensors also have the benefit of crowdsourcing but in contrast to crowdsourced data from dashcams, the data format and resolution is relatively consistent. Another important aspect is the passive gathering of data. In contrast to dashcams which often rely on voluntary and active contributions of data - vehicle sensor data can be gathered passively. This enables for a much greater volume of data to be collected. The computing and communication technologies within the vehicle enable for deduplication of data to be handled in a number of different ways. One of the identified ways used in industry has been to exclusively upload anomalies, such as when a traffic sign has not been identified a number of times (Mobileye, n.d). While another is to only gather data from a limited set of vehicles (HERE Technologies, 2018). While gathering data without the active involvement of the operator enables monitoring of larger-scale it does present more legal challenges, these are discussed more in the regulatory chapter of the thesis.

Data cleaning	**Variations**			
Anonymization	Blurring in images	Anonymize contributors	Pseudonymize contributors	
Deduplication	No deduplication (store all)	Collect no duplicates (active route choosing)	Only anomalies	Limited set of vehicles

Table 3, data cleaning variations

5.1.2.2 Data interoperability

Data interoperability refers to "*the functionality of information systems to exchange data*" (EUROPEAN DATA PROTECTION SUPERVISOR, 2020), the purpose of which is to increase data accessibility, reusability and discoverability. This thesis has investigated interoperability on a macro level, meaning that it has been investigated in regards to whose system the data has been made interoperable with. Which file formats, communication protocols or standards have been used was for example not investigated.

In regards to road asset data, three categories of data interoperability have been observed. The first category is interoperability with enterprise Geographical information systems (GIS) which refers to making data interoperable with systems designed to structure and represent geospatial data (Rao, 2017). Second is enterprise data marketplaces which refer to intermediaries that facilitate data transactions, such as Otonomo or Inrix. The third is National Access Points (NAPs) and governmental data platforms which refers to making data interoperability within private to public collaborations, such as Data Task Force project in regards to Road Safety Data (Datex2., 2020).

Road asset data needs to be georeferenced and is thus often combined and structured in Geographical Information Systems (GIS). GIS is used at many different levels in governments to support decision making relating to urban development (Saladin et al., 2002) (Basegmez, 2020). McPherson and Bennett (2006) research conclude compatibility with common GIS is a requirement for effective road asset management systems. Indeed most companies that have as a core business activity to monetize road asset data for maintenance have been observed to advertise compatibility with common GIS. The most common GIS is ArcGIS which is developed by ESRI. ESRI is estimated to have a global market share of over 40% (Howell, 2019). Another popular GIS is the open-source project QGis and automotive consortium owned Here's GIS. Besides offering the geospatial structure of data these GIS sometimes offer marketplaces and analytical tools (HERE, n.d) (ESRI, n.d).

Another way of promoting reuse and discoverability is by making the data interoperable with marketplaces like Otonom or Inrix. Although data marketplaces exist for other data types than that vehicle sensor data, in the context of road asset data only vehicle sensor data have been observed to be accessible on data marketplaces. In most cases, the burden of transforming and formatting data is put on the marketplace owner, while in some cases the data provider is responsible (Bergman, 2020). The burden of quality assurance and data storage are also shared with the data marketplace owner in some cases (Bergman, 2020).

The third category of data interoperability is related to data platforms within the public sector. The identified efforts within this context have been in relation to data generated by mapping vehicles (Luiten et al., 2018) and vehicle sensors (KPMG, 2020). An example of interoperability within data from vehicle sensor data is NAP which are platforms designed on a national level in Europe to gather, assess and use data from the automotive sector. The Interlink project is in contrast on a European level and aims to harmonize data structure and formatting within road authorities, such data likely include data gathered by mapping vehicles (Luiten et al., 2018). Another example of a European effort in relation to vehicle data and mapping sensor data is the TN-ITS project which is an effort to produce maps within the context of an intelligent traffic system. This effort involves several road authorities as well as both map producers with mapping vehicle fleets and OEMs which have access to vehicle sensor data (T'Siobbel, 2018).

Data interoperability	**Variations**		
System orientation	GIS	Marketplaces	Public

Table 4, data interoperability variations

5.1.3 Data analytics

Data analytics have been observed to refer to pre-processing of data, as in Currys (2016) interpretation, or to postprocessing as in Gorkas (2019) study. This thesis has chosen the latter interpretation to enable investigation of additional value-adding activities.

The majority of data analytics have been observed to be performed on either a descriptive or predictive level as defined in the Napoleons' article (Napoleon, 2020) (Gorka 2019). Descriptive analytics aims to describe the current or historical state of events while predictive analysis aims to explain what is probable to happen in the future. Analytics in the context of road assets has been observed to be either oriented to solving problems within urban planning for decreasing traffic congestion or increased safety - or within road asset maintenance for condition-based repairs, predictive maintenance, annual budget forecasting and budget allocation optimisation.

5.1.3.1 Descriptive analytics

Within descriptive analytics, two distinctly different modes of analytics have been observed. First, is analytics, called herein as road asset inventory, which aims to describe road assets in terms of location and semantic meaning. The semantic meaning being what road rules apply where and to which roads. This kind of analytics is suitable for activities relating to urban planning. The second mode of descriptive analytics is analytics that aims to facilitate maintenance with descriptions of where assets are, how many there are within certain zones and what condition they are in.

An example of a company performing the first kind of analytics is Inrix analytical software which provides information on what road rules apply where illustrated in a geographical information system. This information is used by municipalities for urban planning as well as promoting mobility innovation or research.

An example of a company performing the second mode of analytics is Mapillary analytical software which describes where road signs are located, what sign it is and provides snapshots of those signs so that practitioners can assess the condition of the sign off-site. Another example of descriptive analysis for optimising road asset maintenance is Mobileyes service. In contrast to Mapillary service, Mobileyes service is limited to a reactive maintenance strategy, meaning that they detect failures after they have happened. Mapillary on the other hand does enable preventative maintenance strategy as images provide information on the level of deterioration of assets.

5.1.3.2 Predictive analytics

Examples of predictive analytics in the context of road assets are budget forecasting or budget allocation optimisation and predictive maintenance. A recent example of a project using traffic sign data for annual budgeting forecasting and budget allocation optimisation was a project driven by a consultancy firm called Kimley-Horn which used image processing software from Transconomy. The analytics were made possible by the creation of a baseline inventory of signs, including a conditioned assessment and geotagged imagery. Kimley Horn stated in an article that the project was successful and resulted in short and long-term maintenance and capital improvement plans (Keegan et al., 2021).

Predictive maintenance based on deterioration models and historical maintenance is a research field that has grown in both interest and importance in recent years. Predictive maintenance is often discussed in relation to the pavement and seldom in relation to other assets such as traffic signs and curbs. The major benefit of predictive maintenance is that it is preemptive, this increases the safety and performance of roads by mitigating the risk of having faulty assets until a failure is detected. It furthermore enables long-term planning and data for greater optimisation of budget allocation (Karimzadeh & Shoghli, 2020). These sorts of analytical activities often fall within the domain of Road Management Systems (RMS) such as Cyient (Bhandari, 2018).

Data analytics	**Variations**		
Descriptive analytics	Reactive maintenance	Road asset inventory	Urban planning
Predictive analytics	Predictive maintenance	Budget forecasting	Budget optimisation

Table 5, data analytics variations

5.1.4 Data implementation

Although researchers use different wording such as “apply” (Gorka 2019), “data usage” (Curry 2016, as cited by Gorka 2019) or “make a decision” (Miller & Mork 2013, as cited by Gorka 2019) the semantic meaning is often the same and refers to the data being used to make a decision. In the context of road asset data for maintenance use, the road authority is assumed to be the actor making a data-driven decision. Since the investigation aims to understand variations in how *organisations* add value within this context the investigation has focused on how the data-driven service is implemented.

In regards to how data is implemented three aspects have been identified to vary; scale funding and ownership. The scale on which data-driven services are implemented has been observed to occur either on an international level (Data Task Force, 2020), national (Asp et al., 2020) or regional (DriveSweden, 2020). While a larger business area enables for economies of scale to be achieved it also increases complexity as it entails engaging more stakeholders and handling larger volumes of data.

How the mapping effort was funded varied between public procurement contracts, research or innovation grants and “bartering”. Public procurement contracts refer to open procedures (anyone can submit tender) and restricted procedures (only selected can submit tender). This method of funding was found to be used both in regards to national and regional efforts, such as Nira Dynamics in Sweden (Asp et al., 2021) or Cyclomedia in Utrecht (TED Europe, 2019). Research or innovation grants refers to when the mapping effort is funded by the public sector through innovation partnerships or research grants. Grants have been observed to fund both international efforts, such as in the case of Crowd4Roads in Europe (CORDIS, 2019), and in regional efforts such as with Univrses in Stockholm (DriveSweden, 2020). “Barter” for lack of a better word refers to cases in which organisations share data or analytical capabilities for gain other than monetary payment. Examples of this is the Data For Road Safety (Data task force, 2020) or Mapillary which offers data for free (Mapillary website). In both of these examples, the data contributors gain access to data rather than monetary payment.

A third distinction is made concerning licensing design which can be divided into two categories unrestricted license and restricted license. A third theoretical category could be exclusive ownership, meaning that the organisation providing the data doesn’t have any rights to reuse data for internal use or redistribute data to other actors. Exclusive ownership in public-private licensing was not however observed to occur in practice. The unrestricted license refers to when the data user is given unrestricted right to process and redistribute data. Such licensing was commonly found in cases where mapping companies such as Cyclomedia were hired to survey areas. Restricted licensing was found mostly in relation to crowdsourcing efforts by the use of dashcams or vehicle sensors. Examples of such licensing is Mapillary licensing which is shared under a ShareAlike contract (Mapillary, 2021) or Nira’s license with the Swedish road authority which hindered the redistribution of data to private actors (Asp et al., 2021).

The most relevant variations within data implantation were identified as activities relating to coordination of data integration with road authorities and pricing. Responsibility of coordinating data integration has been observed to be on either a designated organisation, the road authorities (which could be at a national, regional or local level) or a mixture in the form of B2G collaborations models. Pricing mechanisms refers to how the solutions have been paid for by the road authority and have been observed to happen through public procurement, research funding or for free(freemium models).

Data implementation	**Variations**		
Scale	International	National	Regional
Funding method	Public procurement	Innovation grant	“Barter”
Licensing	Unrestricted	Restricted	

Table 6, data implementations variations

5.1.5 Value chain overview

Data access				
Data Generation	Data source	Mapping vehicles	Dashcams	Vehicle sensors
Data collection	Operation of vehicle	Organisation	Individual	
	Route selection	Active	Passive	
	Data identification	Static parameters	Request based	
	Uploading of data	Batches	Continues	
	Preprocessing	Cloud computing	Edge computing	
Data curation				
Data cleaning	Anonymization	Blurring in images	Anonymize contributors	Pseudonymize contributors
	Deduplication	No deduplication	Only anomalies	Limited set of vehicles
Data interoperability	System orientation	GIS	Marketplaces	Public
Data analytics				
Descriptive analytics		Reactive maintenance	Road asset inventory	Urban planning
Predictive analytics		Predictive maintenance	Budget forecasting	Budget optimisation
Data implementation				
Scale		International	National	Regional
Funding method		Public procurement	Innovation grant	“Barter”
Licensing		Unrestricted	Restricted	

Table 7, data value chain overview

5.1.6 Business models

The constructed artefact regarding variations in primary activities was utilized in the assessment of three companies, Cyclomedia, Here and Mapillary. The assessment aims to shed some light on how various companies operate, as such the companies chosen were so because they could be said to represent three major categories of companies monetizing data for road maintenance use.

First, the analysis of the separate companies is presented. Then the constructed data value chain artefact is utilized to illustrate the business model configurations. This is followed by an analysis comparing the models using the value chain as the model for investigation.

5.1.6.1 Cyclomedia

Cyclomedia can be described as a “mapping-as-a-service” company. They map road assets and produce street view images on demand. Their primary consumers are municipalities and road authorities within Europe and the US. The targeted use case is tax assessment, asset management, urban planning, utilities (network planning and asset management) and safety & security (Wegen, 2017).

Cyclomedia operates its own fleet and is estimated to have a fleet size of around 44 cars. These cars are operated by professional drivers and are equipped with omnidirectional cameras which capture images every 5 meters, lidar sensors enabling representation of objects in 3D and highly accurate GPS that enables positioning of objects with a tolerance of centimetres. The data captured is of high density and uploaded in batches via cable to a data portal where it’s processed.

Since the vehicle is operated by the organisation the only anonymization required is in regards to blurring faces and license plates in images. No major deduplication effort is thought to be required since what routes the mapping vehicles record is actively chosen by the professional driver. Cyclomedia offers its own user interface to visualise and manipulate data but it is also made interoperable with Arcgis.

The analytical service offered by Cyclomedia is exclusively on a descriptive basis. The primary analytical capabilities related to road asset inventorying, meaning image recognition software capable of identifying various assets and describing where they are. In terms of reactive maintenance analytics, the organisation performs condition assessment in regards to poles and vegetation and change detection in places where historical data exists. While Cyclomedia doesn’t possess the software to perform condition assessment of other assets such as pavement they do have partnerships that enable this sort of analytics (Cyclomedia, n.d) (EIJ Journal, 2017). In an interview with Cyclomedias CEO it was made clear that Cyclomedia considered itself a data company and not a software company and as such prefered to acquire data analytics capabilities from partnerships rather than from in-house development (Wegen, 2017).

Cyclomedias services have been almost exclusively observed to be procured on a regional level through public procurement (OpenTender, n.d). In the public procurement contracts analyzed Cyclomedia have given unrestricted rights to some municipalities (AGREEMENT

FOR LIDAR AND IMAGERY SERVICES, 2017) (Professional service agreement, 2019) and restricted rights to others (LAR-IAC5, 2015) (IT Federal Sales, n.d). In these contracts, Cyclomedia has used a similar pricing scheme which is based on distance mapped, what features are extracted and what additional service such as support or user interface is procured.

While municipalities and road authorities are Cyclomedia's primary consumers they have been observed to map for companies. This could be in the context as a subcontractor to another company or in the context of HD maps for the automotive sector (Geoforum, 2012) (Wegen, 2017).

5.1.6.2 HERE

HERE can be described as a "map-as-a-service" company and is considered one of the leading location platforms. They provide a wide range of location services such as traffic information, route optimisation, geocoding, point of interests and enable enterprises to integrate these services into their own applications. HERE gathers data from a wide range of sources such as probe data from smartphones, on-board vehicle sensors (through partnerships), satellites, aerial images and their own mapping vehicle fleet. HERE was estimated to have a mapping vehicle fleet of around 400 cars in 2016 (Seif & Hu, 2016). The driving force behind the acquisition of such a large fleet might be the large demand for HD maps from the automotive sector. The automotive sector is a key market for location platforms such as HERE and TomTom. And HERE is in a rather unique position in this landscape as it is owned by a consortium of OEMs. (Patel, 2019)

Concerning road asset data for maintenance use, HERE launched a product called Road Roughness. While it was developed using mapping vehicles the intent is to use vehicle sensors to expand and keep the map up to date (HERE Technologies, 2018). For the purpose of road surface measuring HERE receives data from multiple OEMs which collects data from vehicles used by individuals. HERE could receive sensor data from marketplaces such as AutoMat and be extensively involved in the development of algorithms used to estimate road surface condition or receive data from service providers such as Nira or Tactile Mobility which themselves develop these algorithms and sources data from multiple OEMs (Nira Dynamics, 2021) (Rajan, 2020). Since the vehicles are operated by individuals and data is gathered passively the routes that are mapped are not actively chosen but rather a result of which vehicles they chose to collect data from and the driving habits of the individuals. In regards to what data was collected a set of static parameters was used, as referred to in the "Data Access" chapter. In the AutoMat project preprocessing occurred after the data was received at HERE's data portal. It is however interpreted the reason for this was underdeveloped algorithms and that the intent is to preprocess the data within the car in the future, as in the case of Nira Dynamic. This enables for less data to be uploaded, V2V communication, anomalies detection and real-time warnings for the driver. In both the AutoMat and Nira case data is uploaded continuously, as referred to in the "Data Access" chapter (Automat, 2017).

Since no images are collected and the data is uploaded by individuals, anonymization activities are relevant only in regards to protecting the privacy of those individuals operating the vehicles. What exact anonymization or pseudonymization technique was adopted was not identified. In the AutoMat case deduplication was handled by limiting data collection to a limited set of vehicles. No information was found in regards to how deduplication was handled on larger scales, such as in the case of Nira Dynamics and Tactile Mobility. In regards to interoperability, it can be said that HERE reference road references towards the International Roughness Index (IRI) and offers visualisation, analytics and data manipulation through its own user interface. In interviews with Nira Dynamics and Tactile Mobility, HERE's marketplace and third-party developer environment is portrayed as the primary reasons for these service providers joining HERE's platform (Nira, 2021) (Tactile Mobility, 2020).

Analytics was observed mostly on a descriptive basis, HERE offer visualisation of road conditions in their own UI. It does however offer route optimisation for the transportation sector which considers road conditions effect on fuel economy and vehicle wear (HERE, 2017). HERE strategy has by other researchers been identified as to aggressively promote a third-party developer environment and outsourcing the development of such analytics (Patel, 2019).

There has not been any identified case in which HERE's product Road Roughness is implemented for the purpose of road maintenance. In regards to the mentioned service providers Nira and Tactile Mobility these are procured on a national scale (Leichman, 2021) (Asp et al., 2021). In regards to funding, Nira was observed to have used innovation grants for running pilot projects which was used to develop specifications for public procurement documents used in later stages (Asp et al., 2021). The license agreement in Nira's case restricted reuse of data to specified purposes (Asp et al., 2021).

5.1.6.3 Mapillary

Mapillary is a platform for sharing and analyzing crowdsourced geotagged photos. Contributors can't upload photos captured from smartphones, cameras, dashcam and even panoramas recorders (Solem, 2014). The platform enables users to post mapping requests with specific quality specifications as well as annotation or verification requests. Users can however upload data independently of requests, and as such both individuals, organisations and municipalities upload data to the platform, either for their own use, for altruistic reasons or to fulfil requests by other users. The platform thus enables both organisations and individuals to operate the vehicle and both active and passive route identification. Mapillary platform aggregates photo data and as such data is uploaded in batches and isn't processed until it's transferred into their cloud storage.

After data have been uploaded it's curated by blurring faces and license plates (Solem, 2020). The privacy of contributors isn't however automatically anonymized, users can choose whether or not to use their real name and when what recordings to upload. Deduplication isn't either handled in any way, frequently travelled roads could thus be mapped several times. The platform is interoperable with common commercial GIS such as ArcGIS and HERE as well as with nonprofit organisation OpenStreetMap (Mapillary, n.d).

Data analytics capabilities are limited to a descriptive level. Mapillarys traffic sign recognition algorithms and collection of images makes the data very suitable for reactive maintenance purposes and road asset inventory analysis, as their numerous "success cases" illustrates

(Mapillary, n.d). What features Mapillarie's platform is able to recognize is largely dependent on the needs of the community, as it is the community that does the majority of the annotations (Mapillary, 2016).
Mapillary started off by charging municipalities for the use of their image recognition and platform system, since then it has however transitioned into offering it service free of charge for non-commercial use in which case it's licensed under a ShareAlike license (MapillaryI(L), 2021). Mapillary primary consumers could thus be considered other businesses, such as companies developing autonomous vehicles (Mapillary, n.d). The large repository of annotated images is of significant value to the automotive sector (Leon & Quinn, 2018).

5.1.6.4 Comparative value chain overview

Illustrations		Cyclomedia - C	HERE - here	Mapillary -
Data access				
Data Generation	Data source	Mapping vehicles C	Dashcams	Vehicle sensors here
Data collection	Operation of vehicle	Organisation C	Individual here	
	Route selection	Active C	Passive here	
	Data identification	Static parameters C here	Request based	
	Uploading of data	Batches C	Continues here	
	Preprocessing	Cloud computing C	Edge computing here	
Data curation				
Data cleaning	Anonymization	Blurring in images C	Anonymize contributors here	Pseudonymize contributors
	Deduplication	No deduplication C	Only anomalies here	Limited set of vehicles here
Data interoperability	System orientation	GIS C here	Marketplaces here	Public here
Data analytics				
Descriptive analytics		Reactive maintenance C here	Road asset inventory C	Urban planning C
Predictive analytics		Predictive maintenance	Budget forecasting	Budget optimisation
Data implementation				
Scale		International here	National here	Regional C
Funding method		Public procurement C	Innovation grant here	“Barter”
Licensing		Unrestricted C	Restricted C here	

Table 8, applied data value chain comparison overview

5.1.6.5 Comparison

The investigation into the three companies Cyclomedia, HERE and Mapillary elucidates in what areas said actors are involved and what activities they invest effort into. In order to gain access to data Cyclomedia invests in a mapping vehicle fleet, while Mapillary relies heavily on voluntary contribution and must thus invest into mechanisms to ensure user engagement. HERE on the other hand relies on partners such as Nira Dynamics and Tactile Mobility which offers software service to OEMs and extracts data from OEMs data portals. HERE must thus invest in the resources and capabilities that attract such partners, for example, an active third-party developer community and customer distribution channels.

The variety of data extracted reflects the method in which it was collected. Cyclomedia collected the widest range with raw data from lidar sensors and panorama image recorder as well as insights extracted from sensor data. Mapillary on the other hand gathers geotagged images as well as insights, while HERE collect only insights - at least within the context of vehicle sensor data.

The approach to preprocessing (as defined in “Data Access” chapter) is also distinctly different in the three models. Cyclomedia have developed image recognition software for public sector use for over thirty years and as such have a rather unique and specialized software for just this purpose. In developing new features such as pavement condition assessment the investigation indicates that the primary strategy is to acquire such features through partnerships. HERE on the other hand relies exclusively on partnerships (for large scale implementation). For Mapillary preprocessing could be seen as a core activity. The algorithms are developed using annotated images, the majority of which has been provided for free by their user community (Mapillary(a), 2016). As such what algorithms are developed and what features are annotated is heavily influenced by the needs of the community.

In regards to further analytics, it can be said that most analytics are done on a descriptive basis. Cyclomedia could be considered offering the most suitable data for road urban planning purposes, while Mapillary could be considered more suitable for traffic sign inventory and HERE in reactive maintenance in regards to pavement. It should also be noted that the software development strategy differs significantly.

In relation to market maturity, the investigation indicates that Cyclomedia operates in the most mature market (mapping vehicle data) as this company was observed to have operated for the longest period of time, had the most competitors and had the most historical cases identified during the investigation. Mapillary could in a similar reasoning be considered operating in the second most mature market (dashcam/smartphone data). While HERE could be considered to operate in a very nascent and exploring market (vehicle sensor data) as the product Road Roughness is very recent, no cases in which its product was implemented was observed and very few cases in which its partners (Nira Dynamics & Tactile Mobility) products was implemented. The following tables illustrate the companies (Cyclomedia, HERE and Mapillary) variations in the value chain and the strengths and weaknesses as perceived by the researcher.

Cyclomedia	
Strengths ● High data quality and variety ● Image recognition software tailored for public sector use ● Coverage and quality assurance ● Have operated for a long time - established processes, refined algorithms for public sector use and repository of historical data ● Historical data enables “change detection” features ● Much experience from working with road authorities and municipalities → established customer channels and extensive knowledge of municipalities internal processes ● Unrestricted licensing contracts enable further reuse and redistribution	Weaknesses ● The high cost of mapping severely limits frequency and coverage afforded by customers ● High data volumes - HD panorama images & Lidar ● Data quality is “over-dimensioned” ● Lack of internal capabilities to automatized road asset condition assessments ● A one-sided approach to data monetisation contributes to higher mapping costs ● New generation of consumer-grade vehicle sensors might make specialised sensors obsolete
HERE	
Strengths ● Extensive third-party developer community ● No effort on the side of the individual operating vehicle and more potential vehicles to source data from ● A multi-sided approach to data monetisation contributes to increased incentive and potentially lower end-price ● international coverage allows for economics of scale and efforts on a European level ● Unprecedented map freshness and coverage ● Cost-effective and high-quality sensor ● Highly mature algorithm - high level of effort is put on developing image recognition and road surface monitoring by technologically mature companies ● The data providers, such as Volvo or Nira Dynamics, are also data consumers - enables bartering and business model innovation which might lower end price for public sector	Weaknesses ● Restrictive licensing agreements, data might have strategic and commercial value decreasing incentive to allow reuse/redistribution ● Underdeveloped market, new and novel product with unclear value proposition in a industry resistant towards innovation ● Products primarily developed for ADAS purposes - not tailored towards road asset maintenance, and public sector not prioritised as a customer ● Roads that are less travelled will be less frequently mapped - independent of demand
Mapillary	
Strengths ● A large community of users providing “free labour” in regards to mapping and	Weakness ● Relies on voluntary contributions and requires active participation by data

annotations ● A large repository of annotated images makes for powerful image recognition software ● Both restrictive and unrestrictive licensing contracts are available (paid vs free version) ● Market ready and proven solution ● Enables for the user to upload images or request for specific roads to be mapped or specific objects to be annotated/identified ● Although it's a recent company (2013) they store historical data which enables manual change detection	contributors ● Mixed data quality, both in terms of camera quality and operator experience ● Lack of capabilities to automatize road asset condition assessments, pavement condition estimation from smartphones are unreliable ● Lack of support and quality assurance

Table 9, subjective interpretation of strengths and weaknesses in three companies

5.1.7 Conclusions & discussion

This chapter aims to discuss some of the key learnings from the value chain analysis. These learnings are centred around three themes; data suitability, partnerships and strategy.

The findings are interpreted to indicate that the most suitable use case for vehicle sensor data within road maintenance is within reactive maintenance and road roughness estimations. The reasoning behind this is the following;

- Vehicle sensor data is suitable for the task - high reliability can be achieved
- Pavement might be the most important road asset
  - Pavement needs more frequent maintenance than other assets such as traffic signs - which usually needs replacement every 15 years.
  - Bad roads pose a safety risk and increase fuel consumption
- Greater coverage compared to other solutions gives an advantage
  - The increased coverage enables benchmarking between regions or comparative analysis of rural vs more highly traffic roads.
- Greater timeliness/frequency compared to incumbent solutions gives an advantage in regards to reactive maintenance
  - Slipper roads can pose a great safety risk - timeliness is important
  - Frequency is also important in the sense that conditions change during the year. Data on when roads become slippery from ice and leaves could provide very useful insights.
- Can be used for a variety of purposes
  - Data can be sold to other actors such as logistic companies
  - Can be used to develop internal software applications functionality, such as recommending drivers to tear and fuel optimised routes or warn drivers of hazardous road condition

While vehicle sensors might be more suitable than other means of data collection for some of the other discussed purposes, such as traffic signs inventorying, vegetation estimation or constructing digital twins of cities - road roughness is believed to pose the more lucrative option. Both since the asset is worth more and receives more attention than other assets, but also because timeliness and coverage have increased importance - which is a major upside to vehicle sensors' value proposition in road maintenance.

It further plays to vehicle sensors limitations - restrictive license contracts and limited data transmission. Road roughness estimation doesn't have to be used by a variety of stakeholders to provide great value. Other kinds of road asset data such as traffic signs, fire hydrants and curbs might be beneficial both for reactive maintenance, budget planning and urban planning. A restrictive licensing agreement might thus matter more for these areas than that of road roughness. To judge the condition of other assets such as traffic signs a visual inspection is required, thus an image. This would entail more data to be uploaded compared to a number indicating the roughness of the road.

In regards to partnerships, it has been observed that incumbent firms often have partnerships with ArcGIS. As the market-leading enterprise GIS ArcGIS is expected to be utilized by many public sector bodies and as such interoperability with ArcGIS might provide many benefits, such as availability of third-party data analysis software and easier data integration.

The service providers monetizing vehicle generated road surface data have been observed to form partnerships with HERE. While this might be due to HERE's strategic position as an OEM consortium owned entity, its position within the AD industry and its already existing data set on road roughness - it might also factor in the scale in which the solution is implemented. Interoperability with ArcGIS might have been more crucial in a market where solutions are implemented regionally. But as Nira and Tactile have demonstrated these solutions can and have been implemented on a national scale.

In the case of Digital Winter it was stated that the road authority created their own interface in order to facilitate inviting more actors to provide data in the future. Following this strategy and becoming a data provider after the infrastructure has been set might lessen the need to partner with GIS providers and the dependency on these. This can be compared with Mobileye's approach, which has been to partner with - and offers their maintenance related service through - ArcGIS.

Mobileye's services offer a wider range of analytics, such as road asset surveys and change detection. Their services are thus more comparable to existing solutions using mapping vehicles relative to previously mentioned service providers. It should also be noted that in the one observed implementation of Mobileye maintenance service it was deployed on a regional basis which then expanded (Mobileye, 2020).

Mobileyes collaboration with ArcGIS in this context might facilitate the integration of their services into customers' workflow. To what extent this approach creates dependency on proprietary solutions co-owned - or solely owned - by Mobileye might depend on customers current solutions and Mobileyes approach. But it could be speculated that this approach gives greater bargaining power to the data supplier or GIS provider compared to the approach adopted in Digital Winter.

OEMs might be better positioned than service providers, such as Nira, to create more holistic solutions for road maintenance purposes, but the effort and investment required for such an endeavour can be extensive. While it remains unexplored to what extent Mobileye's maintenance service is open for collaboration - it could be speculated that their incentive to invite other actors is low. Both because it entails sharing of profits but also since it might entail challenges in ensuring reliability. Encouraging and supporting efforts made by public sector bodies might thus provide OEMs with a more feasible and low-cost solution.

5.2 Regulatory analysis

The regulatory analysis chapter starts by describing the scenario in which the investigation is made. The chapter is then divided into subchapters based on this scenario. The subchapter starts with describing what regulations were considered, and if applicable, their scope. This is followed by an analysis in terms of opportunities and risk. The implications of which are summarised at the end of each subchapter. The regulatory analysis chapter concludes with a summary and discussion of the findings.

Some of the delimitations made in this chapter should be emphasized. For example, other data generation methods such as mapping vehicles and dashcams are not considered during the regulatory analysis. The regulatory analysis is further limited to European regulations. The limitation is made to simplify the investigation and allow for further depth rather than breadth. One could however argue that Europe could be considered more stringent and the exclusion of other regulations might thus be partly justified by the Brussel effect. Meaning that the effect in which the more stringent regulation in vital markets gains global effects. The regulations that were considered relevant were analyzed in terms of opportunities and risks as from the perspective of the OEM.

5.2.1 Scenario

To identify the key regulation a scenario in the form of a transaction chain was constructed. The motivation of which came from - and was constructed in collaboration with - a legal subject matter expert within the automotive industry. The transaction chain assumes the use of a third-party for the delivery of data-driven maintenance service. This is justified both in the transferability of the scenario to a scenario excluding the use of third parties but also by the observations made in the previous chapter. The connected transaction chain was used to identify, categorise and analyze the implications of regulations.

The transaction chain used for regulatory analysis was developed based on observings within the industry and interviews with subject matter experts. The value chain was constructed in the context of an OEM monetizing traffic sign data for the purpose of maintenance. The scenario was used as a starting point to identify and categorise regulations.

The first phase in the value chain is georeferenced image data being generated from vehicle camera sensors. The data is then processed in the car into insights. In the context of traffic signs, the insights could be where traffic signs are located, what type of sign it is and when it was detected. It could also mean providing a condition assessment of the traffic sign or providing a snapshot of the traffic sign. Owners of vehicles in this scenario are external parties such as for example individuals, ride-sharing companies or taxi companies.

In the second phase, the insights generated from vehicles are transferred to a data portal accessible by an OEM. The insights are then anonymized, which could mean removing metadata describing which vehicle generated the data or blurring faces or number plates in snapshots. The insights can then be sold for cash or bartered for data/insights/services for use by third parties.

The OEMs could then utilize third parties capabilities to deliver these insights to road authorities or municipalities. Third parties could add value by for example;

- providing a distribution network to reach customers and/or run pilot projects demonstrating the value of the data.
- Providing analytic services such as illustrating which road rules apply where, gathering historical data could help spot changes such as signs disappearing, image data could be used for condition assessment
- Aggregate data from multiple sources such as road accident data with speed limits or road direction with traffic flow data
- Constructing easy to use user interfaces, or adapt products to fit into customers internal processes

The municipalities or road authorities that receive the service from third parties have the primary goal to increase public benefit. They may make data publicly available free of charge or restrict availability to internal use. Rights to redistribution and reuse of data are most often regulated contractually. The constructed transaction chain is illustrated in the image below.

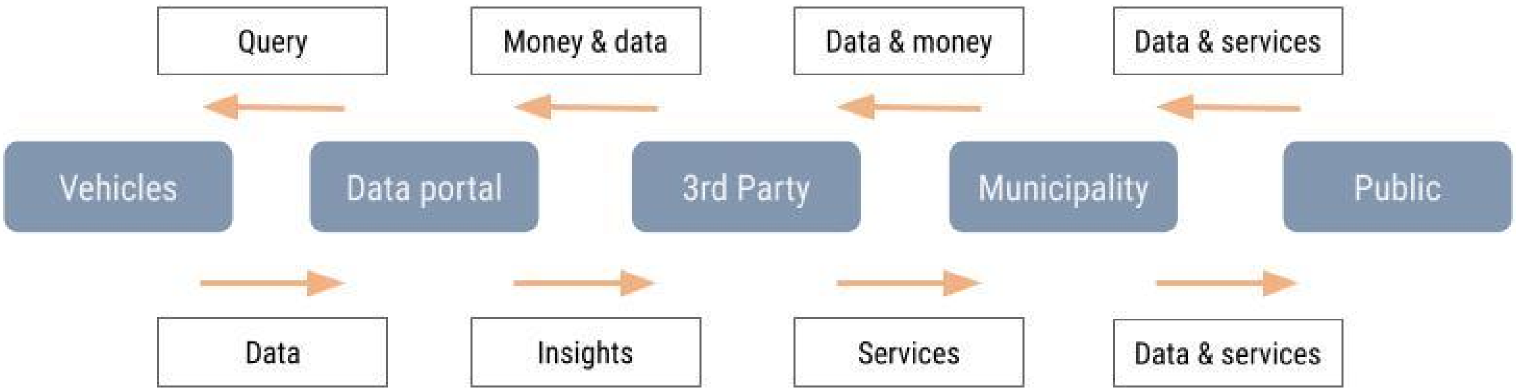

Figure 6, transaction chain

5.2.2 Identified regulations

The narration of the regulatory analysis follows the above-illustrated transaction chain. Accordingly, the first subchapter entails regulation perceived as the most relevant in the transmission of data between vehicles and data portal, the second subchapter between data portal and third-party, the fourth subchapter between third-party and municipality. Each subchapter starts with describing what regulations were considered, and if applicable, their scope. This is followed by an analysis in terms of opportunities and risk. The implications of which are summarised at the end of each subchapter.

Regulations can be interpreted in many different ways. This can be illustrated by how differently member states implement the regulation into national law (Réka, 2015). To mitigate the risk of misunderstanding the results were discussed with a subject matter expert. Other sources such as articles by Lexicology were also used to get another opinion on interpretation if it were available.

5.2.2.1 Between the vehicle and data portal

The most relevant regulations to consider in this phase were perceived to concern privacy and security related regulations. The identified regulations were:

- GDPR (2016/679)
- ePrivacy directive (2002/58)
- Personal data (Vehicles) (01/2020)
- Personal data (ITS) (03/2017)
- Cybersecurity act (2019/881)
- Certificate Policy for Deployment and Operation of European Cooperative Intelligent Transport Systems (C-ITS)

The General Data Protection Regulation entered into force in May 2018 and regulates processing and collection of personal data. Personal data is data that can be used to directly or indirectly be used to identify individuals.

The **ePrivacy regulation** is intended to replace the directive on Privacy and Electronic Communications (Directive 2002/58/EC) and would apply to processing of personal data. The regulation was intended to apply from the same time as GDPR went into effect but unlike the GDPR member states have not been able to agree on the draft legislation. (Sippel, 2021). An article by CMS law presents an analysis stating that the ePrivacy regulation is not expected to enter into force before 2023 and with the expected transitional period of two years it would not come into effect before 2025 (CMS LAW, 2021).

The ePrivacy directive is relevant in the described scenario as article 5(3) stipulates that legal grounds, as per art 6(1) in GDPR is required for storing information or gaining access to information in a individuals or legal persons terminal equipment such as a connected vehicle or any kind of computer (Guidelines 1/2020).

In relation to vehicle generated data, most of the data can be considered personal data and thus fall under the domain of the ePrivacy regulation (Guidelines 1/2020). In relation to traffic sign data and other road asset data that is communicated from a consumer-owned vehicle to a privately operated data portal the Data Protection Working Party mentions two reasons as to why it may be considered personal data; First being that the communication can contain authorisation certificates associated with the sender. And Second being that metadata such as timestamp and location makes it possible to single out individuals by just a few location points (Opinion 03/2017).

Privacy regulations are thus a relevant consideration in the communication between vehicles and a privately owned data portal. In the communication between vehicles and other vehicles (V2V) or smart roadside infrastructure (V2I), this falls under the domain of Cooperative Intelligent Transport Systems (C-ITS) . The ITS Directive (Directive

2010/40/EU) and the 2008 ITS Action Plan sets the legal and policy framework for C-ITS (SWD/2019/0096).

The C-ITS related policies and regulations were considered an important consideration since security certification policies creates a standard that may influence to what extent actors must invest in security for the communication of data considered personal (considering art 32, 25 in GDPR). Another aspect to consider is the supplementing directives to the ITS directive that poses obligations on data sharing and can greatly affect the availability of road asset data.

The cybersecurity act (Regulation (EU) 2019/881) was considered relevant by a similar reasoning mentioned above in relation to security certification. While the proposed act doesn't pose any obligations as yet for actors to get certified or adhere to the published security schemes it may become mandatory for critical products, such as vehicles. Considering article 32 and 25 in GDPR, regulations concerning security certifications become worthy of consideration in the communication of personal data (Stassen, 2019).

Implications

Privacy regulations can be said to generally increase control or ownership rights to individuals thus increasing their bargaining power. The right to data portability for example (art 20 GDPR sec 3) lets individuals access personal data collected by a service provider and can enable third parties access (De Hert et al., 2018). The individual's increased bargaining power increases the importance of gaining trust, this raises the importance of having branding, PR and might encourage private actors to perform publicly altruistic acts (Foroudi, 2020).

Sharing of personal data is associated with increased transaction costs, lower flexibility of collaborations and increased dependency between actors (Broek & Veenstra, 2018). This disincentives data holders to share road asset data before it has been anonymized. Road asset data generated by vehicles operated by private actors or multiple individuals (such as ride-sharing companies) is not subject to privacy regulation to the same extent as those operated by individuals and might thus have an advantage in comparison (Federle & Asbroeck, 2020).

Increased security regulations and requirements of anonymization might increase the entry market barriers in the form of required investments to establish compliant software architecture (McKinsey, 2020). Additional legal certainty in the form of opinion papers and guidelines can on the other hand lower entry market barriers as the resources that are required for the legal departments as well as the financial risk in the form of penalties is lowered.

5.2.2.2 Between the data portal and third parties

The most relevant regulations to consider in this phase are regulations targeted towards hindering anti-competitive behaviour or creating protection mechanisms for intellectual assets such as data, information and software.

- Trade secret directive (2016/943)
- Copyright directive (2019/790)
- Database directive (96/9)
- Regulation of non-personal data (2018/07)
- Competition law (TFEU)

The trade secret directive, copyright directive and database directive was considered relevant due to the fact that they can grant *erga omnes* exclusive rights (Martens et al., 2020). Exclusive control strengthens the economic position of the data holder. Data in contrast to physical goods isn't excludable by nature, organisations transacting data must thus rely on either technical or legal means to establish exclusive control. The current IPR for data is however quite restrictive.

In article 3(1) in the **Database directive** it is stated "databases which, by reason of the selection or arrangement of their contents, constitute the author's own intellectual creation shall be protected as such by copyright". In relation to road asset data the *arrangement of content* isn't likely to satisfy the requirements as a *creative* intellectual creation due to standardised database structures and interoperability tools. (EuroGeographics, 2017). It also doesn't protect the content itself, which is further emphasized in article 3(2).

The database directive also mentions sui generis database protection in article 7. This right is granted if "there has been qualitatively and/or quantitatively a substantial investment in either the obtaining, verification or presentation of the contents" as mentioned in article 7(1). This has however been interpreted in a very restrictive way by the CJEU and substantial investments in the device that collects the data doesn't necessarily mean sui generis is granted (Drexl, 2016). CJEU judgment in Case C-490/14 does however state that detailed content of maps qualifies for sui generis rights - and establishes legal praxis for preventing third parties from extracting or re-utilizing individuals elements of official maps without a license (EuroGeographics, 2017). Paragraph 29 from the ruling stating that

"... Article 1(2) of Directive 96/9 must be interpreted as meaning that geographical information extracted from a topographic map by a third-party so that that information may be used to produce and market another map retains, following its extraction, sufficient informative value to be classified as 'independent materials' of a 'database' within the meaning of that provision." (Case C-490/14)

The **trade secret directive** is applicable to information of economic value, either in whole or in a set of elements, which is not generally known or easily accessible and *protected* by the enterprise controlling the information. The directive is thus applicable to data, but only as long as secrecy is preserved - once it is lost so is the legal protection. In relation to road asset data and the constructed scenario, the trade secret approach to protecting data faces multiple challenges. Establishing the necessary steps to keep the data secret in a network environment and allocating rights in a network environment might be extremely difficult, as pointed out by previous researchers (Stepanov, 2019). Moreover, the protection regime might not be applicable at all to data gathered by publicly utilized sensors. Drexl (2016) for example argues data generated by vehicles on public roads are very unlikely to fulfil the requirements as many organisations have generated and have access to road asset data.

Regulation of **non-personal data and competition law** was considered relevant since they pose obligations on transparency and codes of conduct in the design of data licensing contracts. Competition law can also limit to what extent actors are able to refuse to license data, either through litigation, such as in the case of Magill or through sector-specific regulation, such as the motor vehicle regulation (Lundqvist, 2016) (Kerber & Moeller, 2019).

In assessing whether or not a **refusal to license data** constitutes a market abuse and an obligation to share data is imposed, there are three cases that have established legal praxis; the Magill case, IMS Health case and Microsoft' case (Orrick, 2013)(Moortel, 2017) (Lundqvist, 2016) (Drexl, 2016). The Magill case involves three broadcasting companies which themselves provided program schedules free of charge to consumers. Magill wanted to license these schedules to provide one listing including all three program schedules - the broadcasting companies did however refuse. The European Commission decided in Magills favor, stating that while refusal to license IP rights itself couldn't constitute abuse the exceptional circumstances did. These cirsumentstanses were:
"... *(i) the lack of actual or potential substitute for the new product which was prevented market access and for which there were potential consumer demand, (ii) the lack of justification for a refusal to license, and, (iii) the fact that the broadcasters reserved the second market to themselves by excluding competition*" (Ansari, 2009)

The IMS case further builds upon this by defining unacceptable intentions of the licensee, Orrick (2013) wrote in their analysis in regards to the case;
"*The refusal by an undertaking in a dominant position to allow access to a product protected by an intellectual property right (where that product is indispensable for operating on a secondary market) may be regarded as abusive only where the undertaking which requested the license does not intend to limit itself essentially to duplicating the goods or services already offered on the secondary market by the owner of the intellectual property right, but intends to produce new goods or services not offered by the owner of the right and for which there is potential consumer demand.*"(Orrick, 2013)

In regards to road asset data generated from vehicle sensors it's challenging to answer the question of whether or not a refusal to license constitutes market abuse since (i) substituting, but less, advantages ways of generating data exist, such as mapping vehicles or dashcams (see Case C-7/97 Bronner) (ii) there are several potential products one could create from traffic signs data besides reactive maintenance data services such as improved driver awareness services (iii) it's challenging to determine what constitute differentiating products, take for example reactive maintenance data vs predictive maintenance data services (iii) road asset data is generated by publicly utilized sensors and several, but few, organisation have access to generating said data.

Competition law is also relevant in the aspects that it prohibits anti-competitive behaviour such as **discriminatory access to data and marginal squeeze pricing strategy** (Lundqvist, 2016). Abuse in the form of marginal squeeze pricing strategy becomes applicable when an organisation with a dominant position in the upstream market is active in both the downstream and upstream and narrows the margin between price of the input and price of the product. A case that isn't unlikely when market actors such as Mobileye deliver both services to OEMs, in the form of software, and municipalities, in the form of road asset data.

Anticompetitive behaviour can also be the result of an **unequal distribution of bargaining power**. Unequal bargain power is partly addressed in the regulation of non-personal data (2018/1807). The regulation of non-personal data aims to remove unnecessary data localisation requirements and avoid vendor-lock in practice by means of a self-regulatory process in which users and providers have developed codes of conduct (art 6 2018/1807). Vendor-lock in practice refers to situations in which the customer cannot easily switch to a different vendor without substantial costs, legal constraints or technical incompatibilities (Aerts, 2019). The codes of conduct apply to all types of cloud offered services such as SaasS, IaaS and PaaS and covers aspects such as regulation, cloud contracts, governance considerations, exit processes and technical aspects (SWIPO, 2020).

Implications

Weak IPR for road asset data can result in weakened barging power for data holders and increased emphasis on contracts and technical solutions for data control. This could result in a decreased incentive to share data due to the increased transactional cost in the form of contractual arrangements and technical solutions. Contracts offer great flexibility and can simulate legal relationships akin to property protection but is limited to contractual parties - meaning that only the parties under contract are liable (Stepanov, 2019). Technical solutions for data control were discussed by several subject matter experts to support the data holder but has been mentioned to be limited to factual excludability and detecting infringements. The analysis of IPR for road asset data indicates that sui generis rights as stipulated in the database directive, combined with contractual and technical solutions is the most appropriate for protecting road asset data in transactions between OEMs and third parties.

In relation to competition law, the analysis identified some potential threats such as limitation in refusals to license data, pricing strategies, licensing contracts. The threat of litigation in relation to refusal to share data was deemed to be lowered by the fact that there exists substituting technologies and that several actors have access to generating road asset data. The threat was considered increased by oligopoly market structure within OEMs - and product differentiating factors compared to substituting data generating methods, most notably in regards to scale and timeliness of data collection.

Other aspects of competition law relating to discriminatory access to data, marginal squeeze pricing strategy and unequal distribution of bargaining power were also considered relevant during this part of the value chain. The effects these have on the market might include increased bargain power to buyers due to lowered supplier switching costs and increased threat from startups due to limitation in discriminatory access and prohibitions of anticompetitive pricing strategies.

5.2.2.3 Between third parties and municipalities

The most relevant regulation in this phase is regulations in the context of data sharing obligations. These obligations could be on the public sector to make certain data available to the private sector or on the private sector to make certain data available to the public sector:

- Open data directive (2019/1024)
- INSPIRE directive (2007/2)
- Regulation on real-time traffic data (2015/962)
- Regulation on road-safety data (886/2013)
- Data governance act (2020/767)

The open data directive imposes requirements on member states in regards to availability, cost and transparency in data licensing contracts. The aim of which is to increase data re-use. Road asset data might fall under the domain of the open data directive depending on who provided said data and under what circumstances. Data held by public undertakings in the transport sector as well as publicly-funded research data will be governed by the regulation. In other situations it might not be so, article 1(2)(c) for example excludes data for which third parties hold IPR and article 1(2)(d) data of which has commercial confidentiality. For data falling within the scope of the directive member states are obliged to not charge more than marginal cost for re-use and dynamic data, such as real-time traffic, should be available by API. The directive also introduces the concept of high-value datasets which are subject to a separate set of rules to ensure their availability free of charge and through an API (European Commission, n.d). Although the European Commission hasn't defined these data sets, road signs are mentioned within recital 66 and are thus likely to be included in the upcoming implementing regulation.

The INSPIRE directive (Directive 2007/2/EC) stipulates rules relating to infrastructure for spatial information which includes information on transport networks and to some extent traffic signs and road rules (Guidelines D2.8.I.7). The directive covers areas such as metadata, interoperability, sharing, monitoring and reporting of data (Minghini et al., 2021). The directive is aimed at the public authorities but does allow for third parties to contribute data under certain conditions. The efforts within the INSPIRE legal framework has good results in the context of data sharing - the INSPIRE geoportal being the entry point to the infrastructure, but faces some challenges in regards to incentivising private sector data sharing and engaging users (Minghini et al., 2021).

The data governance act is a proposal published in November 2020 and "*aims to foster the availability of data for use by increasing trust in data intermediaries and by strengthening data sharing mechanisms across the EU"*(European Commission) The act introduces rules for how the public sector makes data available in a situation where data is subject of IPR, commercial or statistical confidentiality and personal data regulations. The above-mentioned exemptions in relation to the Open data directive might thus in the future not be applicable in certain situations. The data governance act furthermore introduces a framework for allowing companies to share data in so-called European data spaces, such as the INSPIRE geoportal.

While there is nothing in the regulation forcing private actors to contribute data to these data lakes there might exist an incentive to do so on a voluntary basis within the automotive sector. A current example of voluntary contribution is in relation to the Data Task Force project regarding data falling under the domain of the road Safety Related Traffic Information regulation (Directive 886/2013) (Data Task Force, 2020). In this context, several automotive companies share data with each other and authoritative actors in order to improve their service and the safety of drivers. While traffic sign data isn't relevant in this collaboration, other types of road asset data relating to reactive maintenance are shared, such as real-time data on oil spills and obstacles on roads.

Moreover, the data governance act introduces the concept of *data altruism* and rules for so-called *data sharing providers* including obligations to remain neutral and a notification regime. These efforts aim to improve trust among organisations and solve issues relating to incentivising private actors to share data.

The Intelligent Transport System (ITS)(2010/40) directive and supplementing directives safe and secure truck parking (Directive 885/2013), safety-related traffic information (Directive 886/2013), real-time traffic information (Directive 2015/962) and multimodal travel information (Directive 2017/1926) - established the legal framework for the deployment and operation of ITS for pan-European improvements. In relation to the maintenance of road assets, the SRTI and RTTI were identified as the most relevant.

The ITS legal framework imposes obligations on member states to implement National Access Points (NAP) with agreed-upon standards and terms, like Datex II and non-discriminatory access (Directive 2015/962 article 3,4 & 5). The supplementing directives furthermore stipulate obligations on the sharing of data. The SRTI directive for example imposes obligations on both private and public road operators and service providers while the RTTI imposes no such obligations on service providers. Traffic sign data falls under the RTTI directive and is classified as static data in Annex 1(c). Article 8 of the RTTI directive poses obligations on member states to ensure the timely update and accessibility of such data as well as the obligation to provide information in relation to when an update has occurred (article 8(2)) and changes in the condition of road assets (article 8(1)(c)). Article 8(3) stipulates obligation on service providers and map producers to ensure that updates are processed in a timely manner when using road data updates.

Implications

The introduction of NAP and European data spaces might have several implications for road asset data in the context of maintenance. Centralization of buyers might for example increase the buyers bargaining power. The construction of easily accessible standards and diligence in the use of non-discriminatory practises in licensing might increase the threat of new entrants within the market. The aggregation of data and more clearly defined data categories might facilitate discoverability and accessibility and in this way increase use and demand. Clearer definitions might also facilitate navigation of legal frameworks for the transaction of road asset data.

Obligations on road operators and in certain cases service providers to make road asset data available to authoritative actors might increase the supply of data. This can lead to both increased use and demand but could also lead to an increased supply and lowered acquisition cost for authoritative actors.

Obligation on member states and authoritative actors to make certain data available might lead to inflexibility in licensing contracts between private and public actors. This could result in decreased incentives for private actors to share due to loss of control. There is however also the possibility of these obligations not being enforced in relation to maintenance data projects, a lack of praxis makes it challenging to estimate how these regulations will be implemented. One scenario might be that more urgent and safety-related information such as when a traffic sign hasn't been detected several times in a row, is shared publicly - and less urgent and more sensitive information such as a condition assessment of a traffic sign isn't shared, as that data could might be used by competitors to build a similar service.

Lack of legal praxis as well as awaiting and proposed regulations such as the wait for a clearer definition of high-value data sets in the context of Open data directive or the proposed data governance act creates a rather volatile legal environment. For some companies such as Nira, which creates reactive maintenance services in collaboration with OEMs, this might provide fantastic opportunities as larger corporations with more inertia might be more hesitant to invest effort into navigating this environment.

5.2.3 Conclusions & discussion

The investigation of the regulatory landscape indicates that privacy regulations are the most relevant in the transmission of data from the vehicle to data portal, followed by IPR and anticompetitive related regulation in relation to data transfer between OEM and third-party. In the later stage between third-party and municipality sharing obligation regulations and those relating to data handling on the public sector side. The below image illustrates a summary of the findings. This is followed by a discussion of the findings.

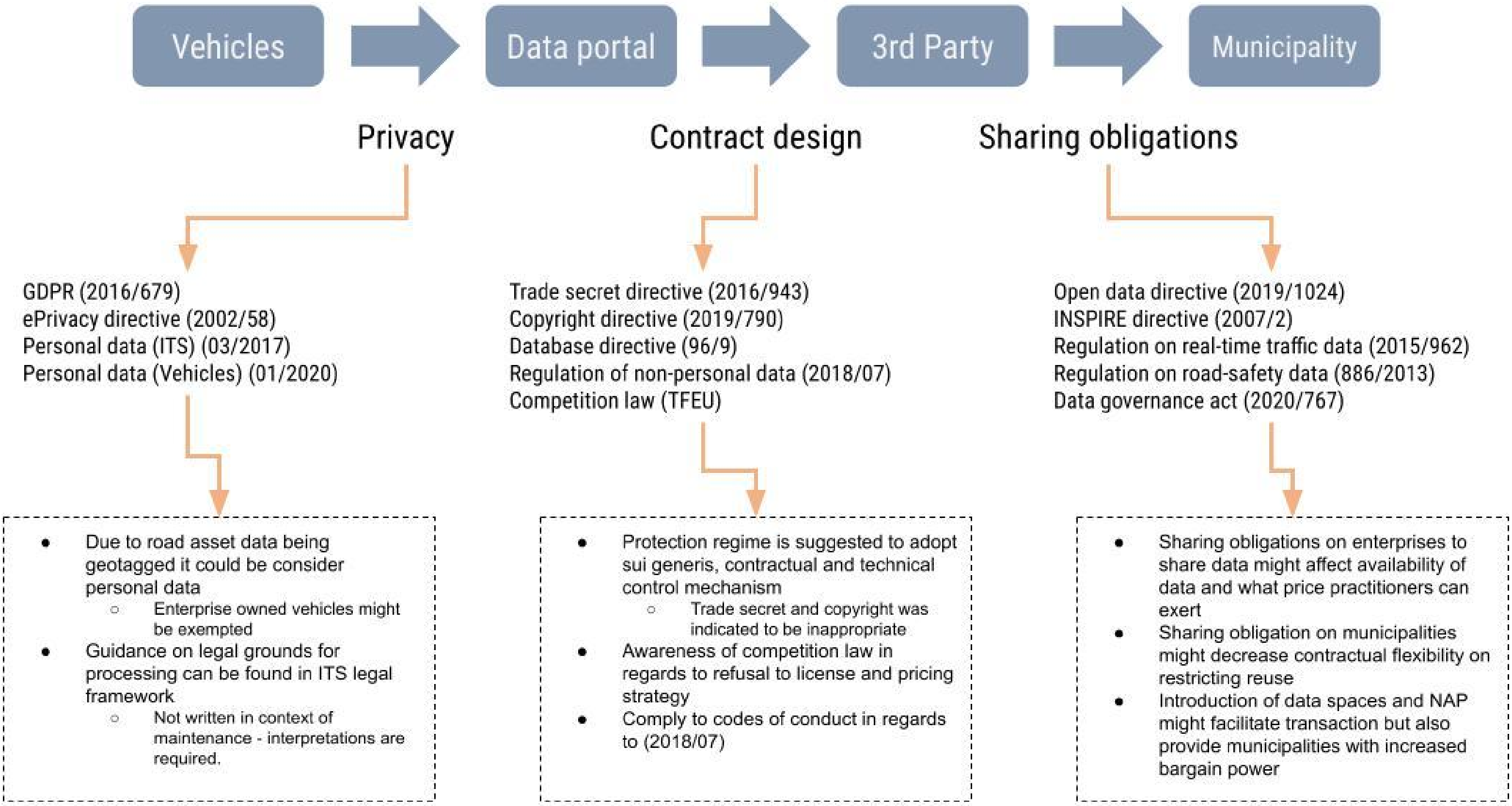

Figure 7, regulatory analysis summary illustration

Although road asset data isn't likely to gain value by being personally identifiable in the context of road maintenance the privacy-related regulations are relevant since legal grounds for extracting and anonymizing data might still be required. To what extent consent is required is likely to depend on whether the vehicle is owned by an enterprise, such as an OEM or a ride-sharing company, and what other legal grounds could be argued for. Privacy regulation can in the investigated context be speculated to result in an increased market entry barrier as only those who own their own vehicles or are able to gain consent and handle the associated requirements inherent to personal data, such as portability requirements, are able to compete on the market.

In relation to the next phase, data transferring between OEM and third-party, the most relevant regulation were IPR and those relating to anti-competitive practices. In relation to anti-competitive practices, the investigation identified some risks in relation to the refusal of licensing, marginal squeeze pricing strategy and vendor lock-in practises. In relation to when refusal to license data is considered market abuse, previous cases were investigated. The risk of this happening in the investigated context was considered low due to the fact that substituting ways of generating road asset data exist and that the data provider itself can use this data to improve its technologies and that sharing it might give away competitive advantage from this aspect.

In relation to IPR the investigation indicates that trade secret and copyright protection regimens are unlikely to provide control but that sui generis protection, as well as contractual and technological protection regimes, might. While the findings indicate that sui generis protection might be applicable, further cases might be required to create certainty in this. Contracts were found to offer great flexibility and can simulate legal relationships akin to property protection but are limited to contractual parties - meaning that only the parties under contract are liable (Stepanov, 2019). Technical solutions for data control were discussed by several subject matter experts to support the data holder but has been mentioned to be limited to factual excludability and detecting infringements.

In sharing of data between the third party and the municipalities, the most relevant regulations were those relating to sharing obligations and construction of data spaces. While there is a lack of praxis on how sharing obligations on enterprises will be applied it can be speculated that data falling under regulation such as Road Safety-Related Data will have to be available without “great” margins. It could further be speculated that the obligations stipulated in the ITS legal framework will make more data available for the municipalities which might lower the price third parties can exert.

Obligation stipulated in Open Data Directive as well as in the ITS legal framework and INSPIRE framework, on member states and authoritative actors to make certain data available might lead to inflexibility in licensing contracts between private and public actors. This could result in decreased incentives for private actors to share due to loss of control. Current cases such as Digital Winter and Data For Road Safety does however indicate that exemptions can be made in the investigated context.

The ITS legal framework is furthermore interesting because of its introduction of National Access Points. The introduction of such data spaces can be very beneficial for OEMs wanting to monetize road asset data for maintenance use directly towards authorities without becoming part of a competitors ecosystem or investing in the development of an entire service. It can however also be disadvantages in that the centralization among buyers and decentralization among providers creates increased competition and lower margins. The development of new data-driven services might also suffer within this context.

In conclusion, the regulatory landscape can be perceived as quite volatile in that regulations relating to sharing obligations and IPR remain to a large extent open for interpretation until further cases are made.

5.3 Challenges

Challenges are investigated from the perspective of the OEM and in the context of sharing road asset data for maintenance use. The investigation is framed by an adapted version of Fridolins' (2019) taxonomy. This taxonomy was constructed in relation to barriers that inhibit the implementation and advancement of the API economy within the automotive sector. The adapted taxonomy distinguishes between legal, technology and business-related challenges. Identification of challenges was made by analyzing previous research and interviewing subject matter experts. Due to the small size of interviewees and the extensive studies already made on the topic - the interviews were primarily used to confirm or put nuance to findings made in literature.

5.3.1 Legal

In regards to legal challenges, Frisolins (2019) analysis was used as a starting point. This was put into the context of road asset data and built upon by previous studies as well as observation from the previous legal analysis. In Fridolins (2019) research identified barriers related to: data privacy, data ownership, liability and certifications requirements. **Data privacy** was the most mentioned barrier in Fridolins (2019) interviews and relates to compliance to privacy laws in the implementation of data collection software. Interviewees' interpretation of this challenge was however quite dispersed. One interviewee stated that **consent** was a major barrier while another didn't - citing a consent rate of end-users of around 60-70% in relation to data monetisation. Another example is that one interviewee stated that GDPR was a satisfactory framework for designing privacy complaint data collection while other interviewees argued that the framework was too unclear in terms of what data should be considered personal. In the context of road asset data, **personal identifiable related data** doesn't contribute to the value - as discussed in the regulatory chapter it's quite the opposite as this **restricts monetisation**. This barrier can thus be translated into the challenge of establishing **legal grounds** for processing so that road asset data can be extracted and **anonymized**.

Uclear **data ownership** was the second mentioned barrier in Fridolins (2019) paper in the context of legal challenges. The major part of the discussion revolves around GDPR and whether the OEM who produced the vehicle, the owner of the vehicle or the driver of the vehicle have ownership of the data. Data ownership is commonly understood as "... the legal right and ability to create, alter, share, or restrict any piece or set of data" (Tribaleval, 2018), in the context of road asset data it is probable that **ownership is at least partly fragmented** since (i) the driver or the owner of the vehicle isn't likely to have the ability to alter such data (ii) **consent** might not be required to gather such data (as mentioned in ITS opinion paper) and the driver or owner thus not be able to restrict access or even share such data for themselves (iii) the OEM might not be able to affect the creation of data as this is dependent on the operation of the vehicle (iiii) as mentioned in the regulatory chapter the data holder might gain **IPR** in the form of sui generis rights and thus have legal rights to exclude actors from access (iiii) also mentioned in the regulatory analysis **- obligations to share** data might mean the legal right is authoritative actors. Due to these factors, the challenge of determining ownership in regards to road asset data can be narrowed down to the questions of who holds what rights over what data during which part of the data value chain.

The third topic raised in Fridolins (2019) investigation in relation to legal barriers is around **liability concerns**. This discussion considers obligations on the OEM, and potentially third parties, to inform drivers of safety-related concerns. Some interviewees argued that if an OEM collects safety-related data they are obliged to share such data if it affects the safety of the driver - some interviewees further argued that this obligation is extended to third parties. A more in-depth study of liability concerns in the context of connected vehicles was performed by Piantoni (2021). He identified primarily two regulations that are relevant for liability concerns - the **Product Liability Directive (PLD)** and the Type Approval Regulation. The study concludes under the PLD " ...*strict product liability may only apply for damages triggered by defects that are already present at the time of putting the product into circulation*." Piantoni (2021), meaning that the PLD excludes defective software for evolving or added technologies. This assumes however that the failure could be **tracked to such an extent to single out a vehicle component** such as the feeding data accessed or an app and its installation or update. According to the **Type Approval Regulation (TAR)** it is the OEMs responsibility to provide a safe and **secure environment within the vehicle**. Meaning that if third-party software onboard the vehicle is non-compliant with security or safety regulation the main responsibility - as a starting point - is still put on the OEM. The lack of sector-specific regulations or guidelines leads to uncertainty in regards to what risk who is taking (Piantoni, 2021). The challenge of liability can in this context be considered relevant for road asset data as third-party actors such as Nira produce software components for OEMs while also producing road asset data for maintenance use.

The fourth barrier mentioned - certification requirements are discussed in relation to third-party hardware and are mentioned as an especially relevant barrier for startups. The barrier was interpreted to relate to **cybersecurity** as this was identified as the most relevant topic in regards to certifications within automotive data sharing. A report by Mckinsey (2020) which examines the cybersecurity requirements for connected vehicles in detail mentioned primarily four capabilities companies must acquire - either internally or from external actors - to navigate this landscape. These were; **Procurement of security components** which due to the complexity of cybersecurity can become a challenging task in regards to evaluating providers. **Project management,** which must regard and account for cybersecurity-related tasks. **Dealerships communication** since these actors must assist in maintaining up to date software and report vulnerabilities in regards to cybersecurity. **Customer communications,** which was discussed in terms of communicating potential vulnerabilities and addressing public fears (Mckinsey 2020). The burden of becoming compliant to security regulations might add to the resources OEMs must spend to share road asset data for maintenance use as more efforts within project management and procurement of security components are required.

Interviews

While several interviewees mentioned challenges in relation to the legal aspect of data sharing project only one interviewee was actively working with the legal aspects of data sharing. The interviewees not working with legal aspects often mentioned privacy and ownership as the primary challenges. It was furthermore observed that these interviewees mentioned managing legal concerns as the most time-consuming phase of establishing new data-sharing practices.

The legal subject matter interviewee highlighted other nuances of the challenges than those mentioned in Fridolins (2019) research or by other interviewees. The issues raised were primarily related to **complex contractual relationships** and lack of praxis, especially in relation to IPR and transferring data across juridical borders (eu→ asia). Complex contractual relationships were mentioned in terms of determining what rights were allocated to which actors for what data. This challenge is thus very intertwined with the ownership question. The fact that OEMs often have several contracts with multiple partners and those contracts can specify varying rights for varying data - makes examination a tedious and time-consuming effort.

The lack of previous cases or sector-specific guidelines inhibits interpretation of regulations and was framed as a challenge to most legal aspects of data sharing, such as ownership, IPR and transferring data across juridical borders. This was considered a major challenge as it creates uncertainty into what is allowed and what risk who is taking.

5.3.2 Business

In regards to business-related challenges, factors identified in Fridolins (2019), Lindgrens et al (2017) and Graham (2020) were used as a foundation. Further studies were then used to complement and further analyse the identified issues. The analysis identified challenges related to low market maturity, long development cycles, lack of customer pull and perceived strategic value of road asset data.

In relation to **low market maturity,** interviewees in Fridolins (2019) study mentioned challenges in relation to having **no clear strategy in monetisation** of data and lack of cases showing significant revenue justifying the added costs and risk. Interviewees in this study mentioned data monetisation still being in an exploratory phase in regards to constructing **pricing models** and identifying **use cases**. Lindgrens et al (2017) concludes similar findings which are exemplified by quoting a manager implementing a cloud solution for connected services

"*When it comes to connectivity features, we typically end up discussing whether they should be standard, optional, or accessories, then we find a business model that goes beyond traditional thinking. But Then: "No...it doesn't fit here." It's scary and unknown, and our finance people tell us we can't trust such revenue streams.*"

While several research findings confirm that OEMs perceive increased value in data-related services (KPMG, 2020)(Fridolins 2019) (Lindgrens et al 2017) venturing from an unambiguous and profitable market to a nascent one with undefined market structure, unclear relationships and no clear product definition can become a daunting task.

This challenge becomes especially hard to manage because of the **long development cycles** within the traditional OEM business model. Since the development of a new car takes around seven years - experimentation with new business models is a more challenging task in comparison to other industries with shorter development cycles (Fridolins 2019) (Lindgrens et al 2017). While development within software often takes a more fast-paced and non-linear approach to development competing interests, persistent culture and shifting of focus can contribute to longer development cycles for efforts for data-related services (Lindgrens et al 2017). These findings are further endorsed by a study performed by McKinsey (2018) in relation to co-creating data-driven services in collaboration with OEMs concluding that;

"*Many executives shared frustration regarding the inability of OEMs and large companies to operate in an agile fashion, make decisions quickly, and explore new possibilities without imposing artificial constraints*." - McKinsey (2018)

In relation to road asset data for maintenance use the challenges related to low market maturity is especially prominent. A study by McKinsey (2021) examined the potential value of various categories in which OEMs could monetize data. The by far most valued categories were those relating to the development and maintenance of cars - while road infrastructure related cases were rated to be amongst the least valuable. In another study made by KPMG (2020) which investigated the maturity of various data monetisation cases the most valuable and mature markets by far were insurance related while road infrastructure applications were deemed very low in both market maturity and potential value. A potential answer as to why the maturity of this market is low is the **lack of customer pull** which might be due to severely limited budgeting for road maintenance (European Commision, 2019), few road asset management systems being able to digest vehicle data (Graham, 2020), as well as road authorities having disadvantages culture for innovation adoption and lacking technical infrastructure (Graham, 2020) (Bastien et al., 2018). While there certainly exist incentives for OEMs to improve road maintenance - such as increased safety, reduced tear & fuel consumption and improved customer experience - the efforts provide neither direct return nor competitive advantage. The lack of customer pull combined with a lack of direct returns results in an **unclear business model** for road asset data for maintenance use.

The above-mentioned issues might be partly addressed by sharing the risks and costs with external actors. This means adopting a more open software ecosystem in which external actors are enabled to access road asset data. The **high strategic value** of data and fear of losing control to competitors has however created a situation where each OEM tries to become the sole owner of a business model that's built upon a **proprietary software ecosystem** (Fridolin 2019). This creates a customer lock-in effect in which the consumer is limited to services within the proprietary ecosystem controlled by the OEM. The high strategic value of data furthermore leads to OEMs trying to dominate the whole data value chain by acquiring internal capabilities for monetizing data (Gorka, 2020). The development of such **capabilities is however costly and time-consuming** (Gorka, 2020). The high strategic value of data thus results in the inhibition of data-driven service within the industry. But not all data is perceived to be of equal value.

A study by KPMG (2020) investigated the strategic importance of data for OEMs in relation to the data market penetration by digital platforms. This study concludes that driver data such as entertainment, wellbeing, insurance and home integration was of low strategic value and had a high market penetration by digital platforms - while the opposite was true for vehicle data, which included usage and car maintenance data. Context data, such as safety, traffic and road data, was however considered to be in the friction zone between these two forces, meaning its of medium strategic importance and had medium market penetration by digital platforms. This friction was thought by the researcher to imply increased complexity and competition in accessing such data. These findings indicate the challenge resulting from strategic value is relevant for road asset data.

While the economic value of road asset data for maintenance use can be immense, the cost of developing software capable of the feat is hard to justify without **economies of scale**. The reactive attitude within road authorities towards innovation means the burden of convincing stakeholders on a strategic level and demonstrating value on an activity level is likely to be put on the OEM.

Interviews

The interviews with subject matter experts endorsed many of the findings discussed above. Low market maturity was mentioned by several interviewees, this was usually framed in the discussion of a still-evolving data value chain with unclear relationships and market structures. Another topic often mentioned was disadvantages culture for creating data-driven services. This was mentioned both in terms of opening up the software ecosystem and in terms of switching from traditional feature selling to service selling. While the high strategic value of data wasn't mentioned as a challenge directly, governing third parties and deciding what they are allowed to do with the data they were provided were mentioned several times.

5.3.3 Technical

Fridolis (2019) and Graham (2019) research as well as Automat's report was used as a foundation to identify challenges. The identified challenges were then investigated more in-depth and within the context of road asset data for maintenance use. Additional data was gathered both from interviews and complementing research such as Mchardy's et al (2018) study on data transmission challenges. The identified challenges related to; Transmission of data from vehicle to data portal. The OEMs internal IT infrastructure and data portal. Intraorganisational collaborations and interoperability. Integration of data flow from OEMs to end-users.

Transmission of data from vehicle to data portal was the most mentioned technical barrier in Fridolins (2019) research. The discussion in Fridolins (2019) in relation to transmission of data is however limited to barriers related to cellular communication. McHardy et al (2018) which goes more in-depth into communication technologies have identified and investigated two primary contesting communication technologies; Dedicated Short Range Communication (DSRC), which is a wifi-based protocol, and cellular communication technology.

DSRC technologies have the benefit of technology readiness, near zero-cost transmission, reliability and ultra-low latency. Some current challenges are the availability - due to required investment in **roadside units equipped with DSRC**, required **line-of-sight** for the technology to work with satisfactory reliability, unstable performance in **congested scenarios** and relatively **low ideal data-rate** (optimal performance is around 6 Mbps while 45-80 is estimated to be required). (McHardy et al., 2018)

Cellular communication technology has the benefit of availability throughout the developed world, ability to support a high number of connected devices and having more well studied and easier solved security challenges. Some current challenges are the high **cost of data transmission** (even hybrid version - only using it for VPKI certification incurs a vehicle cost three times as much), **latency constraints** not able to satisfy safety application and guaranteeing absence of **blind spots**. (McHardy et al., 2018)

How major of a challenge data transmission is for road asset data could depend on the specific use case. In relation to data that could be critical to the safety of the driver, such as a missing traffic sign or a slippery road, such data is communicated relatively infrequent and with relatively low volume. But in the context of less urgent maintenance such as overall road quality and vandalized - but still recognisable signs - such data could be of much greater volume/frequency and thus present a bigger challenge in regards to transmission.

Internal IT infrastructure capable of handling data collection and distribution was another barrier raised in Fridolins (2019) research. This was discussed in relation to heterogeneity of internal applications used to store data, **inability to distribute data in realtime** and absence of interorganisational interoperability. These factors contribute to the challenge of quality assurance in relation to road asset data for maintenance use. **Heterogeneity in internal systems** could decrease **data reliability** as additional **testing** and data **correlation** are required (Fridolin, 2019) (Automat 2018). As timeliness could be considered a vital quality factor for maintenance, the inability to share data in a timely manner further decreases quality (HERE Technologies, 2018). To what extent these quality factors contribute to value degradation might depend on how urgent the maintenance is, if the customer or data aggregator already had knowledge of the maintenance need or to what extent precision/reliability is required. Lack of interorganisational interoperability, such as between OEMs, disincentives interorganisational efforts by hindering the sharing of costs, inhibiting innovation speed and decreasing potential coverage.

An example of an **inter-organisational effort** is Here's Road Roughness Product. One of the primary challenges in developing this product is the **heterogeneity of sensor data**. This resulted in **limited data being viable for use, decreased coverage and increased cost in relation to data pre-processing**. And as was illustrated within the report - extensive ground truth data is required to develop a road roughness estimation coherent with the International Roughness Index. In the case of Here's product, the ground truth data was generated by their own mapping vehicle fleet which estimates IRI by relatively mature algorithms. **Synchronization between ground truth data and training data** pose another challenge that can be approached by either additional preprocessing or having an OEMs datalogger installed in the mapping vehicles.

Another challenge in developing data-driven service within road maintenance is the **construction of feedback mechanisms**. In the context of interorganisational efforts, this could require both feedback from the organisation developing the product such as Here - and the end-users i.e the road authorities. Feedback mechanisms from the road authority could provide information in regards to the reliability of given maintenance data but could also provide information able to improve the ADAS. An example scenario of the latter being the distinction between traffic signs being changed intently vs being vandalized.

Integrating data-driven service in road authorities workflow can however be a challenging task as subject matter experts working with road authorities and Graham (2019) research highlight. The **lack of standards** for road asset management makes **benchmarking** between different datasets challenging. The solutions employed by road authorities - though expensive - creates data of high validity. A switch rather than a compliment to less qualitative data is unlikely (Graham 2019). The problem of integrating various data flows into the workflow on an activity level is made more problematic by road authorities' **reactive attitude towards innovation and severe resource constraints** (Graham 2019). Contributing to this problem is that **several bodies** (local, regional & national) may **have responsibility** for road maintenance (European commission, 2019).

Interviews

The subject matter experts from industry refrained from disclosing their technical challenges within the report. The aspect was however discussed with several experts and it can be said that what technical challenges face depends greatly on what technology they are using and how mature the development is.

Subject matters experts within the public sectors confirmed the findings in relation to technical challenges for road authorities. The two interviewees indicated that the reactive nature towards innovation and lack of internal resources as the two most prominent challenges. It was further observed that integrating data flows from OEMs into current systems wasn’t considered viable but that services complementing current systems was. This is in line with the findings mentioned above in relation to the integration of OEMs data flow into road authorities current workflow.

5.3.4 Conclusions & discussion

This study has deconstructed and analyzed findings from previous research related to challenges for OEM to monetize data. This analysis is complemented by information gathered from interviews with subject matter experts. A summary of the identified challenges is illustrated in the image below. This is followed by a short discussion on the findings.

Legal

- **Legal grounds for processing**
  - Anonymization
    - Consent vs other grounds
  - Personal data
    - Purpose limitation restricts recapitalization of legacy data
- **Fragmented ownership**
  - Privacy regulations
  - Complex contractual relationship
  - Sharing obligations
  - IPR
- **Liability**
  - Product Liability Directive (PLD)
    - Tracking failure to single component
  - Type Approval Regulation (TAR)
    - OEM responsible for secure environment
- **Cybersecurity**
  - Procurement of security components
  - Project managemen
  - Dealerships communication
  - Customer communications

Business

- **Lack of monetization strategy**
  - Resistance towards uncertain revenue sources
  - Low market maturity
  - Lack of historical cases
    - Lack product definition & pricing strategy
  - Unclear business model
    - Requires economic of scale to justify cost
    - Road maintenance → no direct return nor competitive advantage
- **Long development cycles**
  - Resistance towards agile
  - Expermintes & collaborations suffer
- **Lack of customer pull**
  - Customer lack funding & capabilities
  - Disadvantages culture for innovation adoption
  - Interoperability with RAMS
- **Perceived strategic value of road asset data**
  - Proprietary ecosystem hinders collaboration
  - Sensitive info about progress
  - Development of competing solutions

Technical

- **Data transmission (Vehicle → portal)**
  - Dedicated Short Range Communication (DSRC)
    - Availability; roadside units
    - Line-of-sight; reliability
    - Low ideal data-rate
    - Vulnerable to congestion
  - Cellular communication
    - High cost of transmission
    - Latency constraints
    - Cellular blind spots
- **The OEM's internal IT infrastructure**
  - Heterogeneity of internal applications
  - Distributing data in realtime
- **Intraorganizational collaborations**
  - Heterogeneity of sensor data
  - Synchronization; ground truth data & training data
- **Integration of data flow from OEM to end users.**
  - Construction of feedback mechanisms
  - The lack of standards in RAMS
  - Integrating data to workflow

Figure 8, challenges analysis summary illustration

As in the research conducted by Fridolin (2019) the interviewees in the study portrayed legal obstacles as among the most changeling to overcome. But they diverge in what aspect was perceived as challenging. Fridolins (2019) interviewees identified data privacy as the principal barrier, while the information gathered from interviewees in this study indicate fragmented ownership as the principal barrier.

In the context of road asset data for maintenance use, privacy concerns might not be as burdening as in other use cases. Fragmented ownership can however be more relevant in this context than others since the generation of road asset data could rely on a multitude of sensors and algorithms provided by third parties but also because additional regulations such as sharing obligations might become applicable.

The problem of fragmented ownership was perceived to be related to the OEMs internal IT infrastructure in the sense that legal tags incorporated in the data storage could communicate what rights are allocated to what data sets. In the process of establishing such a structure, the major concerns practitioners faced was not of technical character, the major challenge was identified to be convincing of stakeholders. This was challenging because it imposes new obligations on employees and gives no direct returns.

Fragmented ownership might also contribute to the lack of monetisation strategy and long development cycles. Lacking knowledge of how the firm is allowed to utilize data makes it challenging to establish a strategy for profiting from it. The interviews from this study indicate that identifying data that is suitable from a legal perspective is among the primary reasons new projects are being postponed or not initiated.

Another challenge that was perceived as among the more complicated was the perceived strategic value of vehicle sensor data. The perceived strategic value of data contributes to the establishment of proprietary ecosystems and the raising of barriers for third parties entering such ecosystems. This results in technical challenges when establishing collaborations due to the heterogeneity of sensor data and hinders OEMs to share costs and acquiring external capabilities in developing new services. This makes it harder to justify the costs of developing data-driven services for external parties. The perceived strategic value could also contribute to the lack of monetisation strategy in that its strategic worth as an internal asset disincentive for OEMs to survey for external opportunities.

5.4 Success factors

Potential success factors for monetizing road asset data for maintenance use were identified inductively by analyzing white papers, reports, studies and conducting interviews with subject matter experts on both the data provider and user side. Due to much research being done in surrounding areas the investigation has distinguished between the factors depending on what context they were written in: B2G data sharing & software projects, sharing vehicle sensor data and case-specific factors.

The investigation includes analysis of best practices, learnings from projects and successfully used principles as these could be considered closely related to - or a subcategory to - critical success factors.

5.4.1 B2G data sharing and software projects

Success factors relating to B2G data sharing and software projects were identified in Jørgensen & Mohagheghi (2017) and studies conducted by the European Commission (SWD/2018/125) (ALEMANNO, 2020). Jørgensen & Mohagheghi (2017) research identified success factors relating to project management for B2G collaborative software projects. The studies from the European commission investigated success factors relating to licensing contracts for B2G data sharing. The studies thus complement each other in regards to identifying success factors for the construction and implementation of data-driven services within a B2G context.

Jørgensen & Mohagheghi (2017) investigation identified six success factors whereas the top three were mentioned around twice as much comparatively. These three were; involvement of stakeholders, adequate project management & development processes and competence. Involvement by the stakeholders was defined as "*good dialogue between the client and the supplier, high priority by the client (including top management), good cooperation between stakeholders and the involvement of the right users*". While competence referred to "*Competent project personnel e.g., competent clients with good domain knowledge, competent suppliers, skilled developers and competent project leaders*". (Jørgensen & Mohagheghi 2017)

In the context of adequate project management and development processes, the study found that taking advantage of agile practices such as frequent delivery and flexible scope increased the success rate of projects. Software scoping usually refers to establishing project requirements, setting objectives as well as outlining budget and timescale (Lynch 2017). Flexible scope can thus be interpreted to refer to continually updating requirements and budget depending on the current progress. A study by Jorgensen & Molokken-Ostvold (2005) which goes more in-depth into comparing development methods found that managers using a flexible approach cited better requirements specification and communication with clients. Having a flexible scope might thus be especially important in cases where the customer has limited capabilities to design requirement specifications and foresee future needs. This might have contributed to the high correlation (87%) of successful projects and flexible scope in Jørgensen & Mohagheghi (2017) study.

Frequent delivery also had a strong correlation to success, the author stating that;

- "*Projects with only one delivery into production had a success rate of 64% (12 projects).*
- *Projects with a few deliveries into production (four or less) had a success rate of 77% (13 projects).*
- *Projects with frequent deliveries (more than four) had a 100% success rate (8 projects).* " Jørgensen & Mohagheghi (2017)

Although the sample size is limited the findings are aligned with what previous researchers have found (Jorgensen & Molokken-Ostvold, 2005). It should further be noted that frequent delivery might contribute to the factors such as involvement and competence which respondents in Jørgensen & Mohagheghi (2017) attributed their success to. Frequent delivery could have contributed to these by enticing confidence and dialogue as well as providing a feedback mechanism that fosters learning on both sides (Jorgensen & Molokken-Ostvold, 2005).

Potential success factor	Description - as defined by Jørgensen & Mohagheghi (2017)
Involvement by the stakeholders	"...*good dialogue between the client and the supplier, high priority by the client (including top management), good cooperation between stakeholders and the involvement of the right users"*
Adequate Project management and development processes	"...*the ability to change the scope based on external changes and learning, frequent delivery, good management of the project and thorough testing"*
Competence	"...*Competent project personnel e.g., competent clients with good domain knowledge, competent suppliers, skilled developers and competent project leaders*"

Table 10, potential success factor from Jørgensen & Mohagheghi (2017) research

In the communication *Towards a common European data space* the European Commission laid down six principles on B2G data sharing that could support preferential conditions for re-use (SWD/2018/125). These principles were later revised by the High-Level Expert Group on Business-to-Government Data Sharing which formulated suggestions on improvements (ALEMANNO, 2020). The principles were developed by consulting stakeholders and analyzing what had worked in previous cases. They could thus be interpreted as success factors for developing data licensing agreements or codes of conduct in a B2G environment.

The first principle is referred to as; Proportionality in the use of private-sector data. Proportionality refers to both proportions of data detail in regards to the purpose and the proportion of cost in regards to public-interest benefits. In describing the principle it is further explained that requests for data should be justified by demonstrable public interest. The implications of this principle in designing licensing contract were interpreted to be (i) stipulate the minimum required granularity, quantity and frequency for the public interest to be served (ii) base pricing on the savings made when data is used or risk of harm if data is not used (iii) use pilot projects as a way to demonstrate that the service benefits the public interest.

The second principle is referred to as; Purpose limitation. The implications of which were interpreted as (i) contractually regulate limitations of processing to specified purposes and potentially specified time-periods as to allow the data provider to further monetize data (ii) consider and respect existing legislation and policies to which the user is bound (iii) stipulate conditions for the safeguarding of data as to prevent misuse.

The third principle is referred to as; "Do no harm" or *Risk mitigation and safeguards* as suggested by the High-Level Expert Group. This principle addresses liability and fair competition concerns. The implications of which have been interpreted as (i) the data provider should not be held liable for the quality of the data or its use (ii) the public-sector bodie should not use private-sector data in a way that distorts competition such as using it for commercial purposes or to compete with companies (iii) include contractual safeguards to protect privacy, security and non-discrimination rights of stakeholders, including the individuals.

The fourth principle is referred to as *Conditions for data reuse* in the communication *Towards a common European data space* while the High-Level Expert Group suggested the principle to be divided into two separate principles called *Compensation* and *Non-discrimination*. In regards to compensation, the principle states that while collaboration should seek to be mutually beneficial the data provider should acknowledge the public-interest goal by giving preferential treatment to public-sector bodies. The assessment of compensation should take this - as well as the first principle regarding proportionality - into account. In regards to non-discrimination the principles state that organisations should treat public authorities that perform similar functions the same and that public entities shouldn't discriminate towards organisations having similar datasets.

The fifth principle is referred to as *Mitigate limitations of private-sector data*. The principles state that organisations should offer proportionate and reasonable support to help assess or verify the quality of the data for the specified purpose, but that improvements shouldn't be required without additional compensation. Since *proportionate and reasonable* can be interpreted quite widely and the verification of data quality for the purpose of maintenance can be quite challenging it might be beneficial to clearly stipulate what obligations each party have in regards to quality assessment.

The sixth principle is referred to as *Transparency and societal participation* and encourages transparency on behalf of the public sector. Meaning that objectives, algorithms applied as well as the result and impact of project should be made transparent by the public sector. The implication for the data provider could entail enablement of feedback mechanisms. Such mechanisms in the context of road asset data could improve both the ADAS and the service offerings in regard to road maintenance. It is suggested that the public sector make best practices and learnings identified in previous experiences publicly available. For the data providers, this might mean they have an incentive to contractually regulate what is made public and look at prior publications that could aid in establishing new collaborations.

Principles for B2G data sharing	Interpreted implications
Proportionality in the use of private-sector data	Stipulate the minimum required granularity, quantity and frequency for the public interest to be served. Base pricing on the savings made when data is used or the risk of harm if data is not used. Use pilot projects as a way to demonstrate that the service benefits the public interest
Purpose limitation	Contractually regulate limitations of processing to specified purposes and potentially specified time periods as to allow the data provider to further monetize data. Consider existing legislation and policies to which the user is bound. Stipulate conditions for the safeguarding of data as to prevent misuse.
“Do no harm” or *Risk mitigation and safeguards*	Stipulate (i) that the data provider should not be held liable for the quality of the data or its use, (ii) that the public-sector bodie should not use private-sector data in a way that distorts competition, (iii) safeguards protecting the privacy, security and non-discrimination rights of stakeholders, including the individuals.
Conditions for data reuse or *Compensation* and *Non-discrimination*	Take into consideration that preferential treatment and non-discriminating treatment amongst public-sector bodies are expected.
Mitigate limitations of private-sector data	Clearly stipulate what obligations each party have in regards to quality assessment
Transparency and societal participation	Encourages transparency on behalf of the public sector. The implication for the data provider could entail enablement of feedback mechanisms and increased incentive to contractually regulate what is made public and investigate prior publications that could aid in establishing new collaborations.

Table 11, interpreted factors from (SWD/2018/125) communicated by the European Commission

5.4.2 Sharing vehicle sensor data

McKinsey’s white paper *From Buzz to bucks - automotive players on the highway to car data monetisation* was used as a foundation to identify and categorise potential success factors in the context of sharing vehicle sensor data (McKinsey 2018). Additional white papers by Capgemini (Winkler et al., 2020), Deloitte (Helbig et al., 2017) and further articles from McKinsey (Bertoncello et al., 2016) as well as interviews with subject matter experts were analyzed to complement and provide nuance to the identified factors. McKinsey's (2018) investigation aimed to identify best practices, these were categorised into three distinct categories which were; communicating value, redefining organisational model and establishing partnerships.

Since no distinction was made between primary (i.e the vehicle owner) and secondary consumers (i.e the data user) in relation to *communicating value*, it was interpreted to refer to both communications with the primary customer and the secondary consumer. The companies performing the best in regards to communicating value was identified to (1) define a clear vision of the customer experience and share it internally and with relevant partners. (2) Define a multi-sided approach to use and capture data for internal (various units & departments) and external clients (clients along the value chain). (3) Systematically evaluate use cases and work closely with the financial department to prioritise and focus on a few manageable use cases.

Defining a clear vision of the customer experience in the context of sharing road asset data generated by primary consumers might have implications for both incentives to share data and revenue from vehicle sales. A study commissioned by Otonomo (Rosner, 2020) comparing drivers interest in various connected services found that drivers had the highest interest in applications that alert the driver of dangerous driving conditions. This combined with surveys indicating that consumers are more likely to share data for public-interest benefits (Ziefle et al., 2016) indicate that the primary customers interest in road condition data is high and that they are willing to share data for the improvement of such services. This suggests that a compelling value proposition to the primary consumer could be based on benefiting the public interest or increasing the driver's awareness of road conditions.

Defining and sharing a vision of the secondary customer experience might have implications for collaboration opportunities. A lack of transparency on behalf of the OEM was mentioned by several subject matter experts as one of the primary hindrances to creating compelling value offerings and acting on new collaboration opportunities. Sharing a vision of the desired scenario to selected partners could open up for new collaborations and might thus accelerate development and decrease cost.

The best practices regarding (2) identification of both internal and external use cases as well (3) systematically evaluating and focusing on a few manageable cases was mentioned in both McKinsey's (2018) and Capgemini's (Winkler et al., 2020) white papers. Internal use cases and customer-facing services are perceived by OEMs to have greater value potential compared to selling data (Ptolemus, 2020). Originating from internal use cases and trying to find synergistic effects from external collaborations might thus alleviate some of the issues regarding unclear business models. Such synergistic effects could for example entail access to higher quality data, utilization of algorithms or creation of metadata.

Best practices categorised in the second category, redefining organisational model, include "*Choosing and quickly deploying an organisational model that facilitates cross-functional collaboration and implementing mechanisms that ensure it*" and "*Hiring managers with* *experience in agile, customer-oriented, and data-centric environments*" (McKinsey's 2018). In regards to designing an organisational model that facilitates cross-functional collaboration, Capgemini (Winkler et al., 2020) research suggests decoupling service innovation from existing departments and embedding it in a new organisational setup. A case study of just such a scenario at Volvo illustrated how competing concerns relating to capability (existing versus requisite), focus (product versus process), collaboration (internal versus external), and governance (control versus flexibility) can be managed by balancing new opportunities with established practises (Fridolin et al., 2017). The exploratory nature of OEMs embracing digital innovation does however make it challenging to identify what mechanisms are successful in ensuring the transition.

Hiring personnel with experience from more digitally mature industries was mentioned as an important element in redefining the organisational model by three subject matter experts as well as in McKinsey's (2018) and Capgiminis white papers (Winkler et al., 2020). The subject matter experts further emphasised the importance of enabling these actors to influence the organisation. While McKinsey's article (2018) emphasised the importance of identifying capability gaps and adopting an aggressive hiring plan. During Fridolins et al (2017) research, the practice of hiring external personal with experience in more digitally mature industries was observed and was deemed very successful.

Best practises relating to the third category, establishing partnerships, observed in McKinsey (2018) research include; Adopting a project-based structure for managing collaborations and conducting joint coaching programs with partners. Adopting a project-based structure, as opposed by the traditional centralized setup with product owners managing collaboration, was mentioned in Capgemini's (Winkler et al., 2020) white paper as well. Both papers emphasize the importance of the project-based structure to incorporate cross-functional working processes.

Conducting partnership boot-camps or other formal joint coaching programs with partners on both executive and operational level was described as a key focus area by leading OEMs in McKinsey's (2018) research. Previous research on interorganisational partnerships indicates that trust might be the most crucial success factor in establishing new collaboration (Casey, 2007). Interpersonal relationships and social networks have been indicated by several researchers to closely relate to the building of trust, it has also been shown that such relationships are unlikely to develop in the absence of organisational support (Casey, 2007). Conducting formal joint coaching programs and expending focus and effort on improving these might thus be a worthwhile investment.

Category	Best practises identified in McKinsey's (2018) research
Communicating value	Define a clear vision of the customer experience and share it internally and with relevant partners
	Define a multi-sided approach to use and capture data for internal (various units & departments) and external clients (clients along the value chain)
	Systematically evaluate use cases and work closely with the financial department to prioritise and focus on a few manageable use cases.
Redefining organisational model	"*Choosing and quickly deploying an organisational model that facilitates cross-functional collaboration and implementing mechanisms that ensure it*" - McKinsey's (2018)
	"*Hiring managers with experience in agile, customer-oriented, and data-centric environments*" - McKinsey's (2018)
Establishing partnerships	Adopting a project-based structure for managing collaborations
	Conducting workshops and coaching programs with partners

Table 12, best practises from McKinsey's (2018) research

Eleven subject matter experts lacked experience in B2G projects but had experience from data sharing projects within the automotive sector - the potential success factors identified in these interviews are listed in the table below. Some of these subject matter experts had experience from working with OEMs while others had experience from working with digital service providers. The factors were categorised in legal, organisational and technical depending on the context of the discussion. Due to the limited number of interviewees, the importance of factors cannot be expected to correlate with how many times they were mentioned. To mitigate misunderstanding in regards to this the number of mentions has not been included.

Legal	The legal department at OEM can be quite influential and are often not very pragmatic - come up with concrete suggestions that are tied into OEMs business goals and interest.
	Establishing data governance practices is key to efficient legal reviews. Incorporating legal tags into data storage and distributing accountability amongst data stewards were mentioned as key focus areas.
	Process data onboard the vehicle was mentioned as a way to facilitate navigation of some legal concerns.

	Aim to contractually regulate as extensively as possible.
	Don't get stuck in trying to figure out what to do with existing data and instead look forward. In a legal context, this has to do with legal grounds for processing data.
	Try to identify legal solutions/activities with synergistic effects. Such as creating data packages for sharing or implementing anonymization software.
Organisational	Have a flexible perspective on third parties in terms of supplier vs partner. Many times there are other things to offer besides monetary payment, and many times we can gain other things other than monetary payments that are more aligned with business goals.
	Use partnerships to strengthen the strategic position.
	Create transparency into expectations and incentives with third parties.
	Decrease barriers for getting into the software ecosystem, do shorter development cycles with POC and evaluate.
	Drive change top to bottom - set objectives with deadlines to reference towards.
Technical	Have awareness into strategic vs operational interests - an efficient software architecture might take time to build but decreases future manual labour.
	Invest in good description of code and standardize processes extensively.
	Have awareness of innovation/flexibility vs security interests.
	Have a bottom-up approach to establishing communication channels in regards to code, Q&A and meeting protocols - Awareness of what tools fit and what tools are available are better on activity level, wrong tools leads to loss of communication, frustration and decreased efficiency
	Create centralized solutions - separate story solutions or host an API. Focus on internal tools and make them available rather than develop separate external tools.

	Smaller and faster steps lead to better solutions.

Table 13, factors interpreted from interview with group B

5.4.3 Case specific

Potential case-specific success factors were identified by analyzing reports from successful cases in which vehicle sensor data was used for road maintenance and by interviewing subject matter experts in both the private and public sectors.

In regards to the analysis of previous cases, the most comprehensive source of information was found in regards to the project called Digital Winter in Sweden (Asp et al., 2021). The actors providing data in this scenario include Volvo and Nira. The former being an OEM and the latter a service provider. The project was considered successful since it provided more reliable data than conventional point measurement and resulted in an extended collaboration lasting an additional six years. The Swedish road authority, Trafikverket, published a report at the end of the initial innovation partnership which concluded that the following factors (Table below) were attributed to the success of the project.

Activities that Trafikverket attributed the success of Digital Winter project to (Asp et al., 2021)
Adoption of agile project methodology. Both sides worked in small teams with clearly defined responsibilities and with short decision paths.
Early identification of key personal able to lead the project
Sponsor and project coordinator put much effort into defining project specifications for the project as a whole and subprojects.
Clearly defined roles, expectations and responsibilities before initiating the project.
Project coordinator worked actively with communication activities and communication plans against all parties
Trafikverket utilized public procurement to ensure involvement from private actors
Trafikverket adapted the procurement model and requirements to the specific scenario. In this scenario Trafikverket only allowed tenders from selected actors and contractually regulated use of procured data.
Trafikverket signed contracts with several actors to build a network of suppliers and secure satisfactory coverage of road networks.
Project used pilot project to test the model before larger-scale implementation
Project utilized a university as an independent party to evaluate the model

Table 14, activities associated with success in Digital Winter project

Besides these factors, it's worth mentioning that Trafikverket chose to develop its own user interface as to in the future enable other data suppliers to contribute data. The project allowed for new actors to join as the project progressed and new needs were identified. It was furthermore observed that the data licensing contract restricted data redistribution or reuse for other purposes than those specifically specified within the contract (Asp et al., 2021).

Four subject matter experts that had experience from projects involving vehicle sensors data for maintenance use were interviewed - the interviewees attributed the success of projects to the factors listed below.

Factor	Description
Scalability	Scalability in regards to coverage was mentioned as a highly valued factor by road authorities. Interviewees from the private sector argued that this is dependent on the specific use case.
Pilot projects	Running pilot projects to demonstrate the value of new services and how those services can be integrated into current workflows was mentioned by both interviewees from the private and public sectors.
Knowledge of internal process	Understanding how new services can be integrated into current workflows and what data the road authorities have and how it can be complemented was also mentioned by both private and public sector interviewees.
Ecosystem of partners	Having the right ecosystem of actors involved early on in the project and trying to distribute responsibility amongst stakeholders. Interviewees from the public sector said that when actors try to do too much themselves the projects often fail.

Table 15, factors from interviews with group A

5.4.4 Aggregation of factors

The factors described in the above chapters have been categorised based on similarity in regards to implications and independently from which context they were written in. The result is nine different focus areas which consist of elements associated with success. The categorisation is illustrated in Appendix A.

Acquiring the right competences
Acquiring the right competencies was discussed in the context of B2G software projects, OEM data sharing and vehicle sensor data for maintenance use. Trafikverket attributed part of its success in Digital Winter to early identification of key personnel able to lead projects. While Jørgensen and Mohagheghi (2017) identified "*...Competent project personnel e.g., competent clients with good domain knowledge, competent suppliers, skilled developers and competent project leaders*" as a CSF in B2G software projects. In McKinsey's (2018) whitepaper "*hiring managers with experience in agile, customer-oriented, and data-centric*

environments" was identified as a best practice by OEMs that was considered as leading in data monetisation.

All in all, it can be said that acquiring the right competencies to lead projects involving utilizing vehicle sensor data for maintenance use is a potential CSF. As such, practitioners might benefit from putting extra effort into mapping capability gaps and identifying potential ways of fulfilling such gaps, be it hiring personnel from other, more digitally mature industries or establishing collaborations.

Project scoping & methodology

Project scoping and methodology was discussed in the context of B2G software projects, OEM data sharing and vehicle sensor data for maintenance use. In regards to project scoping, Trafikverket stated that extensive effort put into defining project specifications by the project coordinator and sponsor was considered a success factor. Jørgensen and Mohagheghi (2017) observed that the ability to change scope based on external changes and learnings was associated with success. This suggests that a purposefully balancing between investing effort initially and continuously during projects leads to good project specifications. In regards to delivery strategy, Jørgensen and Mohagheghi (2017) observed a strong correlation with frequent delivery and success, while interviewees with experience in OEMs data sharing collaboration mentioned that smaller and faster steps lead to better solutions compared to longer and slower steps. Working in smaller teams with short decision paths was mentioned as a best practice by McKinsey (2018) and by Trafikverket (2021). Trafikverket (Asp et al.,2021) emphasized clearly defining teams responsibilities while McKinsey (2018) emphasized the importance of enabling a cross-functional operational model.

Balancing effort invested in initial vs continuous scoping, adopting a frequent delivery strategy and working in smaller teams with short decision paths, clear responsibilities and with a structure that enables cross-functional working methods is indicated to be associated with success in regards to project scoping and methodology.

Transparency and understanding

Transparency and understanding were discussed in the context of B2G software projects, OEM data sharing and vehicle sensor data for maintenance use. Understanding how new data-driven services can be integrated into road authorities current workflow was considered crucial by interviewees with experience from project entailing vehicle sensor data for maintenance use. The European Commission (SWD/2018/125) in its communicated principles for data sharing recommended stipulating the minimum required level of granularity, quantity and frequency for the public interest to be served. While McKinsey (2018) in their whitepaper suggest defining a clear vision of how the service is used and sharing that vision, both internally and with partners. Some interviewees with experience from data sharing projects in the automotive sector argued that transparency into expectations and incentives with partners was of major importance. They furthermore recommended having a flexible perspective on what those expectations and incentives might be, many times there are incentives other than a monetary payment that's more aligned with business goals.

Encouraging transparency into expectations and incentives of stakeholders to facilitate understanding is associated with success. Defining a clear vision of partners' experience, defining the minimum data quality to ensure the interest is served and exploring different avenues for incentive besides monetary payment have been discussed as additional elements associated with success.

Efficient communication

Communication was discussed in the context of B2G software projects, OEM data sharing and vehicle sensor data for maintenance use. Jørgensen & Mohagheghi (2017) concluded "*...good dialogue between the client and the supplier*" and "*...good cooperation between stakeholders*" as a CSF for B2G software projects. Trafikverket's report stated that the project coordinator working actively with communication activities and communication plans against all parties contributed to the success of the project. McKinsey's (2018) whitepaper concluded that conducting coaching programs was associated with success. Interviewees with experience from data sharing projects in the automotive sector mentioned two challenges, communication channels and unpragmatic legal departments, and suggested solutions for these. In regards to communication channels, it was argued that the awareness of what communication tools fitted the purpose existed on activity level, and as such establishing communication channels in regards to code, Q&A and meeting protocols might benefit from a bottom-up approach rather than the opposite. In regards to unpragmatic legal departments on the OEM side, it was suggested to suggest concrete solutions that are tightly tied to the OEMs business goals and interests.

The above-mentioned research suggests that good communication between stakeholders is a potential CSF. Potential activities to fulfil this CSF include for the project coordinator working actively with communication activities and plans, having a bottom-up approach to establishing communication channels and conducting formal joint coaching programs.

Designing beneficial licensing contracts

License contract design was discussed primarily in the context of B2G data sharing projects but was also mentioned in the context of vehicle sensor data for maintenance use. It was argued by Asp et al., that adapting the procurement model to the specific scenario contributed to the success of Digital Winter. In the case of Digital Winter the Swedish road authority only allowed tenders from selected actors and contractually regulated reuse of procured data for specified purposes. Contractually regulating reuse and redistribution of data was suggested by the European Commission communication data sharing principles as well. In this regard, they suggest considering regulating reuse to specified purposes or time periods. Other aspects discussed in the communication by the European Commission include liability, compensation, quality assessment and safeguarding. In regards to liability, it was suggested that the data provider should not be held liable for data quality or use. In regards to compensation, it was indicated that prices could be based on the savings made when data was used or potential harm if it weren't. It might also be beneficial to take into consideration that preferential and non-discriminatory treatment is expected. Quality assessment could entail major costs and clearly stipulating who has what responsibilities in regards to this was considered good practice. In Digital Winter the project utilized a university as an independent party to evaluate data. Safeguarding was discussed in the context of privacy, security and non-discrimination rights of stakeholders, including individuals. In consideration of this, clearly stipulated conditions and mechanisms, such as data stewards, as to prevent misuse was suggested in the communication.

In consideration of the above-mentioned research designing a beneficial licensing contract is suggested as a potential CSF. The investigation indicates that such a contract regulates reuse and redistribution of data as well as addresses liability, compensation, quality assessment and safeguarding concerns by considering the above-mentioned elements.

Identify synergetic solutions
Identifying synergetic solutions was exclusively discussed within the context of data sharing projects in the automotive sector (without the context of a specific purpose). McKinsey (2018) made the following suggestion based on observing leading actors - “*Define a two-tiered approach to capturing and using data for use cases – one for internal clients (various departments and units) and one for B2B clients along the value chain*”. Interviewees with experience from data sharing projects within the automotive sector gave additional nuance to this when discussing the importance of not getting stuck in trying to figure out what to do with existing data and instead looki forwards. This might be related to legal barriers arising from regulations regarding legal ground or from contracts regarding reuse of data. Identifying solutions with synergistic effects was also discussed in the context of creating centralized solutions such as a separate story solution, as opposed to a solution relying on partners API, or making certain internal tools available for external use, as opposed to making separate tools for external vs internal use. Identifying solutions or activities with synergetic effects was also discussed within a legal context. Here interviewees discussed things such as creating ready to share data packages, implementing certain anonymization software and establishing certain data governance practices such as incorporating legal tags into data storage and distributing accountability amongst data stewards.

Surveying for and acting upon opportunities and solutions with synergistic effects might be especially important in the context of data monetisation. The investigation indicates that surveying for opportunities to recapitalize on data should be balanced towards future data as opposed to legacy data. Interviewees also suggest solutions with synergetic effects within a technical and legal context.

Choosing the right partners
Choosing the right partners was discussed in the context of sharing vehicle sensor data for maintenance use and data sharing within the automotive sector. Having the right ecosystem of actors involved early on in the project was associated with success by interviewees who had experience from vehicle sensor data sharing for maintenance use. Interviewees from the automotive sector emphasized the importance of considering the effect on the firm's strategic position in choosing partners while also arguing for decreased barriers for third parties to enter their software ecosystem. In relation to vehicle sensor data for maintenance use, partnerships that enable scalability in regards to coverage could be said to strengthen a firm's strategic position as this was mentioned to be amongst the most crucial aspects when choosing a provider by road authorities. In Trafikverkets (2021) report one of the mentioned success factors of the project Digital Winter was described as; Trafikverket signed contracts with several actors to build a network of suppliers and secure satisfactory coverage of road networks. Partnerships that enable interoperability (such as in the case of Mobileye and

Arcgis) or further analytical and monetisation capabilities (such as Tactile mobility and several OEMs) could also be said to increase a firm's strategic position.

Based on the research mentioned above, choosing the right partners is suggested as a potential CSF. What is considered a right partner is likely dependent on what capabilities or resources the firm requires. In the terms of road maintenance, such capabilities and resources might be those enabling scalability, interoperability or further analytical or monetisation capabilities. Activities that contribute to choosing the right partners include defining structured criteria for evaluating potential partners, record and assess what criteria are associated with success and considering how partners could strengthen the strategic position of the firm.

Running pilot projects

Running pilot projects to demonstrate and test the value of new data-driven service was discussed mostly in the context of sharing vehicle sensor data for maintenance use but was also implied to be associated with success in the European Commission communication in regards to B2G data sharing projects (SWD/2018/125). In Trafikverkets (Asp et al., 2021) report on Digital Winter conducted a pilot project and considered this a success factor. Interviewees from both the private and public sectors mentioned that conducting pilot projects was associated with success. In the European Commission communication “pilot projects” weren't explicitly stated as being associated with success, but demonstrating value was. Because pilot projects is one way of clearly demonstrating value, this was interpreted as such.

Conducting pilot projects was associated with success in B2G projects, and especially so in relation to vehicle sensor data for maintenance use. The exploratory nature of the use case and nascent market condition might be contributing factors to this, in which case the suggested CSF regarding pilot projects could be considered a temporary one which might not be as critical in a future, more mature data market for vehicle sensor data for maintenance use. An example of this is the Digital Winter project in which Trafikverket reports that the end goal is to enable Trafikverket to procure data from multiple sources to implement in their self-developed user interface.

Cohesively manage intraorganisational forces

Identifying and managing intraorganisational forces was exclusively discussed in the context of data sharing projects within the automotive sector. As OEM are trying to redefine their organisational model to better embrace digital innovations a variety of intraorganisational forces come into play. Interviewees discussed for example the importance of having awareness of strategic and operational interests. An efficient software architecture and good description in code might require larger investments but decreases future manual labour and enables extensive standardization of processes. McKinsey (2018) suggests for practitioners to not fear workarounds or intermittent solutions to address current gaps but simultaneously suggests not neglecting to build more permanent solutions for future excellence. Lindgrens et al (2017) identified several such forces in their research. In redefining the organisation model interviewees associated top management support and driving change in a top-to-bottom approach with success. McKinsey (2018) found that an organisational model that facilitates cross-functional collaborations was associated with success. They furthermore emphasize the importance of constructing mechanisms that ensure organisational change. Such mechanisms, that were mentioned by interviewees to be associated with success, include defining clear objectives with deadlines to reference towards. Continuously revisiting and improving the process of defining such objectives and deadlines might thus enable managers to cohesively manage intraorganisational forces resisting a redefined organisational model.

Cohesively managing intraorganisational is suggested as a potential CSF. How to balance between these forces is likely dependent on the specific firm and scenario, but driving change top-to-bottom and purposefully improving the process of defining objectives and deadlines might be associated with success.

5.4.5 Conclusions & discussion

This chapter summarises the methodology used in the construction of the nine conjectured CSF. First, the sources used in the investigation are discussed. This is followed by a discussion on the methodology and result. The result was further investigated in terms of relevancy to actors and context of associated factors, this is illustrated in the image below the discussion.

The investigation of critical success factors is built on primarily four previous studies and 15 interviews categories in either group A or group B. The former, group A, was interviewed within the specific context of the vehicle sensor data for road maintenance use. The latter, group B, was interviewed without context to the specific use case but rather within the broader context of vehicle sensor data monetisation. The information sources used were categories depending on what context they were written in. In total three contexts were identified, these were: Case-specific, B2G data sharing and software projects, and Sharing vehicle sensor data.

A report from the Swedish road authority, Trafikverket, was used to identify case-specific factors, as such, both factors extracted from interviews with group A and from said article was categorised as originating from a case-specific context. Two of the analysed articles were written in the broader context of B2G data sharing and software projects, meaning without context to the specific use case or the specific data source (vehicle sensors). One of these articles was a communication by the European Commission in which principles for data sharing were designed. The other article by Jørgensen & Mohagheghi (2017) identified success factors for B2G software projects. One article from McKinsey (2018) combined with information from interviewees in group B was categorised as being in the broader context of Sharing vehicle sensor data, meaning without the context to either use case or target customer.

The investigation deconstructed the identified factors by interpretive analysis of these. The deconstructed factors were then reconstructed based on similarity. This resulted in nine areas in which the factors were perceived to relate to. These areas were considered to be the conjectured critical success factors for realising data-driven road maintenance services by utilizing vehicle sensor data.

As a result of the sources used to construct the CSF all of the factors could be considered to be actionable. Meaning they are not factors describing environmental factors which could be considered beneficial, nor are they negative, meaning that they don't describe “critical failure factors”. This is a result of using sources that describe either best practices or principles they perceive to be associated with success. While this method may provide a more useful critical success factor in some aspects it could be argued to be detrimental to the research. It can for example be observed that there are no factors describing important data quality consideration, such as timeliness or reliability, which might be critical to fulfilling within the investigated context. To fill this research gap there is however a need to engage more interviewees with experience from realising the investigated use case. Since the investigated context is within a nascent market, such interviewees are hard to find and convince to participate. It should be noted that future research might not have this problem.

The conjectured CSF with associated sources are illustrated in the image below. The factors are further put in the context of the previously constructed scenario mentioned in the regulator chapter. The scenario assumes a collaboration between an OEM and a third party. In which the OEM is seen as a data provider to the third-party while the third-party takes the role of data analyst and project coordinator.

As can be seen in the illustration some factors relate more to the OEM while others could be considered equally relevant for the OEM, the third-party and the municipality. Unsurprisingly the two critical success factors perceived more relevant to the OEM and not so relevant for the other parties were constructed from factors identified within the broader context of vehicle data monetisation. While some of the factors were perceived as relevant for all three actors they could be related to the actors in different ways.

It can be further observed the wide variety in the number of sources associated with the factor. While this shouldn’t be interpreted to relate to the importance of factors - it could suggest which of the constructed factors are too wide or too narrow. *Running pilot projects* have for example three sources associated with it, since this factor is closely related to *Project scoping and methodology; these* might be merged to provide a narrower set of CSF. The CSF termed *Designing beneficial licensing contracts* had the most associated factor which might indicate that this should be further divided to mitigate the loss of information in the simplification

Context	Case specific		B2G data sharing and software projects		Sharing vehicle sensor data	
Sources	(Trafikverket 2021)	(Interviews - case specific, Group A)	European commision (SWD, 2018)	(Jørgensen & Mohagheghi 2017)	(Interviews - OEM data sharing, Group B)	(McKinsey's 2018)
# factors	10	4	8	3	17	7

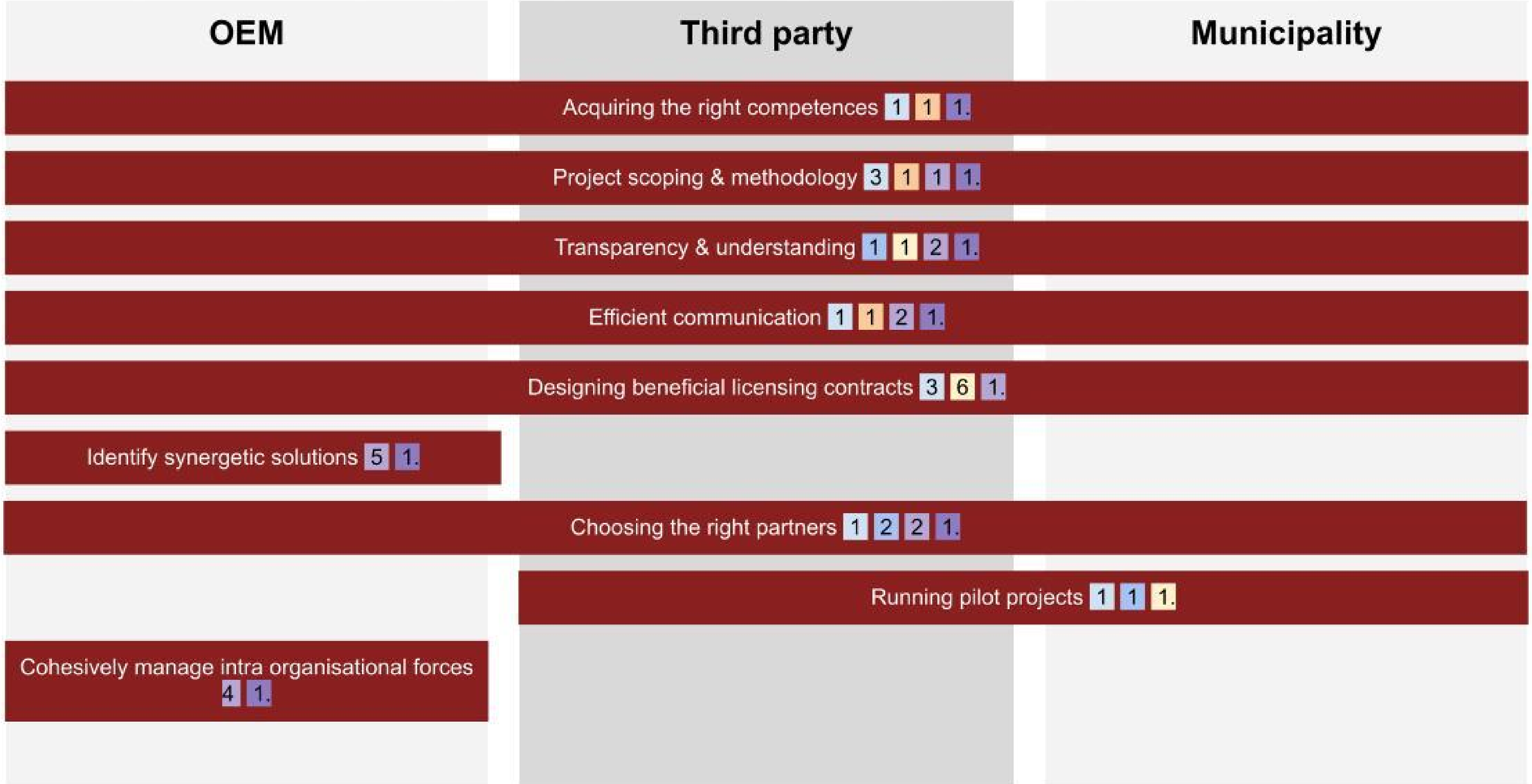

Figure 9, success factors summary illustration

6 Conclusion & Discussion

While still in a nascent stage, utilizing vehicle sensor data for road asset maintenance is an emerging phenomenon. While competing solutions such as mapping vehicles and dashcams might present more market-ready solutions these aren't without limitations. The former suffer severe limitations in regards to coverage and frequency, the latter in user engagement and reliability. As the demand for road asset data (primarily in the form of HD maps and annotated road images) grows within the automotive sector new recapitalization opportunities and fundings drive incumbent solutions towards new heights. The accelerated development of existing solutions combined with the resistant innovation culture, high transition cost, protracted development cycles and long procurement contracts on the road authority side makes time of essence for OEMs aiming to capitalize on data-driven infrastructure maintenance services.

Monetisation of vehicle sensor data is however subject to a wide range of regulations, the interpretation of which remains in an exploratory phase. The lack of praxis and multitude of regulations complicates the realisation of new monetisation opportunities, maybe especially so in the context of B2G data sharing. This study has aspired to identify and contextualise relevant regulations to facilitate the navigation of these regulations.

The investigation of regulation was framed by a constructed transaction chain which provided a basis for categorising regulation. This resulted in - as pointed out by legal subject matter experts - a gross simplification of the relevancy as regulations scopes might span from the data being generated to the data being used. This was however not considered to be a major concern as the discussion of implications could be considered interoperable with the other parts of the chain.

Between the vehicle and data portal the most relevant regulation related to either privacy or security-related regulations. Besides the general implications inherent in vehicle sensor data monetisation discussed previously - the investigation found that the legal grounds for which personal data might be processed to be fragmented into two major areas. Vehicle sensor data that could be classified as Road Safety-related data (Directive 886/2013) and vehicle sensor data that was not. Road Safety-related data is subject to different regulations, accordingly what legal grounds can be argued for might differ. Furthermore, it has implications for sharing obligations - both for the data provider and the public sector bodies receiving said data. Data provided for reactive maintenance purposes might or might not be classified into this category. Consider for example a temporary slippery road, this is clearly defined as Safety-related data in directive 886/2013 and could be considered as data utilized for reactive maintenance. Both "temporary" and "slippery" can however be subject to a rather wide interpretation. Is slipperiness caused by ice for example considered temporary? And how low friction must a car bear before it is considered slippery? While current praxis in projects such as Data For Road Safety in Europe or Digital Winter in Sweden provides some insight to this - the question of what regulatory domain road asset data falls under remains a bit unclear, especially so in cases of aggregated and mixed data sets.

Between the data portal and third parties, the most relevant regulation were those relating to IPR or anti-competitive practices. The analysis of IPR for road asset data indicates that sui generis rights as stipulated in the database directive, combined with contractual and technical solutions is the most appropriate for protecting road asset data in transactions between OEMs and third parties. The appropriateness of sui generis right in relation to road asset data is however largely dependent on the specific scenario and future interpretation made by CJEU. One important consideration might be the level of abstraction of assets and whether or not features could be considered independently and make sense. Another relevant concern is in relation to fulfilling the "substantial investment" criteria. Previous rulings have made clear that substantial investment should be interpreted as to refer to the investment in "obtaining and verification" of data and not to the "creation" of data. Whether data resulting from recordings of natural phenomena would be considered "obtaining" or "creating" data remains unclear, as does what will amount to a "substantial" investment in relation to crowdsourced data generated by individuals and collected by private actors (Alexander & Jankowska, 2018).

After investigating the regulatory environment the study turned to identify challenges. The investigation of challenges indicate that practitioners perceive primarily four legal concerns;

- Data privacy in relation to legal grounds for processing personal data.
- Fragmented ownership due to privacy regulations, complex contractual relationships, lack of praxis in IPR and sharing obligations
- Liability concerns in relation to GDPR, Product liability Directive and Type Approval Regulation
- Compliance concerns in relation to cybersecurity regulations

While the regulatory analysis touched on some of these topics, it can't be said that these uncertainties were clarified or that the regulatory analysis even aspired to resolve these challenges. The research methodology of first researching the regulatory landscape and then researching the challenges might be argued to be detrimental to the applicability of the research result. But due to the limited prior knowledge by the researcher and the many existing researchers engaged in elucidating these uncertainties the potential contribution by this study concerning these challenges would be limited indeed.

In regards to challenges from a business perspective the discussions in prior literature seem to revolve around three areas;

1. Convincing the primary consumer (i.e the driver) of the value of the service or value of giving consent for data collection.
2. Redefining the organisational model as to facilitate cross-functional working methods, shorten development cycles and transition from a vehicle sale based revenue stream to aftermarket service-based revenue
3. Establishing partnerships with third parties and ensuring efficient communication as well as trust and understanding between parties.

In regards to the first challenge, the investigation indicates that primary consumers are more willing to give consent for data being shared for road maintenance purposes than that of other purposes such as usage-based insurance. The second challenge might be complicated by the relatively uncertain business model regarding road maintenance and

B2G projects. The third challenge could also be considered to be complicated rather than mitigated by the specific context of the use case as road asset data is indicated to have a relatively high perceived strategic value. Road asset data could for example reveal sensitive information such as the progress of software development or it might be utilized for commercial purposes by competitors if leaked. As such additional trust and control might be required for realising this use case in comparison to use cases utilizing data perceived to have less strategic value.

In regards to business challenges the additional context provided by investigating the realisation of vehicle sensor data for road asset maintenance as opposed to vehicle sensor data monetisation without context to the purpose - provided much-needed insight into the relevance of challenges in regards to use cases. Concerning business challenges, It should also be noted that interviewees mentioned much of the same challenges identified by previous researchers in this area.

Interviewees perceptions and previous researchers findings were not as congruent in the context of technical challenges. While most of the discussion with both interviewees and within previous literature revolves around the transmission of data - both between the vehicle and the data portal and between the data portal and the data user or third party. How these technical challenges were perceived varied quite a lot. While this is to be expected as what technical challenges practitioners face depend heavily on the level of technical progress it was also identified to vary depending on what technical solutions were employed. For example; if a firm chooses a third-party solution to host and distribute data or internally develop such capabilities - if a firm chooses to invite third parties to their platform to run algorithms or if data was transferred to the third-party platform before further processing was done - if data was transferred via cellular or DSRC technology in communication between vehicle and data portal. Furthermore, what technical challenges exist and to what extent they pose a barrier was identified to depend on exactly what data was transferred - consider for example the difference between safety-related messages and snapshots of traffic signs. Due to many factors heavily influencing technical challenges, the investigation of these might have benefited from additional contexts, such as one specific organisation and one specific type of data.

Due to the inherent subjective - and case-specific exploratory - nature of identifying critical success factors - the inability to achieve scientific rigour in extracting these didn’t discourage the study to move in this direction. Accordingly, the purpose of the study is not to determine the actuality of these factors but rather to propose conjectures for future researchers or practitioners as to what might be the most important factors to consider in realising this use case.

The aggregation of best practices, principles and success factors from three different contexts made for some interesting observations. The identified factors were deconstructed and analyzed in regards to similarity. The factors were imported into an excel sheet and colour coded depending on where they were extracted from and what context they were identified in. This illustration is included in appendix A. In some cases such as with the proposed “Identify synergic solutions” and “Cohesively manage intraorganisational forces” factors - these were discussed exclusively in the context of vehicle sensor data monetisation, meaning without consideration to specific use cases. While others such as

“Acquiring the right competencies”, “Project scoping & methodology”, “Transparency & understanding” and “Efficient communication” were discussed in all three contexts. The fact that some were exclusively mentioned within one context and others in all three might indicate which factors could be seen as inherent in vehicle sensor data monetisation and which are inherent to the specific case. This is not to say however that one is less important to the other in realising said use case.

Another aspect highlighted in the colour coded illustration is the number of references made to the critical success factors. The one aspect that had the most factors tied to it was “Designing beneficial licensing contracts” while the ones that had the fewest were “Running pilot projects” and “Acquiring the right competencies”. The result should however not be interpreted as one being more associated with success than another. But it could indicate which of the factors were interpreted to be widely encompassing and which were too narrow. This is an especially relevant concern as the investigation resulted in 9 critical success factors while 3-5 is the norm and the recommended amount for practical reasons.

The study made no effort to prioritise the factors in regards to importance. While this might provide a more digestible reading it would be purely subjective and entail gross simplifications. It would simply put, be too misleading to outweigh the additional practicality it might induce.

Reference list

Aerts, P.-J. (2019). New EU regulation on the free flow of non-personal data: what is non-personal data and should I be worried about transfers of non-personal data? [web log]. Retrieved November 1, 2021, from https://www.dentons.com/en/insights/articles/2019/november/22/new-eu-regulation-on-the-free-flow-of-non-personal-data.

AGREEMENT FOR LIDAR AND IMAGERY SERVICES. (2017). Party CycloMedia Technology & City of Redlands.

Ai, C. (2013). A SENSING METHODOLOGY FOR AN INTELLIGENT TRAFFIC SIGN INVENTORY AND CONDITION ASSESSMENT USING GPS/GIS, COMPUTER VISION AND MOBILE LIDAR TECHNOLOGIES. *Georgia Institute of Technology*.

ALEMANNO, A. L. B. E. R. T. O. (2020). Towards a European strategy on business-to-government data sharing for the public interest. *High-Level Expert Group on Business-to-Government Data Sharing*.

Alexander, I., & Jankowska, M. (2018). RIGHTS IN GEOSPATIAL INFORMATION: A SHIFTING LEGAL TERRAIN. *Melbourne University Law Review*.

Alkharashi, A., & Renaud, K. (2018). Privacy in crowdsourcing: A systematic review. *Developments in Language Theory*, 387–400. https://doi.org/10.1007/978-3-319-99136-8_21

Amberg, M., Fischl, F., & Wiener, M. (2006). BACKGROUND OF CRITICAL SUCCESS FACTOR RESEARCH WORKING PAPER NO . 2 / 2005.

Ansari, D. (2009). *The Ec Essential Facilities Doctrine, the Microsoft Case and the Treatment of Trade Secrets* (thesis). Commercial and Business Law Programme.

Arnesdotter, M. (2018). Automating the Process: Collecting Traffic Sign Data in Clovis. Retrieved October 31, 2021, from https://blog.mapillary.com/update/2018/11/14/streamlining-traffic-sign-inventory-in-clovis.html.

Asp, A., Casselgren, J., Eriksson, D., & Eriksson, C., Digital Vinter (2021). Trafikverket.

Automat. (2017). FP of Vehicle & OEM Data Products & Services. *Automotive Big Data Marketplace for Innovative Cross-Sectorial Vehicle Data Services*.

Baecker, J., Engert, M., Pfaff, M., & Krcmar, H. (2020). Business strategies for data monetisation: Deriving insights from practice. *WI2020 Zentrale Tracks*, 972–987. https://doi.org/10.30844/wi_2020_j3-baecker

Basegmez, M. (2020). MUNICIPAL GIS. *Geographic Information Systems*.

Bastien, G., Hautiere, N., Khojinian, A., & Shirts, R. (2018). eeevent2018. In *Preparing the asphalt industry for the future*. Berlin; E&E EVENT.

Bennett, C. R., & McPherson, K. (2006). Success factors for Road Management Systems. *Infrastructure Reporting and Asset Management*, 81–85. https://doi.org/10.1061/9780784409589.ch11

Bergman, R. (2020). *A Business Model TaxonomyforData Marketplaces* (thesis). Faculty of Technology, Policy and Management.

Bertoncello, M., Camplone, G., Gao, P., Mohr, D., Möller, T., & Wee, D. (2016). Monetizing car data: New service business opportunities to create new customer benefits. *McKinsey & Company*.

Bhandari, T. (2018). Transform Road Maintenance and Repair with Predictive Analytics [web log]. Retrieved October 31, 2021, from https://www.cyient.com/blog/utilities/transform-road-maintenance-and-repair-with-predictive-analytics.

BRADFORD, A. N. U. (2021). *Brussels effect: How the European Union Rules the World*. OXFORD UNIV PRESS US.

Broek, T. van den, & Veenstra, A. van F. (2018). Governance of Big Data Collaborations: How To Balance Regulatory Compliance and disruptive innovation. *Technological Forecasting and Social Change*, *129*, 330–338. https://doi.org/10.1016/j.techfore.2017.09.040

Bruno, A.V. & Leidecker, J.K. (1984). Identifying and using critical success factors. Long Range Planning, 17, 23-32

Bryman, A., & Bell, E. (2011). *Business research methods*. Oxford University Press.

Case C-490/14, (Freistaat Bayern v Verlag Esterbauer GmbH, October 29, 2015).

Casey, M. (2007). Partnership – success factors of Interorganisational Relationships. *Journal of Nursing Management*. https://doi.org/10.1111/j.1365-2934.2007.00771.x

CMS LAW. (2021). *E-PRIVACY EUROPEAN REGULATION ON PRIVACY AND ELECTRONIC COMMUNICATION*. Retrieved October 31, 2021, from https://cms.law/en/deu/insight/e-privacy.

CORDIS. (2019). *CROWD sensing and ride sharing FOR ROAD Sustainability*. Retrieved October 31, 2021, from https://cordis.europa.eu/project/id/687959.

Cyclomedia. (2021). *Capturing and processing data*. Cyclomedia. Retrieved October 31, 2021, from https://www.cyclomedia.com/us/capturing-and-processing-data.

Cyclomedia. (n.d.). *Automatic detection of road defects*. Retrieved October 31, 2021, from https://www.cyclomedia.com/us/road-surface-analysis.

Data Task Force. (2020). Final report & recommendations. Retrieved October 31, 2021, from https://www.dataforroadsafety.eu/images/Documenten/DTF-REPORT-OCTOBER-2020-021020.pdf.

Datex2. (2020). *Profile for Safety Related Traffic Information (SRTI) created from in-vehicle data*. Retrieved October 31, 2021, from https://datex2.eu/implementations/profile_directory/profile-safety-related-traffic-information-srti-created-vehicle.

De Hert, P., Papakonstantinou, V., Malgieri, G., Beslay, L., & Sanchez, I. (2018). The right to data portability in the GDPR: Towards user-centric interoperability of Digital Services. *Computer Law & Security Review*, *34*(2), 193–203. https://doi.org/10.1016/j.clsr.2017.10.003

Drexl, J. (2016). Designing competitive markets for industrial data - between Propertisation and access. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.2862975

DriveSweden. (2020). *Stockholm Virtual City*. Retrieved October 31, 2021, from https://www.drivesweden.net/projekt-3/stockholm-virtual-city.

Du, Y., Liu, C., Wu, D., & Jiang, S. (2014). Measurement of International roughness index by USINGZ-axis accelerometers and GPS. *Mathematical Problems in Engineering*, *2014*, 1–10. https://doi.org/10.1155/2014/928980

EIJ Journal. (2017). Cartegraph and CycloMedia Partner to Deliver Timely, Objective Asset Data to the Public Sector [web log]. Retrieved October 31, 2021, from https://eijournal.com/news/business-2/cartegraph-and-cyclomedia-partner-to-deliver-timely-objective-asset-data-to-the-public-sector.

Ertler, C., & Quack, T. (2020). Introducing the Quality Score - Automated image quality estimation [web log]. Retrieved October 31, 2021, from https://blog.mapillary.com/update/2020/11/05/introducing-the-quality-score.html.

ESRI. (2017). *Los Angeles, California, Takes Quick Inventory of Its Traffic Signs*. Retrieved October 31, 2021, from https://www.esri.com/library/casestudies/la-ca-takes-quick-inventory-of-traffic-signs-web.jpg.

ESRI. (n.d.). *ArcGIS Marketplace*. Retrieved October 31, 2021, from https://www.esri.com/sv-se/arcgis-marketplace/overview.

EU road federation. (EU road federation, Ed.), ROAD STATISTICS YEARBOOK 2017 (2017). European union road federation.

EuroGeographics, EuroGeographicsBriefing PaperEvaluation of the Database Directive 96/9/EC (2017).

European Commision, Discussion paper: State of infrastructure maintenance (2019). GROW.DDG1.C.4.

European Commission. (n.d.). *From the Public Sector Information (PSI) Directive to the Open Data Directive*. Shaping Europe’s digital future. Retrieved November 1, 2021, from https://digital-strategy.ec.europa.eu/en/policies/psi-open-data.

EUROPEAN DATA PROTECTION SUPERVISOR. (2020). *Interoperability*. Retrieved October 31, 2021, from https://edps.europa.eu/data-protection/our-work/subjects/interoperability_en.

Exner, J.-P., Werth, D., & Nalbach, O. (2020). Monitoring Street Infrastructures with Artificial Intelligence. *REAL CORP 2020:SHAPING URBAN CHANGE LIVABLE CITY REGIONS FOR THE 21st CENTURYAt*.

Federle, A., & Asbroeck, B. V. (2020). Data Access Claims Under Competition Law and Data Privacy Requirements. Retrieved November 1, 2021, from https://www.lexology.com/library/detail.aspx?g=caa18f96-739e-4aed-9622-fa833cdb3804.

Foroudi, P. (2020). *Contemporary issues in branding*. Routledge.

Fridolin, J. K. (2019). *Opportunities and Barriers for Advancing the Api Economy within the AutomotiveIndustry* (thesis). DEPARTMENT OF INFORMATICS.

Funk, A. K., Transport Infrastructure Investments in Switzerland (2017). EUROCONSTRUCT.

Geoforum. (2012). *360⁰ street-view nu tillgänglig via Blom*. Retrieved October 31, 2021, from https://geoforum.se/nyheter/43-medlemsnytt/1017-360-street-view-nu-tillganglig-via-blom.

Gorka, S. (2020). *Moving from tangible to intangible: How carmakers deploy data monetisation* (thesis).

Graham , A. (2020). Driven by informationSecuring the benefits from connected vehicles. *RAC Foundation*.

Guidelines 1/2020, Guidelines 1/2020 on processing personal data in the context of connected vehicles and mobility related applications (n.d.). The European Data Protection Board.

Guidelines D2.8.I.7, D2.8.I.7 INSPIRE Data Specification on Transport Networks – Guidelines (2009). INSPIRE Thematic Working Group Transport Networks.

Helbig, N., Sandau, J., & Heinrich, J. (2017). The Future of the Automotive Value Chain2025 and beyond. *Deloitte*.

HERE Technologies. (2018). Full Prototype of Cross-Sectorial Vehicle Data Services. *Automotive Big Data Marketplace for Innovative Cross-Sectorial Vehicle Data Services (AUTOMAT)*.

HERE. (2017). *Road Roughness - HERE Map Data*. Retrieved October 31, 2021, from https://www.geomer.de/fileadmin/downloads/produkte/here-map-data/here_road_roughness_2017.pdf.

HERE. (n.d.). *HERE Marketplace*. Retrieved October 31, 2021, from https://www.here.com/platform/marketplace.

Howell, J. (2019). Esri and ArcGIS. *Digital Innovation and Transformation*.

IRMD. (2018). Maintaining roads is protecting the environment. In *International road maintenance day*. Europe; Road maintenance day.

IT Federal Sales. (n.d.). *IT Federal Sales GSA Contract GS-35F-0494T through 06/25/2022*. Retrieved October 31, 2021, from http://www.itfederalsales.com/gsa-schedule/.

Karimzadeh, A., & Shoghli, O. (2020). Predictive analytics for Roadway Maintenance: A review of current models, challenges, and opportunities. *Civil Engineering Journal*, *6*(3), 602–625. https://doi.org/10.28991/cej-2020-03091495

Kaushik, V., & Walsh, C. A. (2019). Pragmatism as a research paradigm and its implications for Social Work Research. *Social Sciences*, *8*(9), 255. https://doi.org/10.3390/socsci8090255

Keegan, K., Miller, T., & Sounart, S. (2021). Traffic Sign Inventory and Condition Assessments Get Smarter With Artificial Intelligence [web log]. Retrieved October 31, 2021, from https://www.kimley-horn.com/traffic-sign-inventory-condition-assessments-smarter-with-ai/.

Kerber, W., & Moeller, D. (2019). Access to data in connected cars and the recent reform of the Motor Vehicle Type Approval Regulation. *SSRN Electronic Journal*. https://doi.org/10.2139/ssrn.3406021

Klopfenstein, L. C., Delpriori, S., Polidori, P., Sergiacomi, A., Marcozzi, M., Boardman, D., Parfitt, P., & Bogliolo, A. (2019). Mobile crowdsensing for road sustainability: Exploitability of publicly-sourced data. *International Review of Applied Economics*, *34*(5), 650–671. https://doi.org/10.1080/02692171.2019.1646223

Kovács, G. and Spens, K.M. (2005), "Abductive reasoning in logistics research", International Journal of Physical Distribution & Logistics Management, Vol. 35 No. 2, pp. 132-144. https://doi.org/10.1108/09600030510590318

KPMG. (2020). Automotive Data Sharing. Retrieved October 31, 2021, from https://assets.kpmg/content/dam/kpmg/no/pdf/2020/11/Automotive_Data_Sharing_Final%20Report_SVV_KPMG.pdf.

LAR-IAC5. (2015). Between party County of Los Angeles Cyclomedia Technology Inc. *For the Agreement between County of Los Angeles and Pictometry International Corp for Digital Aerial Imaging (LAR-IAC5))*. https://doi.org/https://egis2.gis.lacounty.gov/hub/lariac_documents/LARIAC5_Pictometry_Change_Notice_22_20191118_CycloMedia.pdf

Leichman , A. K. (2021). Vehicles collect real-time road data, in world's first nationwide survey [web log]. Retrieved October 31, 2021, from https://www.israel21c.org/nationwide-israeli-survey-uses-tactile-data-gathering-to-understand-the-roads/.

Leon, L. F., & Quinn, S. (2018). The value of crowdsourced street-level imagery: Examining the shifting property regimes of OpenStreetCam and mapillary. *GeoJournal*, *84*(2), 395–414. https://doi.org/10.1007/s10708-018-9865-4

Li, W., Burrow, M., Metje, N., & Ghataora, G. (2020). Automatic road survey by using vehicle mounted laser for road asset management. *IEEE Access*, *8*, 94643–94653. https://doi.org/10.1109/access.2020.2994470

Lindgren, R., Mathiassen, L., & Svahn, F. (2017). Embracing digital innovation in incumbent firms: how volvo cars managed competing concerns. *MIS Quarterly*, *41*(1), 239–253. https://doi.org/10.25300/misq/2017/41.1.12

Luiten, B., Böhms, M., Alsem, D., & O'Keeffe, A. (2018). Asset information management for European roads using linked data. *Transport Research Arena TRA*.

Lundqvist, B. (2016). Big Data, Open Data, Privacy Regulations, Intellectual Property and Competition Law in an Internet of Things World. *Faculty of Law, University of Stockholm Research Paper No. 1*.

MacHardy, Z., Khan, A., Obana, K., & Iwashina, S. (2018). V2X access technologies: Regulation, research, and remaining challenges. *IEEE Communications Surveys & Tutorials*, *20*(3), 1858–1877. https://doi.org/10.1109/comst.2018.2808444

Magadzi. (2017, November 7). *Sa National Roads Agency (SANRAL) 2016/17 annual report; transport*. Parliamentary Monitoring Group. Retrieved October 31, 2021, from https://pmg.org.za/committee-meeting/25429/.

Maheswaran, M., Zhu, X., & Yu , T.-Y. (2018). Vehicular Crowdsensing for smart cities. *Handbook of Smart Cities*, 175–204. https://doi.org/10.1007/978-3-319-97271-8_7

Mapillary(a). (2016). *Mapillary Hires Award Winning Computer Vision Team to Lead New Research Lab in Graz, Austria*. Retrieved October 31, 2021, from https://www.globenewswire.com/news-release/2016/05/19/1052915/0/en/Mapillary-Hires-Award-Winning-Computer-Vision-Team-to-Lead-New-Research-Lab-in-Graz-Austria.html.

Mapillary. (2016). *Mapillary Hires Award Winning Computer Vision Team to Lead New Research Lab in Graz, Austria*. Mapillary. Retrieved October 31, 2021, from https://www.globenewswire.com/news-release/2016/05/19/1052915/0/en/Mapillary-Hires-Award-Winning-Computer-Vision-Team-to-Lead-New-Research-Lab-in-Graz-Austria.html.

Mapillary. (2020). *How does Mapillary work*. Retrieved October 31, 2021, from https://help.mapillary.com/hc/en-us/articles/115001770269-How-does-Mapillary-work.

Mapillary. (2021). *https://help.mapillary.com/hc/en-us/articles/360020754199-Pricing*. Pricing. Retrieved October 31, 2021, from https://help.mapillary.com/hc/en-us/articles/360020754199-Pricing.

Mapillary. (n.d.). *Learn how map makers, cities, agencies, and NGOs use Mapillary imagery and map data.* Mapillary. Retrieved from https://www.mapillary.com/showcase.

MapillaryI(L). (2021). *Licenses*. Retrieved October 31, 2021, from https://help.mapillary.com/hc/en-us/articles/115001770409-Licenses.

Martens, B., Streel, A. de, Graef, I., Tombal, T., & Duch-Brown, N., Business-to-Business data sharing: An economic and legal analysis (2020). European Commission.

McKinsey. (2018). FROM BUZZ TO BUCKS – AUTOMOTIVE PLAYERS ON THE HIGHWAY TO CAR DATA monetisation. *McKinsey & Company*. Retrieved from https://www.mckinsey.com/~/media/McKinsey/Industries/Automotive%20and%20Assembly/Our%20Insights/Accel erating%20the%20car%20data%20monetisation%20journey/From-buzz-to-bucks-automotive-players-on-the-highway-to-car-data-monetisation-web-final.pdf.

McKinsey. (2020). Cybersecurity in automotive. *McKinsey & Company*. Retrieved October 31, 2021, from https://www.mckinsey.com/~/media/mckinsey/industries/automotive%20and%20assembly/our%20insights/cybersecurity%20in%20automotive%20mastering%20the%20challenge/cybersecurity-in-automotive-mastering-the-challenge.pdf.

Miller, T. (2009). Infrastructureusa.org. Retrieved October 31, 2021, from https://www.infrastructureusa.org/on-a-crash-course-the-dangers-and-health-costs-of-deficient-roadways/.

Minghini, M., Cetl, V., Kotsev, A., Tomas, R., & Lutz, M. (2021). Inspire: The entry point to Europe's Big Geospatial Data Infrastructure. *Handbook of Big Geospatial Data*, 619–641. https://doi.org/10.1007/978-3-030-55462-0_24

Minghini, M., Cetl, V., Kotsev, A., Tomas, R., & Lutz, M. (2021). Inspire: The entry point to Europe's Big Geospatial Data Infrastructure. *Handbook of Big Geospatial Data*, 619–641. https://doi.org/10.1007/978-3-030-55462-0_24

Mobileye. (2020). Ordnance Survey & Mobileye Create a New Type of Data Collection [web log]. Retrieved October 31, 2021, from https://static.mobileye.com/website/uk/fleets/files/CS_Riact-OS_ENG.pdf%2008032020.pdf.

Mobileye. (n.d.). *Expedite Maintenance Operations with AI-Powered Road Survey Technology*. Retrieved from https://www.mobileye.com/en/data/.

Mohagheghi, P., & Jorgensen, M. (2017). What contributes to the success of it projects? success factors, challenges and lessons learned from an empirical study of software projects in the Norwegian Public Sector. *2017 IEEE/ACM 39th International Conference on Software Engineering Companion (ICSE-C)*. https://doi.org/10.1109/icse-c.2017.146

Molokken-Ostvold, K., & Jorgensen, M. (2005). A comparison of software project overruns - flexible versus Sequential Development Models. *IEEE Transactions on Software Engineering*, *31*(9), 754–766. https://doi.org/10.1109/tse.2005.96

Moon K, Blackman D. A guide to understanding social science research for natural scientists. Conserv Biol. 2014 Oct;28(5):1167-77. doi: 10.1111/cobi.12326. Epub 2014 Jun 24. PMID: 24962114.

Moortel, I. D. (2019). Big Data & Issues & Opportunities: Data Sharing Obligations [web log]. Retrieved November 1, 2021, from https://www.lexology.com/library/detail.aspx?g=b32c5a35-8a6e-440d-8d95-d69b5a27b13a.

Napoleon, B. (2020). [web log]. Retrieved October 31, 2021, from https://www.altexsoft.com/blog/analytics-maturity-model/.

Nira Dynamics. (2021). *Nira Dynamics Road Maintenance*. Retrieved October 31, 2021, from https://niradynamics.se/road-maintenance/.

Nira Dynamics. (2021). Precise data for greater safety: NIRA Dynamics launches Road Surface Alerts with Audi to improve slippery roads warning system. Retrieved October 31, 2021, from https://niradynamics.se/precise-data-for-greater-safety-nira-dynamics-launches-road-surface-alerts-with-audi-to-improve-slippery-roads-warning-system/.

Nvidia. (2021). *HD MAPPING FOR SELF-DRIVING VEHICLES*. https://www.nvidia.com/en-us/self-driving-cars/hd-mapping/. Retrieved October 31, 2021, from https://www.nvidia.com/en-us/self-driving-cars/hd-mapping/.

OpenTender. (n.d.). *Open Tender Netherlands*. Retrieved October 31, 2021, from https://opentender.eu/nl/company/hash::group_EU_body_ce59f2420203460282980d5aa19191f614787591d8b03cab15852e84b3ab1060.

Opinion 03/2017, Opinion 03/2017 on processing personal data in the context of Cooperative Intelligent Transport Systems (C-ITS) - wp252 (n.d.). European commission.

Orrick. (2013). How EU Competition Law Applies To Data Collection Issues. Retrieved November 1, 2021, from https://www.orrick.com/Insights/2013/06/How-EU-Competition-Law-Applies-To-Data-Collection-Issues.

Patel, N. (2019). Automotive, Enterprise, IoT, and the Mobility Sector to Drive Future Location Sector Growth. *Wireless Media Strategies (WMS)*.

Patton, M. Q. (2002). Two decades of developments in Qualitative Inquiry. *Qualitative Social Work*, *1*(3), 261–283. https://doi.org/10.1177/1473325002001003636

Piantoni, M. (2021). Liabilities of Independent Service Providers when providing repair and maintenance under the Secure Onboard Telematics Platform, Legal Study. *Grimaldi Studio Legale*.

Professional service agreement. (2019). Between party Cyclomedia Technology, Inc & City of Coral Gables.

Ptolemus. (2020). VEHICLE DATA MARKET Global Study.

Rajan, P. (2020). Partnership between Tactile Mobility and HERE Technologies. Retrieved October 31, 2021, from https://www.telematicswire.net/partnership-between-tactile-mobility-and-here-technologies/.

Rao, K. N. (2017). UNIT 5 GIS DATA MODELS AND SPATIAL DATA STRUCTURE. *Ignou The Peoples University*.

RetroTek. (2020, August 14). *IS EN 1436 European Standard for Road Markings:* Reflective Measurement Systems RetroTek. Retrieved October 31, 2021, from https://www.reflective-systems.com/usa-and-european-standards/.

Rockart JF. Chief executives define their own data needs. Harvard Business Review. 1979 Mar-Apr;57(2):81-93. PMID: 10297607.

Rosner, L. J. (2020). A Privacy Playbook for Connected Car Data. *Otonomo*.

Réka, S. (2015). Cohabitation of EU Regulations and National Laws in the Field of Conflict of Laws. *Elte Law Journal*.

Saladin, M., Butler, D., & Parkinson, J. (2002). Applications of geographic information systems for Municipal Planning and Management in India. *The Journal of Environment & Development*, *11*(4), 430–440. https://doi.org/10.1177/1070496502238665

Sattar, S., Li, S., & Chapman, M. (2018). Road surface monitoring using smartphone sensors: A Review. *Sensors*, *18*(11), 3845. https://doi.org/10.3390/s18113845

Seif, H. G., & Hu, X. (2016). Autonomous driving in the icity—HD maps as a key challenge of the automotive industry. *Engineering*, *2*(2), 159–162. https://doi.org/10.1016/j.eng.2016.02.010

SIPPEL, B. (2021). PROPOSAL FOR A REGULATION ON PRIVACY AND ELECTRONIC COMMUNICATIONS [web log]. Retrieved from https://www.europarl.europa.eu/legislative-train/theme-connected-digital-single-market/file-jd-e-privacy-reform.

Soilán, M., Riveiro, B., Martínez-Sánchez, J., & Arias, P. (2016). Automatic road sign inventory using Mobile Mapping Systems. *ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, *XLI-B3*, 717–723. https://doi.org/10.5194/isprsarchives-xli-b3-717-2016

Solem, J. E. (2014). Now Supporting Panoramas and Photo Spheres [web log]. Retrieved October 31, 2021, from https://blog.mapillary.com/update/2014/09/10/support-for-pano.html.

Solem, J. E. (2020). Updating our Street Level Image Privacy Blurring. Retrieved October 31, 2021, from https://blog.mapillary.com/news/2020/08/31/imagery-privacy-blurring.html.

Stassen , M. (2019). The EU Cybersecurity Act: Addressing the Risks of a Connected Europe [web log]. Retrieved November 1, 2021, from https://www.retailconsumerproductslaw.com/2019/08/the-eu-cybersecurity-act-addressing-the-risks-of-a-connected-europe/.

Steenhuis, H.-J. (2015). Iterative-Pragmatic Case Study Method and Comparisons with Other Case Study Method Ideologies. In *The Palgrave Handbook of Research Design in Business and Management* (pp. 341–373). essay.

Stepanov, I. (2019). Introducing a property right over data in the EU: The data producer's right – an evaluation. *International Review of Law, Computers & Technology*, *34*(1), 65–86. https://doi.org/10.1080/13600869.2019.1631621

SWD/2018/125, Guidance on sharing private sector data in the European data economy (2018). European Parliament.

SWD/2019/0096, COMMISSION STAFF WORKING DOCUMENT IMPACT ASSESSMENT (n.d.). European Commission, Directorate-General for Mobility and Transport.

SWIPO, Common Scope and Approach to Article 6 of the Free Flow of Non-personal Data Regulation and use ofCodes of Conduct for Cloud Services (2020). SWIPO Common High Level Principles.

Tactile Mobility. (2021). Tactile Mobility Launches First Nationwide Tactile Data Gathering Project. *PR News Wire*. Retrieved October 31, 2021, from https://www.prnewswire.com/il/news-releases/tactile-mobility-launches-first-nationwide-tactile-data-gathering-project-301288433.html.

TED Europe. (2020). *Tender Electronic Daily European Union*. Services - 83228-2020. Retrieved October 31, 2021, from https://ted.europa.eu/udl?uri=TED:NOTICE:83228-2020:TEXT:EN:HTML&tabId=0.

Transconomy. (2021, March 16). *The process*. Transconomy. Retrieved October 31, 2021, from https://transconomy.com/the-process/.

Tribaleval. (2018). *3.1: Understanding Data Ownership*. Retrieved November 1, 2021, from https://www.jbassoc.com/wp-content/uploads/2018/03/3.1-Understanding-Data-Ownership-Data-System-Toolkit.pdf.

T'Siobbel, S. (2018). TN-ITS: A European platform for exchanging changes of road data for Autonomous Driving. *TN-ITS*.

Univrses. (2021). *3DAI™ city - univrses smart city platform*. Univrses. Retrieved October 31, 2021, from https://univrses.com/3dai-city/.

Wegen, W. van. (2017). Pioneers in Capturing Public Space [web log]. Retrieved October 31, 2021, from https://www.gim-international.com/content/article/pioneers-in-capturing-public-space.

Williams, J. J., & Ramaprasad, A. (1996). A taxonomy of critical success factors. *European Journal of Information Systems*, *5*(4), 250–260. https://doi.org/10.1057/ejis.1996.30

WINKLER, M., MEHL, R., MATTHIES, M., & MONSKE, S. (2020). MONETIZING VEHICLE DATA. *Capgemini*.

Yoong, J. (2017). I Saw the Sign: 3 Trends in Traffic Sign Inventory with Street-level Photos [web log]. Retrieved October 31, 2021, from https://blog.mapillary.com/tech/2017/03/02/traffic-sign-inventory-with-street-level-photos.html.

Ziefle, M., Halbey, J., & Kowalewski, S. (2016). Users' willingness to share data on the internet: Perceived benefits and caveats. *Proceedings of the International Conference on Internet of Things and Big Data*. https://doi.org/10.5220/0005897402550265

DEPARTMENT OF TECHNOLOGY MANAGEMENT AND ECONOMICS
DIVISION OF ENTREPRENEURSHIP AND STRATEGY
CHALMERS UNIVERSITY OF TECHNOLOGY
Gothenburg, Sweden 2021
www.chalmers.se
11

CHALMERS
UNIVERSITY OF TECHNOLOGY