# ESRIUM

## Grant Agreement No. 101004181

## Deliverable 6.4
## Market & Business Ecosystem Analysis


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EGNSS-ENABLED SMART ROAD INFRASTRUCTURE USAGE AND MAINTENANCE FOR INCREASED ENERGY EFFICIENCY AND SAFETY ON EUROPEAN ROAD NETWORKS

# D 6.4 Market & Business Ecosystem Analysis

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**Abstract**

ESRIUM is a multi-national project with the common goal to increase the safety and resource efficiency of mobility on the road. The key innovation will be formed by a homogeneous, accurate and recent digital map of road surface damage and road wear. Further addressed as “road wear map”, it will contain unique information, which is of value to multiple stakeholders: road operators will be able to lower the road maintenance effort by optimal planning. Further, road operators will be able to lower road wear and increase traffic safety especially for heavy vehicles: considering the market introduction of partly automated truck fleets and platoons, the precise track of these vehicles can be adjusted by communicating precise routing recommendations in- and cross-lane. Truck fleet operators following these recommendations can receive tolling benefits, and increase the general safety for their vehicle fleet. Especially with the increasing levels of autonomy, systems will utilize infrastructure support to handle the requirements of the automated driving task and additional external requests. In ESRIUM, these opportunities are addressed by utilizing C-ITS infrastructure and EGNSS based localization in planning the trajectories of such automated vehicles. Key to the ESRIUM innovation is a precision localization service, which provides reliable locations of road damages and of the vehicles using the roads. Considering a European-level business-case, only Galileo may provide such a service in homogeneous quality, even at very remote locations on the European continent.

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# EXECUTIVE SUMMARY

Raising awareness of road safety has increased the pressure on road operators for developing systematic and efficient planning for their road maintenance and monitoring. Similarly, new regulations, plans and objectives coming from the European Commission, such as the European Green Deal to achieve an efficient and green mobility as well as Vision Zero, aiming to reduce road deaths to zero by 2050, have enlarge road operators' accountability when it comes to maintenance. Moreover, since 2008 the European Union developed a common framework for road safety impact assessments, audits, management, and inspections that all EU members must comply with, leading to recognition of road damages monitoring importance. Therefore, seeking innovative solutions to improve road conditions by reducing damages and preventing the creation of those, and decreasing risk of accidents, congestion, pollution, and costs is imperative for all road authorities. ESRIUM's services provide a solution for these concerns through implementation of smart road infrastructure, predictive maintenance systems and cutting-edge road-wear mapping based on artificial intelligence.

Nevertheless, the road infrastructure market is a complex one, thus, studying the position of ESRIUM's technology in this market is necessary for further development of the project. The objective of deliverable 6.4 part of WP6 is to present an extensive analysis of the market and business ecosystem for ESRIUM's solution.

The business ecosystem is analyzed in this deliverable by several steps and mechanisms. Starting by studying the target market, we have targeted specific customers and countries, depending on features relevant to ESRIUM's technology. Then, we have identified current market trends related to ESRIUM's topics, such intelligent infrastructure, smart data, virtualization, and artificial intelligence. Following, a PESTLE analysis was carried out to understand the political, economic, social, technological, statutory, and environmental factors affecting the business environment. To provide a complete competitive analysis, an analysis of existing market solutions, together with a Porter's Five Forces Analysis and an assessment of existing and emerging business models was conducted. Moreover, we have estimated the market potential for ESRIUM's solution providing a perspective of the global market, the European market, and the targeted countries market. Finally, a SWOT analysis was developed to describe strengths, weaknesses, opportunities, and threats of ESRIUM's services. All these methods for assessing the business environment provide a broad perspective of ESRIUM's position in the market.

The methodology to achieve the report's results consisted of a mixed methods procedure, that can be divided into internal and external feedback/validation. From project partners within the consortium, specific inputs for developing sub-sections were needed, as well as to conduct internal workshops for improving initial forecasting and figures. From outside the consortium, road operators and potential end-users were contacted to organize interviews and an online survey to get insights and feedback.

# SECTION 1: INTRODUCTION

## 1.1. Scope of the project

The aim of the project is to set up a dynamic data service to foster greener and smarter road usage, road maintenance, and to increase road safety. ESRIUM's core proposition is a data platform, which hosts highly detailed EGNSS-referenced map data of road damages and associated safety risks at high accuracy. It holds information on damage location, damage type and the temporal prediction of the evolution of specific damages. Depending on environmental conditions and the level of traffic running over the damage, the time to a specific level of criticality is predicted and provided to road maintenance.

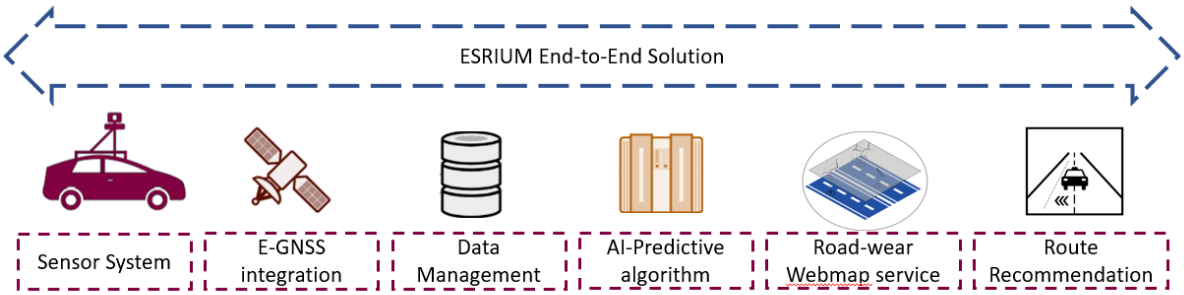


*Figure 1: ESRIUM services.*

As it is explained in D 2.5, ESRIUM's value chain consists of ESRIUM's hardware and sensors for the assessment and survey of the road conditions, EGNSS system integration as a service to enable the required geolocation precision for effective mapping, a data management platform that collects and stores that data in a single database, predictive AI algorithm that detects and classify road surface damages. The next step consists of a data service platform that compiles the data and generates a "road wear" layer. The layer is useful for road operators to plan ahead road maintenance and provide real-time C-ITS services routing/lane change recommendations to end users. The activities within this project will yield business-cases based on the ESRIUM services. While an entity can offer the trunky solution, the components are independent and can be exploited separately. This can provide modularity to the overall solution and the flexibility to clients to choose the component that meets their needs. In D2.5 we have classified these services in four business use cases. Table 1 describes the USP of each business use case.

| Business Use Case | Unique Selling Point |
|---|---|
| **AI-based road damage prediction system** | AI-based road maintenance prediction system that offers the road operators:<br>• A metric for severity of single damage for straight forward management decisions<br>• A prediction of wear changes over time provided with probabilities<br>• Constant information about the road condition (at least weekly)<br>• Cost savings due to better planning<br>• A tool which helps Road Operators understand better the evolution of conditions of each asset<br>• Roadwear sensing and predictions can be extended to lower road classes maintained outside of the highway operators (e.g. by municipalities)<br>• Prediction can be adjusted to see infrastructure degradation on a time scale |
| **Routing recommendations based on the road** | **Road operators:** Reduced and gradual road-wear leading to less maintenance actions and reduced traffic jams. Road degradation can be evened out between parallel routes. |

| | |
|---|---|
| **wear map, provided via C-ITS messages** | Air pollution (particular matter) can be reduced by routing traffic away from degraded routes.<br>**End-users:** Avoid vehicle damage by effectively dodging bad road conditions in a friendly way and with high safety while reducing tolling fees<br>• User-friendly<br>• Improving the vehicle awareness of road conditions (e.g., e-horizon)<br>• Increase safety |
| **C-ITS message 'GNSS- correction data' provision** | We provide supportive robust and precise localization information to your infrastructure operations which:<br>• is easy to integrate into vehicles technology,<br>• uses the established C-ITS technology and standards (public key infrastructure etc.), and<br>• is compatible with the use of ADAS systems which need that kind of positioning. |
| **Wear-map content provision** | A concise wear map with dynamically updated georeferenced road damage information that can be used by **road operators** to<br>• Optimize asset management and planning<br>• Increase safety and eventually save lives and money<br>• Input the data into cloud-based fleet manager systems to route the fleets away from damaged roads. Particular matter in the air at overly crowded and damaged areas can be reduced according to municipality / local public needs.<br>And benefits the **end users** by<br>• Increased convenience / comfort during driving<br>• Better navigation ('comfort mode')<br>• Increased safety by informing the drivers in time on road damages avoiding sudden direction and speed changes.<br>• Increased vehicle lifetime |

*Table 1: ESRIUM Business Use Cases.*

### 1.2. Purpose of document

As part of WP6 Dissemination, Exploitation, this document provides an updated analysis of the market and business ecosystem for ESRIUM business case aimed at supporting a sound exploitation plan for the different involved stakeholders. In particular, this deliverable will:

- Provide an overview of Road Asset Management (RAM) around Europe and market state of art analysis
- Analyze the macro and micro factors that can impact the project and its commercial uptake
- Assess and benchmark current approaches and solutions addressing ESRIUM challenges.
- Estimate the market potential of ESRIUM technologies and services.

### 1.3. Intended audience

This market and business ecosystem analysis is a public deliverable, i.e., it will provide coordinated feedback abreast of the business environment to the other WPs to direct technical developments towards business-relevant solutions. This deliverable will be available on the ESRIUM website and open repository.

### 1.4. Relationship to other deliverables and roadmap

This deliverable is a more complete analysis of business ecosystem and the market opportunities built on top of the one delivered with the proposal of the project with the title "Business plan for ESRIUM". The business cases of ESRIUM are developed in the deliverable D2.4 Business case baseline and then refined in the follow-up update in D2.5 Business case baseline updated. The business cases are based on the ESRIUM use-cases developed in the deliverable D2.1 Use Case Definition.

### 1.5. Structure of the document

This document consists of five main sections. After a brief introduction along with the ESRIUM solution in SECTION 1:, the methodology used is described in SECTION 2:. The state of art analysis will be presented and described in SECTION 3:. Consequently, SECTION 4: describes the business ecosystem analysis. Some final remarks and description of final steps in SECTION 5: will conclude the document.

## SECTION 2: METHODOLOGY

### 2.1. Overall methodology

This chapter provides the reader with an overview on the used methodology and tools for setting-up the analysis of ESRIUM's business ecosystem. The purpose of this deliverable is to evaluate the business environment by knowing existing market solutions and challenges, as well as to estimate the market potential of the technologies. For this, a mix of methodologies have been considered in order to address a complete assessment. Figure 2 aims to supply a framework of the procedures and tools taken into consideration for each one of the sub-sections.

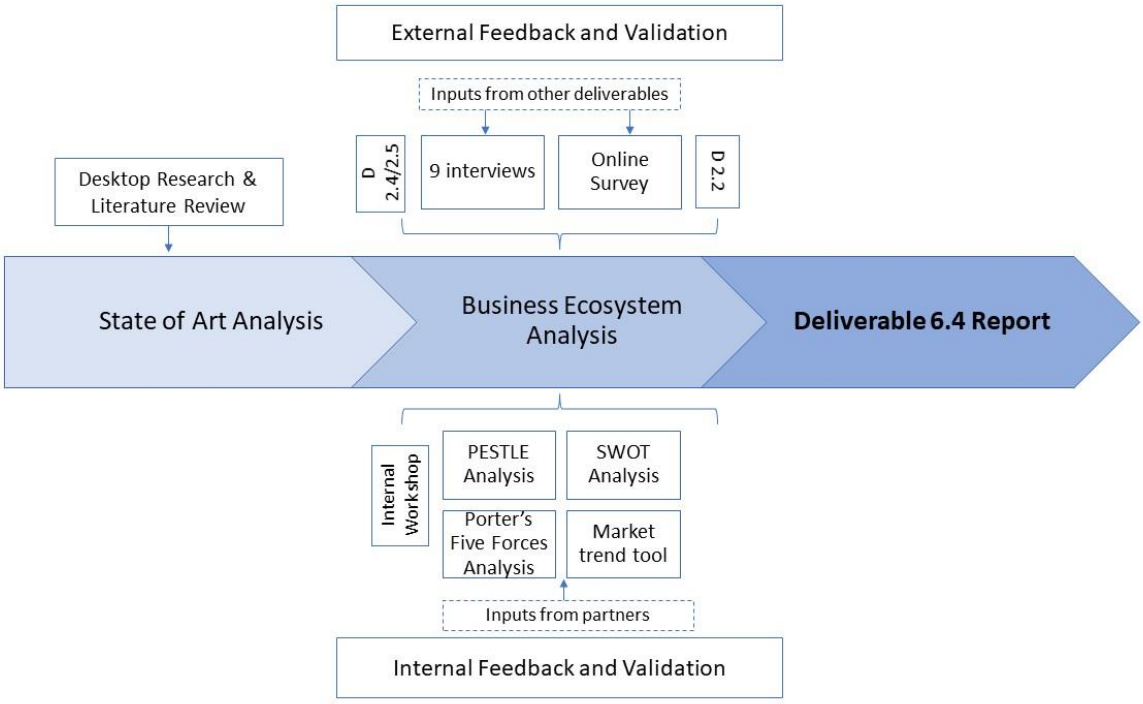


*Figure 2: Overall Methodology Diagram.*

In order to create a benchmark for ESRIUM's services, first a deep understanding of the market context and background is needed; hence, a state of art analysis has been conducted by implementing intense desktop research and literature review to have a broader perspective of challenges and current approaches. Then, an analysis of ESRIUM's business ecosystem was performed following a mixed methods approach, consisting of external and internal feedback/validation. For the former, 9 interviews with road operators and an online survey with potential end-users have been considered, both coming from other deliverables, in particular, D2.4 and D2.5: Business Case Baseline and D2.2: technical and non-technical user requirements, respectively. These external inputs were needed in order to have a clear picture of the target market (i.e., target customer and target location). For the latter, project partners' inputs were necessary for deploying each one of the tools needed for investigating key factors of the business ecosystem so that an analysis for ESRIUM's solution could be performed. The tools used for the business ecosystem analysis were PESTLE analysis, SWOT analysis, Porter's Five Forces Analysis, and a trend monitoring tool, which aimed to describe the business environment, threats, opportunities, and current trends in the market. Also, for the first two, an internal workshop was directed to get insights from different partners. Desktop research has also been employed to study the existing market solutions and business models. Therefore, the main results from this deliverable are coming from different sources, both from within the consortium as from outside of the project partners, resulting on a complete report on ESRIUM's business ecosystem.

## 2.2. Methodology for the State of Art Analysis

The first objective of this deliverable is to have a proper understanding of the background for ESRIUM's market. The assessment conducted aimed to start from a general perspective to a country-specific perspective making use of available knowledge about the market, detailed in the sub-sections of this chapter. A literature search was carried out to cover important facts of the business environment, specified in diagram:

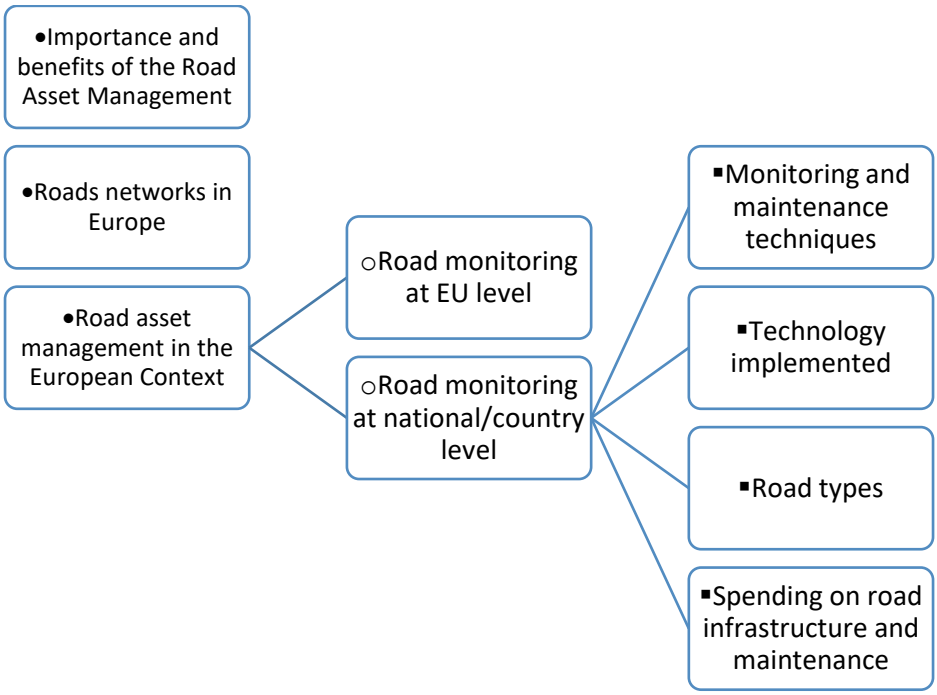


*Figure 3: State of Art Analysis Methodology Diagram.*

Relevant reports and papers from different entities specialized in road management have been considered to develop this section. The literature review includes knowledge already available through the Association Européenne des Concessionnaires d' Autoroutes et d' Ouvrages à Péage (ASECAP), The European Union Road Federation (ERF) and the Conference of European Directors of Roads (CEDR), to name a few. Moreover, the key fields of the research covered Road Asset Management, total kms of road networks of Europe and selected countries, maintenance procedures, technology maturity and financial factors.

The analysis starts by highlighting the benefits for road operators of implementing Road Asset Management systems into their operations. Following, to focus on Europe, a section is dedicated to describing the road networks across Europe. Then, road asset management in Europe is evaluated by considering the situation at the European Union (i.e., regulations) and at a country specific level. To specified further, literature has been reviewed regarding maintenance techniques, technologies implemented, road types and budgets in selected European countries.

All this information enables the further analysis of ESRIUM's market by providing valuable knowledge about country's specific road management, which it is useful for coming up with an accurate target market.

## 2.3. Methodology Business Ecosystem Analysis

The main goal of this deliverable is to come up with an inspection of ESRIUM's business ecosystem, which consists of a variety of mechanisms and tools, as well as inputs from partners for specific sections, explained in the following diagram.

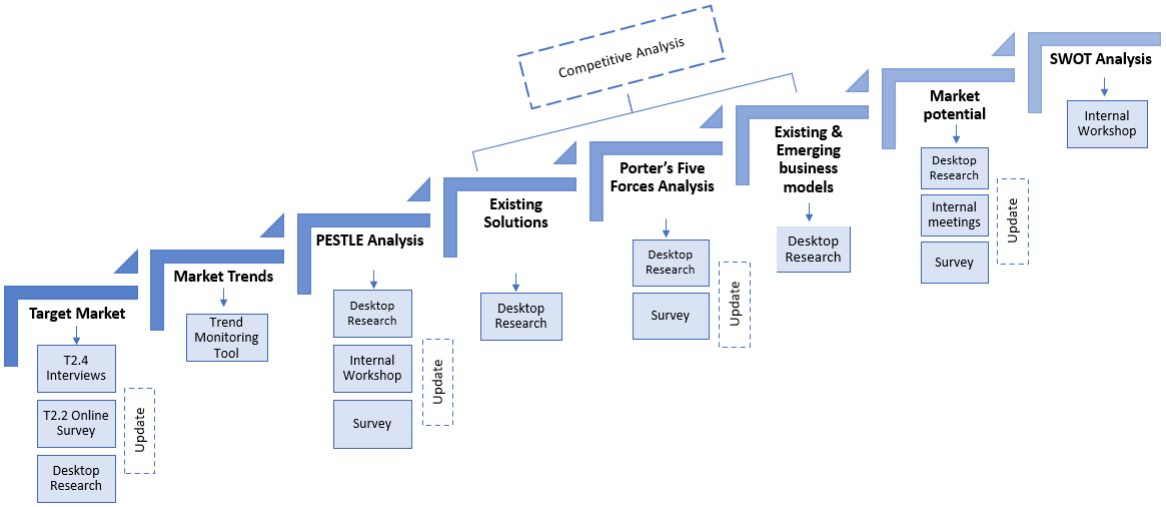


*Figure 4: Business Ecosystem Analysis Methodology Diagram.*

### 2.3.1. Target Market

The analysis for **target market** (section 4.1) have started by doing desktop research. Nevertheless, to accurately target the market, external validation was needed. Interviews with 9 road operators of different countries such as Spain, Italy, Germany, Czech Republic, and Norway done for T2.4 have been considered. Also, an online survey about business use cases with potential end-users like truck drivers, logistics providers, OEMs, and road operators from T2.2, have helped. In this way, the target market could be properly addressed and divided into target customer and target location, referring to countries targeted.

The bulk of this analysis is done by utilizing business and marketing specific tools, namely PESTLE Analysis and SWOT Analysis for understanding the business environment, Porter's Five Analysis for the Competitive Analysis, and a trend monitoring tool for specifying current market trends.

### 2.3.2. Market Trends

Understanding trends that are relevant for one's business market is fundamental to keep growing as a company, therefore for ESRIUM Case, market trends have been specified by Trendmanager, a trend monitoring tool (www.trendmanager.com), in section 4.2.

The online tool Trendmanager helps companies to identify and systematically keep track of trends that are significant for their business. An interactive trend radar shows the most important trends in relation to each other. Currently 50 mega-trends, 352 macro-trends and 38052 microtrends are part of the Trendmanager tool.

### 2.3.3. PESTLE Analysis

This section briefly describes the strategic management tool "PESTLE analysis" which is used to provide an ESRIUM-related PESTLE analysis in chapter 4.3.

The PESTLE Analysis is a tool that has been widely used by companies to keep track of the ecosystem that are operating or planning to operate, taking into consideration key factors of politics, economics, society, technology, legislative and environmental fields that may affect their business. A broader concept is detailed in attachment 7.1.

To address ESRIUM's environment, the analysis was conducted by FHO, one of the project partners. To develop the assessment, desktop research has been conducted, together with inputs from an internal workshop and a survey in which project partners participated to get insights and updates.

### 2.3.4. Porter's Five Forces Analysis

This section provides basic information on Michael Porter's Five Forces to prepare the reader for further ESRIUM-respective strategic analysis in section 4.4.2.

The Porter's Five Forces is a business analysis model helping to explain why various industries can sustain different levels of profitability. The five forces included in this type of analysis are (Harvard Business School, Institute for Strategy & Competitiveness):

1. Threat of substitute products or services
2. Bargaining power of supplier
3. Bargaining power of buyers
4. Threat of new entrants
5. Rivalry among existing competitors

More details can be found in attachment 7.3.

This instrument is useful for developing a competitive analysis that covers factors that are relevant for understanding other companies value and business models. For ESRIUM case, FHO developed the analysis based on desktop research and literature review of current competitors. Also, updates and improvements were provided via results of a survey organized. Furthermore, EVOLIT contributed by conducting literature research on existing market solutions to benchmark with ESRIUM's solution. Moreover, desktop research has been utilized to provide information about existing and emerging business models by EVOLIT, JN and NNG.

### 2.3.5. Competitive Analysis

The competitive analysis is entirely based on secondary data acquired from desktop research. Key words as road inspection technologies, asset management, road maintenance technologies have been used to find similar solutions to ESRIUM. Each company/project website has been visited to find more information about the initiative.

### 2.3.6. Market potential

Moreover, **market potential** (section 4.5) was identified by making use of desktop research and literature review of existing data collected about the market. However, inputs and feedback from project partners were necessary to update the first figures, through an internal workshop aimed at improving initial forecasts.

### 2.3.7. SWOT Analysis

This section sets the scene for the ESRIUM SWOT analysis in chapter 4.6, by providing the reader a theoretical overview of a SWOT Analysis.

In order to evaluate ESRIUM'S position in the market, a Strengths, Weakness, Opportunities and Threats (SWOT) Analysis has been implemented. This is an instrument that has gained importance for analyzing internal and external factors affecting businesses. A broader concept is detailed in attachment 7.2.

This section has been carried out by different partners, namely NNG, VIF and FHO. Also, for the development of the assessment, an internal workshop with partners within the consortium has been done.

## SECTION 3: BACKGROUND: STATE OF ART ANALYSIS

The aim of this section is to provide the reader with an overview of the context of Road Asset Management (RAM) around Europe and most important facts.

In sub-section 3.1, we first begin our analysis by understanding the role and importance of road asset management for road administrator's activities. Also, we highlighted the key benefits of adopting RAM systems into road operations such as enhancement of data collection and higher-quality reports. Sub-section 3.2 starts analyzing the European context, it describes the road network in Europe by specifying how many kilometers each national road network has and the proportion of urban/rural roads in Europe. In sub-section 3.3, we studied the Road Asset Management procedures around Europe. In 3.3.1 we provided a brief explanation of the efforts made by the EU to create a harmonized network across Europe to improve interconnectivity of major roads, namely the TEN-T corridor and the Directive 2008/96/EC. 3.3.2 details the situation for road monitoring, specifying the National Road Authorities and their responsibilities as road operators in 23 European countries: Austria, Belgium, Denmark, Estonia, England, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Ireland, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden and Switzerland. Next, in 3.3.3 information about the monitoring and maintenance techniques is supplied considering key parameters for the assessment of roads and timing for inspections. 3.3.4 is dedicated to classifying countries depending on their level of technology maturity regarding Information Technology Systems in the road sector. Also, in 3.3.5 a short section is devoted to dividing countries by road type predominance, between motorways and non-motorways. Finally, 3.3.6 specifies the financial and economic situation of each country regarding

budget and spending for road infrastructure maintenance, as well as main concessionaires and contracts.

### 3.1. The role of Road Asset Management: benefits and importance

Roads are one of the biggest assets a country has because they ensure connectivity and mobility of individuals and guarantee integration of the transport system. A well-functioning road infrastructure is important for citizens and governments to enjoy economic competitiveness and growth.

However, many European and other OECD's countries are facing problems controlling and assessing road infrastructure. Lack of information, data collection and restricted budgets for the maintenance of the road infrastructure has led to a long-standing deterioration and rise in costs having a negative effect on the overall development of a country. Thus, it is crucial for authorities to properly take care of roads in the most optimal and cost-effective way. Systems to efficiently manage the roads are being needed increasingly due to deteriorating infrastructure, scarce budgets and staff, and high public demands.

Road Asset Management (RAM) solves these issues by supplying the required information, tools, and technology to road administrations, so that they can take better decisions. Road administrations can exploit the potential of asset management systems to systematically manage their networks. Nowadays, upgrades in different asset management systems are coming together to offer better and qualified tools to improve decision making taking into consideration economic and fiscal limitations.

In their report about Asset Management for the Roads Sector, the OECD gathers the key benefits of implementing such systems into road maintenance, in particular, for road administrators. The report enlists the different advantages of RAM and classifies them into six categories including :1. communication, 2. asset inventory, condition, and level of use, 3. road network performance, 4. asset management tools, 5. budget process and 6. staff development. A summary of those benefits is provided in the following table:

| Category | Benefits |
|---|---|
| **Communication** | Common benchmarks between administrations to identify and adopt good practices for maintaining the roads |
| **Road asset condition and level of use** | Integrated database: higher quality, better analysis, and reports<br>New skills and technology: improve data collection and management |
| **Road network performance** | Better monitoring reports for planning, maintenance, budgeting, and policy decisions |
| **Asset management tools** | Management Systems for each asset, help to design parameters and levels of services, economic modelling to create spending scenarios and prioritize maintenance requirements based on future costs |

*Table 2: Benefits of Road Asset Management.*

In summary, Road Asset Management improves decision making by providing solid information and knowledge, helping road administrators to prioritize needs, making sure that money is spent in an efficient manner, supplying better and safer roads and preserving assets for the future. Similarly, stakeholders indicated that the most important benefits related to Road Asset Management Systems were the proper development of budget allocation for the maintenance and repair of roads, cost effectiveness, support to decision-making, performance monitoring and consistency in -programming. A clear example is the Norwegian municipality of Larvik, which discovered that they

were losing 2000 euros per day, only because of not using a RAM methodology to maintain their roads. On the other hand, there is a common feeling that a higher-level system is needed.

### 3.2. Road networks in Europe

In this report, we will be focusing on Europe and its most important road networks. As is expected, not all European countries have the same dimensions or types of roads. Also, depending on the country, some have more kms paved than others. For instance, France, Germany, Russia, and Spain have the longest networks (in km). More details can be found in Table 3: urban/rural road network in Europe in comparison to total TEN-T road network length and Table 21: Road network in Europe (km) 2019

Moreover, according to the Trans-European Road Network, TEN-T (Roads): 2019 Performance Report done by the Conference of European Directors of Roads, most of the European road network is still rural. Specifically, 90.6% of the network is still rural, while a 9.2 % can be considered as urban.

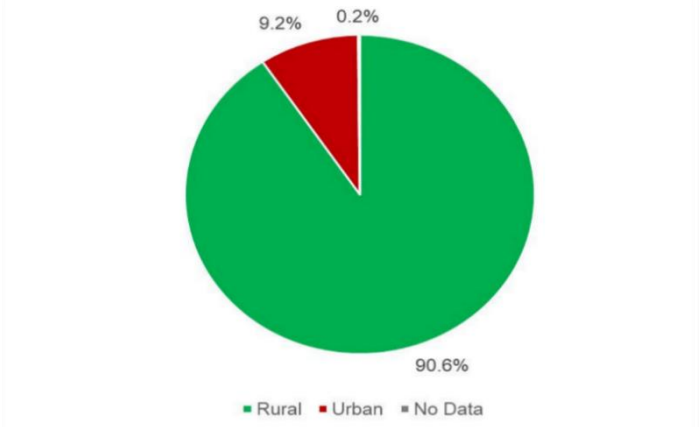


*Figure 5: Road network Europe rural vs urban roads (Pettersson, 2020) .*

| Country | TEN-T Network length (km) | Rural | | Urban | | No data |
|---|---|---|---|---|---|---|
| | | Length (km) | % | Length (km) | % | |
| **Austria** | 1,740 | 1,540 | 88.5% | 200 | 11.5% | 0 |
| **Belgium** | 948 | 792 | 83.5% | 156 | 16.5% | 0 |
| **Denmark** | 1,560 | 1,560 | 100% | 0 | 0.0% | 0 |
| **Estonia** | 1,350 | 1,293 | 95.7% | 58 | 4.3% | 0 |
| **Finland** | 5,205 | 5,063 | 97.3% | 142 | 2.7% | 0 |
| **Germany** | 10,713 | 9,827 | 91.7% | 886 | 8.3% | 0 |
| **Hungary** | 1,474 | 1,397 | 94.8% | 77 | 5.2% | 0 |
| **Iceland** | 1,805 | 1,734 | 96.1% | 71 | 3.9% | 0 |
| **Ireland** | 2,163 | 1,979 | 91.5% | 184 | 8.5% | 0 |
| **Italy** | 3,026 | 2,734 | 90.7% | 282 | 9.3% | 0 |
| **Lithuania** | 1,652 | 1,551 | 93.9% | 101 | 6.1% | 0 |
| **Luxembourg** | 90 | 74 | 82.4% | 16 | 17.6% | 0 |

| | | | | | | |
|---|---|---|---|---|---|---|
| **Malta** | 114 | - | 0% | - | 0.0% | 144 |
| **Netherlands** | 1,886 | 1,439 | 76.3% | 447 | 23.7% | 0 |
| **Norway** | 4,793 | 4,481 | 93.5% | 313 | 6.5% | 0 |
| **Poland** | 7,501 | 6,547 | 87.3% | 954 | 12.7% | 0 |
| **Slovenia** | 599 | 552 | 92.2% | 47 | 7.8% | 0 |
| **Spain** | 12,255 | 10,819 | 88.3% | 1,436 | 11.7% | 0 |
| **Sweden** | 6,417 | 5,844 | 91.1% | 573 | 8.9% | 0 |
| **Switzerland** | 1,325 | 732 | 55.2% | 593 | 44.8% | 0 |
| **UK** | 4,441 | 4,425 | 99.6% | 16 | 0.4% | 0 |
| **Total** | 71,046 | 64,382 | 90.6% | 6,551 | 9.2% | 144 |

*Table 3: urban/rural road network in Europe (TEN-T Network Length).*

## 3.3. Road Asset Management: European Context

### 3.3.1. Road monitoring at EU level: The TEN-T network and Directive 2008/96/EC

**The TEN-T network: overview**

Since 1990, the European Commission has developed several plans to design a harmonized network of roads, railways, airports, and water infrastructure across the EU. In 1996, the European Parliament decided to support the creation of the Trans-European Transport Network, a policy that seeks the coordination between governments in topics such as improvements of main roads as well as development and implementation of Information Transport Systems/Road Asset Management Systems to promote an integrated high-speed route.

The corridor consists of different networks: the Core Network, which includes most relevant connections (to be completed in 2030), the Comprehensive Network which refers to all European regions (to be finished in 2050) and non-core networks.

From Table 4 we can observe the performance of each country in terms of traffic flow: Annual Average Daily Traffic (AADT), Traffic Density (AADT per lane) and the proportion of Heavy Goods Vehicles. For instance, Belgium, Netherlands, and the UK carry the most traffic of the network (AADT). On the other hand, Iceland, Norway, and Estonia have the lowest AADT. Furthermore, if we want to study average traffic per lane, the Netherlands, Belgium, Luxembourg, and UK have the highest traffic density. Meanwhile, Iceland, Norway, Finland, and Estonia have the lowest density.

Finally, the Heavy Goods Vehicles traffic is large in Belgium, Germany, and UK, while is low in Estonia, Finland, Iceland, Ireland and Norway.

| Country | National statistics | | TEN-T (Roads) network length (km)[5] | | | | | TEN-T (Roads) network use (Average) | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Population [1,000s][6] | Total area [km²] | Comprehensive | Core | Non-Core | Motorway | Non-motorway | Traffic Flow [AADT] | Traffic Density [AADT/Lane] | HGV [%] |
| AT | 8,847 | 83,872 | 1,740 | 1,105 | 635 | 1,740 | | 57,554 | 11,590 | 11.6% |
| BE-F | 11,422 | 30,510 | 948 | 604 | 344 | 820 | 128 | 83,014 | 15,542 | 18.4% |
| CH | 8,517 | 41,290 | 1,325 | 300 | 1,025 | 1,143 | 182 | 56,235 | 12,481 | 6.0% |
| DE | 82,928 | 357,021 | 10,713 | 6,365 | 4,348 | 10,350 | 363 | 59,244 | 11,935 | 15.1% |
| DK | 5,797 | 43,098 | 1,560 | 764 | 796 | 1,175 | 385 | 34,213 | 7,823 | 12.3% |
| EE | 1,321 | 45,228 | 1,350 | 481 | 870 | | 1,350 | 10,742 | 3,871 | 12.1% |
| ES | 46,724 | 504,030 | 12,255 | 5,940 | 6,315 | 10,932 | 1,323 | 32,867 | 7,530 | 14.0% |
| FI | 5,518 | 338,424 | 5,205 | 1,100 | 4,106 | 812 | 4,394 | 14,734 | 4,384 | 10.2% |
| HU | 9769 | 93030 | 1,474 | 1,058 | 416 | 1,130 | 344 | 33,936 | 8,256 | 17.6% |
| IR | 4,854 | 70,280 | 2,163 | 499 | 1,664 | 990 | 1,172 | 31,546 | 8,817 | 6.7% |
| IS | 354 | 103,001 | 1,805 | 54 | 1,751 | 3 | 1,802 | 15,158 | 4,283 | 7.1% |
| IT | 60,431 | 301,338 | 3,016 | 827 | 2,189 | 2,297 | 719 | 28,097 | 6,690 | 9.3% |
| LT | 2,790 | 65,200 | 1,652 | 597 | 1,055 | 361 | 1,291 | 11,338 | 3,838 | 17.4% |
| LU | 608 | 2,586 | 90 | 90 | 0 | 90 | 0 | 52,835 | 13,070 | 14.2% |
| MT | 484 | - | 114 | 17 | 96 | - | 114 | - | - | - |
| NL | 17,231 | 41,543 | 1,886 | 643 | 1,243 | 1,886 | 0 | 81,417 | 15,269 | 13.7% |
| NO | 5,314 | 385,252 | 4,793 | 175 | 4,618 | 678 | 4,115 | 15,865 | 4,834 | 14.8% |
| PO | 37,979 | 312,685 | 7,501 | 3,812 | 3,689 | 3,752 | 3,749 | 25,508 | 6,328 | 20.7% |
| SE | 10,183 | 449,964 | 6,417 | 3,012 | 3,405 | 1,913 | 4,504 | 18,382 | 5,102 | 14.4% |
| SI | 2,067 | 20,273 | 599 | 471 | 128 | 556 | 43 | 33,402 | 8,302 | 13.4% |
| UK - E | 66,489 | 223,010 | 4,441 | 2,152 | 2,286 | 2,729 | 1,712 | 77,527 | 13,990 | 15.0% |
| Total/ Average | 389,627 | 3,511,635 | 71,046 | 30,065 | 40,978 | 43,357 | 27,690 | 38,681 | 8,697 | 13% |

*Table 4:Ten-T network 2019 (Pettersson, 2020)*

**Directive 2008/96/EC**

Up to 2008, the EU did not have an integrated and coordinated plan for mechanisms to audit road networks and its safety. Therefore, there was need to have a common framework regarding maintenance and safety of the European network. To achieve this, the EU approved the directive 2008/96/EC with the objective of developing the basis for road network safety and management across the TEN-T network. Precise procedures together with benchmarks that the EU members must comply with are included in this document, for instance, audits and inspections regarding road safety, impact assessments and continuous management of the network.

Despite the harmonization efforts, each country interprets the Directive in different ways, leading to dissimilar management procedures.

### 3.3.2. Road Monitoring at national level: ownership and responsibilities[1]

As we mentioned before, the administration and management of roads is not centralized at a European Level, rather each country has its own National Road Administration (NRAs) and the type/level of responsibilities varies in each country depending on the country's administrative division. Thus, there is not a general framework regarding road authorities, in the sense that in some

[1] For this section, it has been included relevant information regarding ITS maturity levels; however, more detailed information regarding technologies and infrastructure was not included due to lack of information available.

countries the ownership and maintenance of roads is done by a single authority at a national level, while in others it is done by local authorities.

Moreover, the structure of the road administration may vary according to the scale and length of road networks. For instance, a large network might have a decentralized structure in which the ownership and responsibility of roads are of regional or local authorities. At the same time, smaller networks will probably be in charge of a centralized/national authority.

On the other hand, some NRAs also work hand-by-hand with concessionaires for the administration and construction of roads. It is common that toll motorways are owned by private companies, while national and federal roads by national/governmental authorities. Also, NRAs often use third parties service providers for the day-to-day operations and maintenance of the assets. The duration of contracts varies for each country.

Regarding technology for road assessment, the use of Intelligent Transport Systems (ITS) is becoming more common in every country since it enhances efficiency across all activities. Following the criteria stablished by the Conference of European Directors of Roads 2019 report about Trans-European Road Network, TEN-T (Roads) Performance Report and EasyWay Deployment Guideline (Patterson, 2020), the indicator defines the level of maturity of Intelligent Transport System of different countries comprising the TEN-T road network. The different levels go from 0, reflecting zero use of ITS to 4, meaning a cooperative ITS. We will be classifying each country according to their level of ITS maturity:

| | |
|---|---|
| **Level 0** | **None** |
| **Level 1** | Monitoring system (e.g., road administration collects real-time data about traffic/weather conditions) |
| **Level 2** | Traffic information system (road administration passively manages the network, e.g., variable speed limits, dynamic lane management, ramp metering) |
| **Level 3** | Traffic management system (road administration actively manages the network) |
| **Level 4** | Cooperative ITS (I.e., vehicle-to-vehicle or infrastructure-to-vehicle information) |

*Table 5: ITS levels.*

For the analysis of the European context, we will be focusing on a sample of European countries, namely Austria, Belgium, Denmark, Estonia, England, Finland, France, Germany, Hungary, Iceland, Ireland, Italy, Ireland, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Sweden, and Switzerland.

Table 6 provides information about each country's NRAs and its responsibilities, the institution(s) in charge of management of national, federal, regional, and local roads, total km of each national road network and the country's corresponding ITS level. (Some of these countries also have contracts with concessionaires for routine maintenance or tolling activities, which are detailed in section 3.3.6 and attachment 7.5)

| Country | National Road Authority | Responsibility | Management of national and federal roads | Management of regional/local roads | Total National Road Network km | ITS level |
|---|---|---|---|---|---|---|
| **Austria** | ASFINAG | - Ownership<br>- Planning | ASFINAG | ASFINAG<br>Regional authority | 200,000 km | Level 1 :83.6%<br>Level 3: 15% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | a government-owned financing stock corporation | - Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Finance<br>- Toll | | 9 regions: Vienna (Wien), Lower Austria (Niederösterreich), Upper Austria (Oberösterreich), Burgenland, Salzburg, Styria (Steiermark), Carinthia (Kärnten), Tyrol (Tirol) and Vorarlberg | | Level 4: 1.4% |
| **Belgium (Flanders)** | The Agency for Roads and Traffic (Agentschap Wegen en Verkeer/AWV) | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management<br>- Apply mobility policy | AWV – Head office: Brussels | AWV with departments in: Antwerp, Ghent, Leuven, Hasselt, Bruges | 154,012 km | Level 2: 34.3%<br>Level 3: 65.7% |
| **Denmark** | Danish Road Directorate (DRD) | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management | DRD – service centers in: Copenhagen, Fløng, Næstved, Middelfart, Skanderborg, and Aalborg. | Local roads: municipalities<br>Regional roads: counties | 74,558 km | Level 2: 100% |
| **Estonia** | The Estonian Road Administration (ERA)<br>- governmental agency part of the Ministry of Economic Affairs and Communications | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management<br>- Collaborate in elaboration of policies<br>- Implement state policies | ERA – Head office: Taillin | ERA – service centers in 15 counties<br><br>Local authorities | 58,412 **km** | Level 2: 99%<br>Level 3: 1 |
| **England** | Highways England (HE) - governmental agency part of the Department for Transport (DfT) | - Ownership trunk roads (SRN: Strategic Road Network)<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management | **HE** | Local roads: Local authority<br>Scottish roads: Transport Scotland<br>Welsh roads: Welsh Assembly<br>London roads: Transport London | **422,514 km** | Level 0: 0.1%<br>Level 2: 51.3%<br>Level 3: 48.6% |
| **Finland** | Finnish Transport Infrastructure Agency (FTIA) | - Ownership<br>- Construction<br>- Operation<br>- Management<br>- Maintenance - Long-term planning of transport system traffic | FTIA – Head office: Helsinki | **FTIA – Regional centers:** Helsinki, Turku, Tampere, Kouvola, Kuopio, Jyväskylä, Vaasa, Oulu and Rovaniemi. | 78,162 | Level 2: 82.9%<br>Level 3: 17.1% |

| | | | | | | |
|---|---|---|---|---|---|---|
| **France** | State Road Administration (Ministry of Transport) – Directions Interdépartementales des Routes (DIRs) | - Ownership and management of National roads and non-concessionary motorways | DIRs | "Departemental" Roads: Local authority (general council)<br>Local roads: local authorities (city council)<br>Toll motorways: Concessionary Motorway Companies | 1,028,446 | |
| **Germany** | Federal Ministry of Transport and Digital Infrastructure --- Federal Governments | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Finance | Federal Government - Federal Trunk Road Network: motorways (Autobahnen) and highways | 16 Federal Governments (on behalf of the Federal Government) | 644,480 | Level 2: 49.5%<br>Level 3: 50.5% |
| **Hungary** | Hungarian Public Roads – state-owned enterprise | - Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Finance<br>- Traffic management measures<br>- Renewal of technical legislation | Hungarian Public Roads – Head office: Budapest | Hungarian Public Roads – service centers in 19 counties and 94 maintenance centers<br>Concessionnaires | 199,567 | Level 0: 3.5%<br>Level 1: 6.3%<br>Level 2: 69.2%<br>Level 3: 11.3% |
| **Iceland** | Vegagerðin, the Icelandic Road and Coastal Administration (IRCA) | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement | IRCA – Head office: Reykjavík | **IRCA – regional centers:** Selfoss (South), Borgarnes (West), Reyðarfjörður (East), and Akureyri (North).<br>Private roads: Private companies | 12,890 | Level 2: 100% |
| **Ireland** | Transport Infrastructure Ireland (TII) | - Funding agent<br>- Development of programmes<br>- Identification of needs<br>- Collaboration with Regional Governments | Regional Government Adminsitration – owners of roads | Regional Government Adminsitration – owners of roads | 96,602 | Level 0:84.3%<br>Level 1: 7.5%<br>Level 2: 8.1% |
| **Italy** | ANAS S.p.a -- joint-stock company (Italian Ministry of Economy and Finance unique shareholder) | - Ownership<br>- Planning<br>- Construction (in collab with 3rd parties)<br>- Management<br>- Maintenance<br>- Improvement<br>- Implementation of regulation<br>- Research | ANAS – General Directorate | ANAS – 23 regional offices<br>O&M service provider: 19 regional sub-departments | 487,700 | Level 1: 44.5%<br>Level 2: 4.5%<br>N/A: 51% |
| **Lithuania** | Lithuanian Road Administration (LRA) -- part of Ministry of Transport and Communications | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Implement state policies | LRA – Head office: Vilnius | LRA | 21,238 | Level 2: 89.6%<br>Level 3: 10.4% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | - Ensure traffic safety | | | | |
| **Luxembourg** | National Road Administration (Administration des Ponts et Chaussées)-- part of Ministry for Mobility and Public Works | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management<br>- Management of public lightning and traffic lights/signs<br>- Ensure traffic safety | Administration des Ponts et Chaussées | Administration des Ponts et Chaussées | 2,899 | No data |
| **Netherlands** | Rijkswaterstaat (RWS) - Ministry of Infrastructure and Waterworks | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement | (RWS) | Regional roads: Region authorities<br>Urban roads: Municipalities | 139,295 | Level 1: 7.7%<br>Level 2:6.6%<br>Level 3: 85.6% |
| **Norway** | Statens vegvesen, e Norwegian Public Roads Administration (NPRA)- government agency, part of Ministry of Transport and Communications | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Traffic management<br>- Approve regulations<br>- Enforce laws<br>- Research and dissemination | NPRA – Directorate of Public Roads | NPRA – 5 regional units: Northern Region, Central Region, Western Region, Southern Region and Eastern Region | 93,870 | Level 2: 32.1%<br>Level 3: 67.4%<br>Level 4: 0.5% |
| **Poland** | GDDKIA, 'Generalna Dyrekcja Dróg Krajowych I Autostrad' (General Directorate for National Roads and Motorways) -- administrative body, part of Ministry of Infrastructure | - Ownership<br>- Planning<br>- Construction<br>- Management:<br>- Maintenance<br>- Improvement<br>- Traffic management<br>- Road safety<br>- Technology management | GDDKIA – Head office: Warsaw<br>1. toll motorways (and 3 private concessionaires)<br>2. Expressways (toll only for HGV)<br>3. Other trunk roads | GDDKIA: 16 regional offices<br><br>Regional roads: regional authority<br>County roads: county authority<br>Local roads: local authority | 423,997 | Level 0: 11.8%<br>Level 1: 43.8%<br>Level 2: 44.4% |
| **Portugal** | Estradas de Portugal (EP), a government-owned company | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement | EP | County roads: Concessionaires (Associação Portuguesa Das Sociedades Concessionárias De Auto-estradas Ou Pontes Com Portagens (APCAP) | 82,900 | |
| **Slovenia** | Slovenian Infrastructure Agency (SIA) – part of Ministry | - Ownership<br>- Planning<br>- Construction<br>- Management | Main and regional roads: SIA<br>Motorways and expressways: DARS | Local roads: Local authorities | 38,985 | Level 2: 47.9%<br>Level 3: 52.1% |

| | | | | | | |
|---|---|---|---|---|---|---|
| | of Infrastructure / Družba za avtoceste v Republiki Sloveniji (Motorway Company in the Republic of Slovenia – DARS) -- joint stock company (100% government-owned) | - Maintenance<br>- Improvement<br>- Road safety | | | | |
| **Spain** | General Directorate of Roads (DGC), part of the Ministry of Public Works and Transport | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Road safety | DGC – State Road Network<br>Tolled Highways: Concessionaires (I.e Autopistas) | Regional roads: Autonomous Communities (17)<br>Provincial roads: Provincial governments<br>Local roads: City Councils | 683,175 | Level 1: 4.1%<br>Level 2: 47.6%<br>Level 3: 47.7%<br>N/A: 0.5% |
| **Sweden** | Trafikverket, the Swedish Transport Administration | - Ownership<br>- Long-term planning of transport system<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Road safety | Swedish Transport Administration – head office: Borlänge | Swedish Transport Administration: six regional centres Kristianstad (South), Gothenburg (West), Eskilstuna (East), Stockholm (Stockholm), Gävle (Central) and Luleå (North). | 579,564 | Level 2: 92.4%<br>Level 3: 7.6% |
| **Switzerland** | The Federal Roads Office (FEDRO), part of the Federal Department of the Environment, Transport, Energy and Communications (DETEC) | - Ownership<br>- Planning<br>- Construction<br>- Management<br>- Maintenance<br>- Improvement<br>- Road safety<br>- Enforce traffic regulations | FEDRO – Head office: Ittigen | FEDRO – five regional centres: Estavayer-Le-Lac, Thun, Zofingen, Winterthur, Bellinzona | 71,454 | Level 2: 5.5%<br>Level 3: 94.5% |

*Table 6: National Road Authorities, responsibilities and ITS levels.*

In general, National Road Authorities are governmental agencies which are part of the Ministry of Transportation (or similar) of each country. Others, like ASFINAG, Hungarian Public Roads and Motorway Company in the Republic of Slovenia (DARS) are government-owned companies. Their responsibilities cover different tasks from ownership, planning, designing, construction, management, maintenance, improvement of infrastructure to ensuring road safety. Many of them also participate in the elaboration and implementation of new policies and traffic regulations. In addition, responsibilities are shared with concessionaires/private companies, especially for financing, constructing and routine maintenance (detailed explanation in attachment **7.5**). Usually, NRAs operate at a National/State level with centers at Local level.

After analyzing each country's situation, we can classify them into centralized vs decentralized road administration. Centralized Road Administration refers to countries in which the NRAs operate and manage both National Road Networks as well as local roads. The Decentralized Road Administration

takes into consideration those countries which the management of regional/local roads are in the hands of the regional/local authority.

Centralized Road Administration: Austria, Belgium, Estonia, Finland, Germany, Hungary, Iceland, Italy, Lithuania, Luxembourg, Norway, Sweden, Switzerland

Decentralized Road Administration: Denmark, England, France, Ireland, Netherland, Poland, Portugal, Slovenia, Spain

### 3.3.3. Monitoring and Maintenance Techniques

**Parameters**

Over the years, European countries have developed specific procedures for the monitoring and maintenance of their road networks. Even though each country has its own way of managing their roads, there are common benchmarks that countries follow to assess a road's condition. The most common parameters and measures are:

- Skid resistance: measures how good the relation between road and tire is
- Macro and micro texture: measures how rough the surface is (roughness index)
- Longitudinal and transverse profile: measures how comfortable the ride is
- Road defects: rutting, cracks, and potholes
- Bearing capacity measures the capacity of bearing large levels of traffic

To measure the parameters mentioned above and to perform road maintenance activities, road authorities make use of monitoring equipment, which are usually specific vehicles used in traffic to analyze those parameters in real time and to gather data. Then, with the information collected, NRAs can create indexes that enable them to know whether maintenance is necessary and/or when to intervene.

Some examples are:

In England, The Department for Transport and the Highways England have developed a Road Condition Indicator (RCI) to study the quality of their roads surface. Data is collected in an annual basis through road scanning technologies, providing a RCI for each 10 meters. This measure is between 0 to 315, thus, values above 100 reflects unsatisfactory road conditions which need maintenance. Likewise, Germany uses a monitoring vehicle and laser technology to measure the longitudinal and transverse profile of their surfaces. The measures obtained are converted into a score from 1 (very good) to 5 (very bad), which will indicate how used and deteriorate roads are. Roads with the worst scores are prioritized for allocation of budget. A similar approach is done by Portugal and Poland, giving priority to road sections with bad ranking.

**Inspections and assessments**

By law, European countries must have a regime of inspections. The timing of inspections (how often road assessments are done) is divided into two categories: cyclic inspections or risk-based inspections. There are four types of road maintenance activities that countries usually employ: routine maintenance, recurrent maintenance, periodic maintenance, and emergency maintenance. Usually, day-to-day maintenance (routine) is outsourced to service companies. The duration of contracts varies for each country, as well as the regularity of performing monitoring activities.

Some countries that rely on third-parties service providers for the routine maintenance and monitoring of roads are: England, Ireland, Italy, Portugal, Slovenia, Spain.

Normally, general inspections to assess the quality of roads are done every 2-6 years. Some other countries carry out main inspections yearly.

A list of European countries and how often they assess their roads is provided next:

| Country | Timing of inspections |
|---|---|
| **Estonia** | Routine and monthly inspections |
| **England**[1] | General inspections: every 2 years<br>Principal inspections: every 6 years<br>Special inspections (to fix a specific defect) |
| **Germany** | Federal roads: every 4 years<br>State/district roads: every 5 years<br>Urban roads: no consistent monitoring, depends on the municipality |
| **Ireland** | Last inspection of regional roads in 2011 |
| **Italy** | Main inspections: every year<br>Recurrent inspections: quarterly[2] |
| **Portugal** | Depends on the results of their analysis procedures (Sistema de Gestão de Conservação de Pavimentos – SGPa) |

[1] Most of the inspections are risk-based
[2] For emergencies, continuous inspections can be added

*Table 7: Timing of Inspections by Country.*

### 3.3.4. Technology Implemented: Intelligent Transport System (ITS)

In this section we are going to cover in detail the deployment of ITS in different EU countries, according to the classification criteria related to different levels of ITS equipment mentioned before: level 0 (none), level 1 (monitoring system), level 2 (Traffic Information System), level 3 (Traffic Management System) and level 4 (Cooperative ITS).

| Country | Total length (km) | Level 0 | Level 1 | Level 2 | Level 3 | Level 4 | No data |
|---|---|---|---|---|---|---|---|
| Austria | 1,740 | 0.0% | 83.6% | 0.0% | 15.0% | 1.4% | 0.0% |
| Belgium (Flanders) | 948 | 0.0% | 0.0% | 34.3% | 65.7% | 0.0% | 0.0% |
| Denmark | 1,560 | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| Estonia | 1,350 | 0.0% | 0.0% | 99.0% | 1.0% | 0.0% | 0.0% |
| Finland | 5,205 | 0.0% | 0.0% | 82.9% | 17.1% | 0.0% | 0.0% |
| Germany | 10,713 | 0.0% | 0.0% | 49.5% | 50.5% | 0.0% | 0.0% |
| Hungary | 1,474 | 3.5% | 6.3% | 69.2% | 11.3% | 9.8% | 0.0% |
| Iceland | 1,805 | 0.0% | 0.0% | 100.0% | 0.0% | 0.0% | 0.0% |
| Ireland | 2,163 | 84.3% | 7.5% | 8.1% | 0.0% | 0.0% | 0.0% |
| Italy | 3,016 | 0.0% | 44.5% | 4.5% | 0.0% | 0.0% | 51.0% |
| Lithuania | 1,652 | 0.0% | 0.0% | 89.6% | 10.4% | 0.0% | 0.0% |
| Luxembourg | 90 | 0.0% | 0.0% | 0.0% | 0.0% | 0.0% | 100.0% |
| Malta | 114 | 0.0% | 4.6% | 0.0% | 74.6% | 0.0% | 20.7% |
| Netherlands | 1,886 | 0.0% | 7.7% | 6.6% | 85.6% | 0.0% | 0.0% |
| Norway | 4,793 | 0.0% | 0.0% | 32.1% | 67.4% | 0.5% | 0.0% |
| Poland | 7,501 | 11.8% | 43.8% | 44.4% | 0.0% | 0.0% | 0.0% |
| Slovenia | 599 | 0.0% | 0.0% | 47.9% | 52.1% | 0.0% | 0.0% |
| Spain | 12,255 | 0.0% | 4.1% | 47.6% | 47.7% | 0.0% | 0.5% |
| Sweden | 6,417 | 0.0% | 0.0% | 92.4% | 7.6% | 0.0% | 0.0% |
| Switzerland | 1,325 | 0.0% | 0.0% | 5.5% | 94.5% | 0.0% | 0.0% |
| UK | 4,441 | 0.1% | 0.0% | 51.3% | 48.6% | 0.0% | 0.0% |
| **Total** | **71,046** | **3.9%** | **9.8%** | **51.9%** | **31.7%** | **0.3%** | **2.4%** |

*Table 8: ITS levels by country, (Pettersson, 2020)*

Table 8 is useful to assess the maturity of ITS, for example, 52% of the network are in level 2 ITS (traffic information systems), approximately 32% have access to Level 3 (Traffic Management Systems), less than 4% have no ITS and less than 0.5% have deployed level 4 (cooperative ITS). However, it is expected that the proportion of level 4 will increase in each country due to upcoming improvements and adoption of Connected Autonomous Vehicles (CAV).

By looking at each country, we can observe that nowadays only 3 countries have deployed level 4 ITS, namely Austria (1.4%), Hungary (9.8%) and Norway (0.5%). Switzerland (94.5%), Netherlands (85.6%) and Malta (74.6%) have the largest proportion of level 3. Following, the largest proportion of level 2 are ruled by Denmark and Iceland (100%), as well as Estonia (99%). Ireland (92%) and Austria (84%) are the countries with the largest size of level 1.

For a better picture, the map shows how levels are deployed across countries, Figure 6.

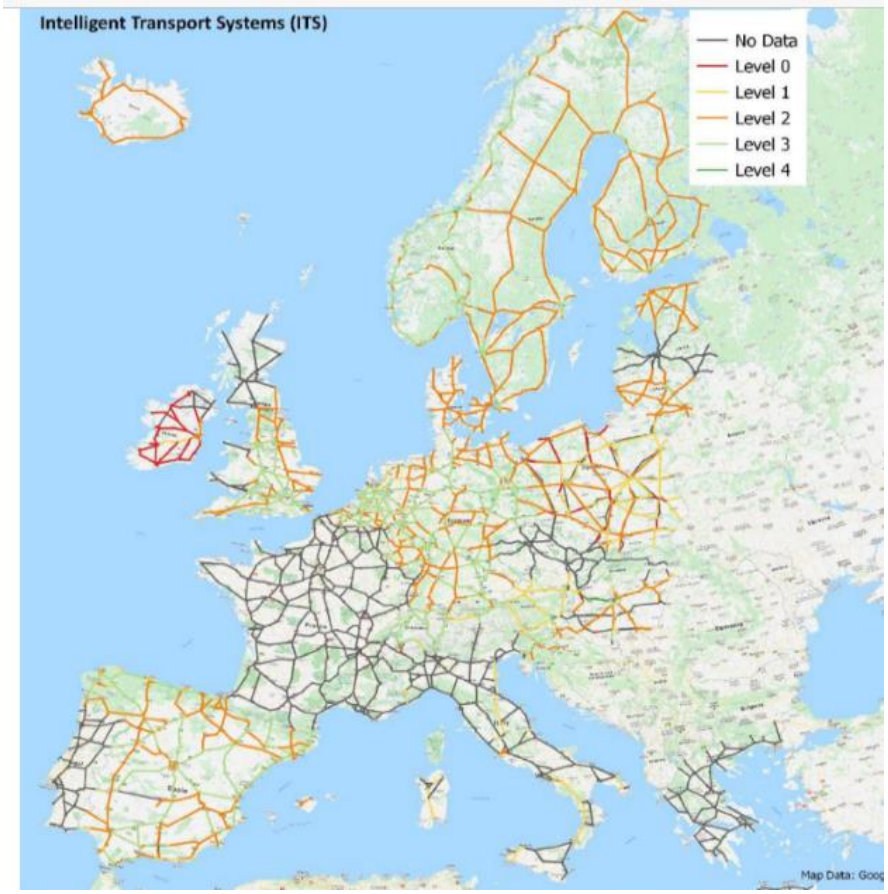


*Figure 6: ITS levels map, (Patterson, 2020)[2].*

### 3.3.5. Road Types

Also, we can assess countries depending on their road types. In general, roads can be motorways or non-motorways. The chart shows that Austria, Luxembourg, and the Netherlands, the TEN-T road network comprises only motorways. In contrast, non-motorway roads are more dominant in countries such as Estonia, Iceland, and Malta.

[2] Source: Conference of European Directors of Roads (CEDR). Working Group 3.5 (2020).11 Annex 4: Thematic Maps, 11.6 Intelligent Transport Systems (ITS)

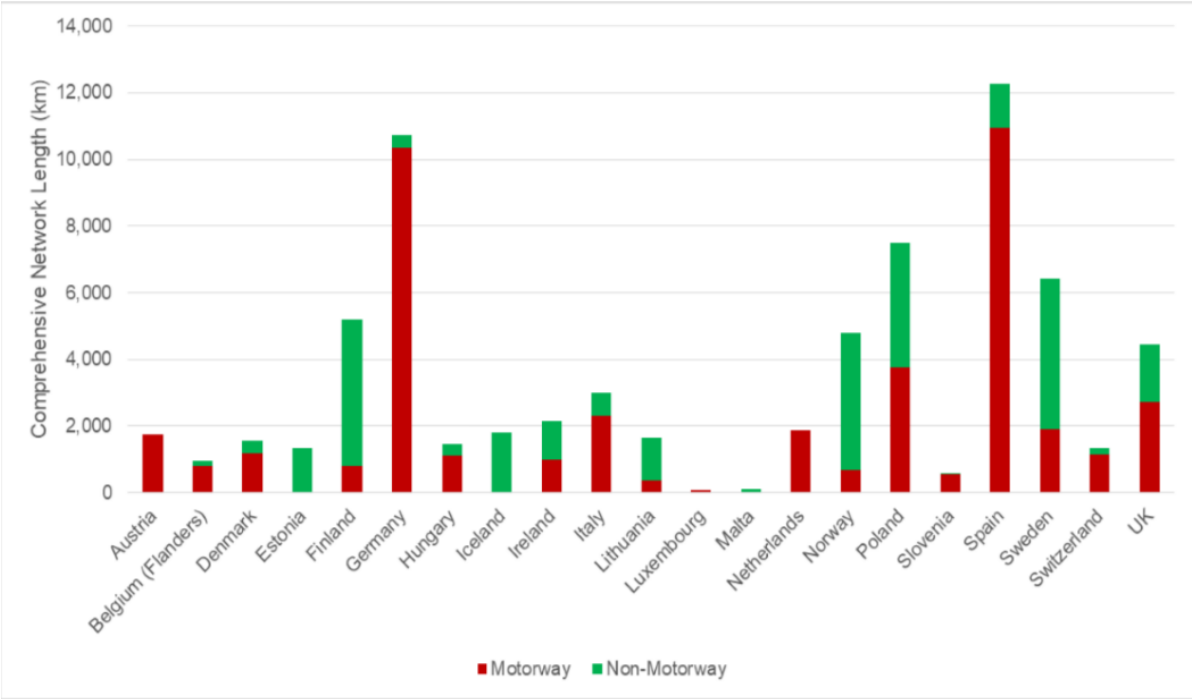


*Figure 7: Road types by country, (Patterson, 2020)*

### 3.3.6. Spending on Road Infrastructure Investment, Maintenance, and Contracts

A summary of the expenditure for road infrastructure maintenance by country is provided by Table 9:

| Country | Road Infrastructure Maintenance Spending (€) |
|---|---|
| **Austria** | 752 000 000 |
| **Belgium** | 396 797 000 |
| **Bulgaria** | 212 700 685 |
| **Croatia** | 256 800 841 |
| **Czech Republic** | 982 477 464 |
| **Denmark** | 1 151 451 725 |
| **Estonia** | 43 000 000 |
| **Finland** | 494 000 000 |
| **France** | 2 324 750 000 |
| **Hungary** | 375 727 022 |
| **Ireland** | 75 000 000 |
| **Italy** | 7 352 000 000 |
| **Latvia** | 179 000 000 |
| **Lithuania** | 147 000 000 |
| **Luxembourg** | 67 048 893 |
| **Poland** | 480 977 312 |

| | |
|---|---|
| **Slovak Republic** | 295 700 000 |
| **Slovenia** | 206 000 000 |
| **Sweden** | 999 839 421 |

*Table 9: road infrastructure maintenance spending[3].*

According to the data (2019) Czech Republic, Denmark, France, Italy and Sweden are the countries with the highest spending for maintenance of their networks.

Moreover, as we have mentioned before, many National Road Authorities share their responsibilities as owners and managers of main roads with private concessionaires, thus outsourcing monitoring activities to third-party service providers through contracts. Depending on the country, budgets and durations for contracts may vary.

Simultaneously, other European countries do not rely on external agencies for their operations and the financing for road maintenance comes directly from the national budget.

Table 22 in attachment 7.5 summarizes countries' budget for maintenance and contracts: (we have only taken into consideration concessionaires that are current members of the European Association of Operators of Toll Road Infrastructures – ASECAP).

In Austria, the total road network, comprising toll roads, motorways, and expressways (2,249 km) is fully managed by ASFINAG. The company is financed through tolls, capital markets and issuance of bonds, hence does not receive any state subsidies. In 2018, the budget for maintenance was approximately 844 million euros.

Following with Belgium (Flanders), The Agency for Roads and Traffic (Agentschap Wegen en Verkeer/AWV) is the road authority in Flanders region, responsible for the management of motorways and regional roads (7,000km), which represents a 4.5% of the total road network (154,012 km). The company is financed by the government and the budget for road infrastructure in 2020 was 782 million euros, of which 170 million euros was for maintenance.

The Danish Road network covers 74,558 km, from which 1,600 km (about 2%) is operated by the Danish Road Directorate. Local roads are 60,000km of the total network (84%) and are managed by municipalities. Similarly, regional roads are operated by counties and consists of 10,000 km (14%). On the other hand, ASECAP member Sund&Baelt covers around 40 km (less than 0.5% of the total network). This company operates under a Public-Private Partnership, and it is financed through state loans.

Highways England operates the Strategic Road Network with 6,920.179 km, that represent 1.6% of the total road network (422,514 km). Since it is a governmental agency part of the Department for Transport (DfT), the company is financed by the government and had a budget for road infrastructure of 17,84 million euros in 2020. On the other hand, Midland Motorway Group oversees 43.45 km (less than 0.5%) under a Long-term Design Build Finance Operate commission (25-30 years). The rest of the network is operated by the authorities of each region, namely Transport for London (London roads), Transport Scotland (Scottish roads), Welsh government (Welsh roads) and local authorities (local roads).

[3] Transport - Infrastructure maintenance - OECD Data

Germany has a total network of 644,480 km, from which 38,018 km are main or national roads operated by the Federal Ministry of Transport and Digital Infrastructure, representing 5.8% of total roads. The agency is financed through federal tax funds and tolls and has a financing plan for road infrastructure of 132 billion euros from 2016 to 2030, of which 67 are allocated to maintenance. Moreover, from 2021, there is a new plan for PPP projects on German federal trunk network (mostly motorways/Autobahnen) in which Autobahn GmbH, private company, will operate and maintain 13,000km of motorways, a 2% of the network (with the federal government as sole shareholder and owner of all roads). Also, Toll Collect GMBH (ASECAP member) is in charge of 50,948.5 km (7.9%). The rest of the network is covered by secondary or regional roads.

In Italy, national roads cover 31,944.812 km of the total Italian network (487,700km). This means that the national road authority, ANAS manages and operates about 6.5% of the total roads. ANAs is financed by the government and by EU funds. The company has a plan for long term investment in road infrastructure of 29.9 billion euros, of which 15.9 are for maintenance. Same as other countries, concessionaires also manage part of the roads, in this case, AISCAT (ASECAP member) operates 4835,4 km, about 1% of total roads. Also, Autostrade per l'italia (Aspi) covers 3,000km (0.6%).

The French network consists of 1,028,466 km, being one of the largest networks in Europe. National roads (21,500km), as well as non-concession motorways (2,800km) are managed by the Interdepartmental Roads Directorate, an entity created by the Ministry of Transport that operates 2.9% of the total network. Contrary, concession motorways (tolled) cover 9,193.3km and are managed by private motorway companies, such as ASFA (0.89%). Furthermore, departmental roads, in hands of local authorities/general council, represent 36.9% of the total network (380,000km) and local roads, operated by local authorities/city council, about 63.2% (650,000km)

In the Netherlands, roads are operated at four administrative levels. National roads, covering 5,200km and 3.7% of total roads (139,295km), are in hands of RWS, the national road authority. Moreover, the 7,800 km of provincial roads are operated by the 12 provinces authorities (5.5% of the total). As per usual, municipality roads cover the biggest share of total road network, up to 86.1% (120,000km operated by local authorities. Also, there are 7,500 km that are managed by other authorities like water management boards. 24 km are dedicated to N.V. Westerscheldetunnel, an ASECAP member

Norway has a total road network of 93,870 km, from which national roads cover 10,713 km and county roads 44,639km. Both types of roads are operated by the national road authority, the Norwegian Public Rods Administration (NPRA). Therefore, they manage a total of 55,352 km, which represents approximately a 60% the total Norwegian network. In 2018, NPRA invested 6,05 billion euros in road infrastructure.

Spanish system is also divided in administrative levels. The total road network is 683,175 km from which national roads are 26,477.46 km representing a 3.8% of the total, operated by the General Directorate of Roads, which had a budget for road infrastructure of 1,913 million euros in 2020. Moreover, toll network is 2878,4 km, of which the 27 companies comprising SEOPAN (ASECAP member) cover 1,879.4 km (Other concessionaires 11 not part of ASECAP cover 999km). The remaining of the network is operated by different regions. (Regional roads by the 17 autonomous communities, provincial roads by provincial governments and local roads by city councils). In Spain usual maintenance contracts last 4 years. Other types of contracts regarding construction concessions or operation concessions could last 40 years and 20 years, respectively.

Finally, Swedish Network covers 579,564 km in which 8,900 km are national roads. This means that the Swedish Transport Administration operates 1.5% of the total network. In 2020, the budget for road infrastructure was 5,10 billion euros.

In summary, ASECAP members operate in different countries helping to manage roads together with National Road Authorities. Most of them operate through the PPP system (Public-Private Partnership) to fund projects, typically used for infrastructure planning. In Europe, it's used different types of PPP. For instance, in England the Design Build Finance Operate Maintain (DBFOM) (or Build Operate Transfer, BOOT) Concessions model, is commonly used for new build facilities. In this model, the private company finances the construction and at the end of the concession, the company transfers the facility ownership to the State. Similarly, France utilizes concession contracts where the financing responsibility and risks rely on the private company, which is funded by toll revenues. At the end of the contract, the toll structure is returned to the State.

Others, like Denmark use a "state guarantee model" kind of system, where the government finances the construction through loans in return for a "guarantee commission", then user fees are charged by the private company to repay the loans. This system is similar to the Build Operate Transfer (BOT) system where governments finance the construction, and the private firm is in charge of building it. However, BOT entails government ownership of the infrastructure.

Also, for existing facilities, the most used are Operations and Maintenance (O&M) Agreements and Service Contracts. Usually, contracts are given for long periods, between 20 to 40 years.

| PPP type | Characteristics | Risk | Ownership |
|---|---|---|---|
| **Service Contract** | - Services are outsourced to private companies<br>-Government controls and supervises | Private company: low risk (no equity risk) | Government |
| **Operation and Maintenance Contract (O&M)** | -Private company manages and operates the facility<br>*Similar to service contract, but the private company holds more responsibilities | Private company: Risk of maintaining the infrastructure under specific standards | Government |
| **1.Build Operate Transfer (BOT)** | -Government finances<br>-Private company builds and operates the facility (concession)<br>-At the end of the concession, transfer to the Government | -Government: equity risk<br>-Private company: Construction risk | Government |
| **2.Build Operate Transfer (BOOT)** | -Private company finances, builds and operates the facility (concession)<br>- At the end of the concession, transfer to the Government<br>*DBFO in UK | Private company: equity and construction risk | Private company until transfer |

*There are other types of PPP, such as Build Transfer/Annuity type, Rehabilitate Own Operate Transfer (ROOT)/(ROT), Build Own Operate (BOO), Rehabilitate Own Operate (ROO) and Privatization.

*Table 10: A brief overview of the types of contracts, characteristics, risks and ownership.*

Moreover, we can see those countries such as Norway, Sweden and Switzerland have robust budgets for the maintenance of their networks. Also, England, Germany and Italy have a long-term investment plan, allocating more than 2 billion to road maintenance.

On the other hand, Estonia, Iceland, Lithuania, and Luxembourg have a restricted budget compared to the ones mentioned before.

## SECTION 4: BUSINESS ECOSYSTEM ANALYSIS

This section aims to provide the reader a complete analysis of ESRIUM's business environment by making use of different mechanisms and tools to understand their position in the market. Sub-sections are divided as follow: section 4.1 targets the market for ESRIUM's solution by specifying on potential customers and countries interested in the service. Following, a variety of instruments have been considered to have a better understanding of the market. SECTION 4: define the current market trends related to ESRIUM's topics, section 4.6 describes the environment of ESRIUM by using a PESTLE type of analysis, , in section 4.4 a competitive analysis have been developed by studying existing market solutions (4.4.1) and using a Porter's Five Forces Analysis (4.4.2), section 4.4.3 asses the existing and emerging business models, section 4.5 seeks to estimate the market potential for ESRIUM's services on a global, European and country specific level, and finally, section 4.6 gives information of ESRIUM's strengths, weaknesses, opportunities and threats via a SWOT analysis

### 4.1. Target Market

By making use of desktop research, together with insights from interviews with road authorities and an online survey with possible end-users, we have been able to properly identify the target market for ESRIUM's services. This sub-section is divided into target customer, referring to potential users, and target location, indicating the most suitable countries for ESRIUM'S technology.

#### 4.1.1. Target Customer

The previous section highlighted different facts about countries and their processes for road maintenance, which enables us to identify potential customers for ESRIUM.

**National Road Authorities (NRAs)** are the main customer segment, as they have the responsibility of planning, designing, constructing, improving, maintaining, and managing National Road Networks. As stated, state road authorities also share those tasks with **concessionaires**, therefore, both entities can be considered the same customer segment. By making use of real-time data gathered by cameras on vehicles, the mapping for road damages will be improved at a large scale. Benefits such as time efficiency and cost-reductions will facilitate road authorities' operations, by decreasing the time of planning for maintenance due to high availability real-time data. Furthermore, the system capacitates road operators to gather data by themselves with the use of their vehicles, which means that hiring external service providers for road maintenance will not be needed anymore, thus decreasing costs. Therefore, the targeted market can be considered the list of NRAs provided above together with ASECAP members.

The same features can enable **cargo fleet operators, engineering firms and logistics firms** to efficiently improve their activities. Updated data of road damages and recommendations for Heavy-Duty-Vehicles to use specific lanes, can be beneficial for both road operators and vehicle operators. For instance, by informing upcoming potholes or cracks, the driver can effectively dodge road deficiencies, thus increasing road safety for all vehicles, upgrading the driving experience, and ensuring less wear for the vehicle itself. Also, vehicle operators can be rewarded with a reduction of tolls if they follow lane-recommendations. On the other hand, this can also benefit road operators because of a reduction of road deterioration.

Other segments that could be considered are **car manufactures.** The near future of automated vehicles is pushing car companies to engage with live data and digital twins, for which ESRIUM's solution is interesting for them. Other targets could be **truck and car drivers themselves** since the use of real-time data on damages on the road may decrease traffic accidents and provide a safe ride for all. Finally, we can also consider **bus travel agencies** (i.e., Flixbus) or **ride-sharing companies** that are interested in giving the best service for their passengers, for example by offering the fastest

routes and shortest trips. Thus, ESRIUM's service can supply accurate date of the roads and lanes, which may induce efficient and fast rides.

### 4.1.2. Target Location

Even though this report has been focusing on Road Asset Management at a European level, it is important to note that not all EU countries are the same, as we have explained in the previous section. Countries may differ in their geography, climate, population, and economic situation. Therefore, to target specific countries it is necessary to identify parameters to compare them and select the ones that comply with the classification criteria.

To target countries, we have based our selection on the following parameters: national road network length (km), Annual Average Daily Traffic (AADT), proportion of Heavy Goods Vehicles, technology maturity and road maintenance budget. The list of targeted countries is the following: Austria, Belgium, Denmark, England, France, Germany, Italy, Norway, Netherlands, Sweden, Switzerland, and Spain.

After analyzing the situation for each country, we have encountered those **Northern European countries** such as **Norway, Sweden, Denmark, England** have high maintenance budget for contracts and high spending for infrastructure maintenance. In 2019, Denmark and Sweden spent 1 151 451 725 euros and 999 839 421 euros respectively in road infrastructure maintenance. Moreover, Norway, Sweden and England have high budgets for maintenance of their networks reaching EUR 5-6 billion. (England invested EUR 17,84 billion during 2015 and 2020). Furthermore, England is one of the top countries with highest AADT and proportion of HGVs. Also, Norway is one of the three countries in Europe with implementation of level 4 ITS. ESRIUM's services will help these countries reach level 4 (cooperative ITS) or increase their deployment (Norway).

Following, **Western European Countries**, namely **Austria, Belgium, France, Germany, Netherlands, Switzerland** have the longest national road network (km) (in particular, France and Germany with 1,028,446 km and 644,480 km respectively). Belgium and the Netherlands have the highest annual average daily traffic. On the other hand, the proportion of HGVs is the largest also in Belgium and in Germany. Regarding technology maturity, these countries have the highest level of ITS technologies (level 3: Switzerland (94.5%), Netherlands (85.6%) and level 4: Austria (1.4%). All of them have high maintenance budgets and spending, for instance France spent 2 324 750 000 euros in road infrastructure maintenance during 2019. Since these countries face heavy traffic daily and Heavy Goods Vehicles operate in high scale in most of them, the value of ESRIUM for them can rely on improving safety of their networks and reducing road deterioration by real-time data of damages and lane-recommendations. Also, by adapting ESRIUM technology, higher levels of ITS can be obtained.

Finally, it is interesting to look at **Southern European countries** like **Italy** since they have long road networks (487,700 km) and mid-levels of ITS technology (between level 1 and level 3) which could be an opportunity for them to use ESRIUM' solution to increase their ITS technology levels. Furthermore, Italy was one of the countries with highest expenditure on road infrastructure maintenance in 2019 (EUR 7 352 000 000) and has a long-term plan for investment in road infrastructure and maintenance of approximately 29.9 billion, from which technology deploying and improvement is one of the main goals. **Spain** could also be included, for similar reasons.

## 4.2. Market Trends (FHO)

The following ESRIUM-related trend selection on megatrends and related macro-trends is focused on the key words predictive maintenance, C-ITS, GNSS, digital map, Smart Road Infrastructure and was done by the project partner University of Applied Sciences Upper Austria.

The following four mega-trends are the result of the trendmanager analysis based on the above-mentioned key words.

- Intelligent Infrastructure
- Smart Data
- Virtualization
- Artificial Intelligence

The following paragraphs provide the ESRIUM-related trends. After mentioning the four mega-trends related macro-trends of the trendmanager tool are mentioned and the ESRIUM specific macro-trends are described additionally.

### *Mega-trend: Intelligent Infrastructure*

Extensive technological measures are needed to overcome the challenges facing infrastructure, for example, mobility and energy supply. Advanced network technology is essential for a functioning City OS operating a smart city.

Advanced network tech is required for a functioning smart infrastructure. It includes technologies such as 5G, NFC and laser, but also energy transmission. Smart cities make use of information and communications technologies along with sensor networks to control the flow of goods, people, and traffic as well as energy consumption and infrastructure utilization.

A wide variety of mobility solutions come under the heading of Connected Mobility. People can make use of various services seamlessly. Autonomous systems are self-driving cars and other autonomous systems for land and air.

Energy supply, too, relies on smart infrastructure. Smart grids control the generation, consumption, and storage of energy. A reliable and resilient energy system and uninterrupted access to energy are integral to modern life. The energy transition is making energy storage systems one of the greatest infrastructural challenges. Green IT is supporting energy conservation by means of suitable technologies as well as the optimization of energy consumption and use of resources in the production, operation, and recycling of technological devices.

**Related Macro-trends**

Autonomous Systems, Smart Grid, Energy Storage Systems, Connected Mobility, Advanced Network Tech, City OS, Green IT

### *Macro-trend: Autonomous Systems*

Autonomous vehicles that operate on land, water and in the air will fundamentally change our understanding of mobility. With the aid of sensors, such as radar, LiDAR and camera systems, cars can scan their environment with more accuracy than human drivers. Autonomous robots deliver goods, explore bodies of water and pick up rubbish.

**Traffic management using algorithms**

Traffic will fundamentally change when vehicles can communicate with one another, and artificial intelligence manages the flow of traffic. Systems that facilitate accident-free and legally safe driving already exist. Algorithms continuously calculate possible routes in transit with the aim of finding a route that is guaranteed not to cause damage. In the process, they predict other drivers' legal maneuvers in fractions of a second.

**Acceptance by society**

However, for the technology to make a breakthrough, it requires acceptance by society. Many people do not like relinquishing control. Plus, other drivers have to be convinced that the artificial intelligence will decide according to their moral code if, for example, an accident cannot be avoided. This code varies from region to region.

### *Mega-trend: Smart Data*

Smart data are data sets that have been extracted from larger amounts of data (Big Data) using algorithms according to certain structures and obtain meaningful information. This data has already been collected, ordered and analyzed beforehand and prepared for the end user. The data must also be able to be understood by the user in order to achieve a meaningful result. The semantics of the data, data quality, data security and data protection must be considered. Smart data can be used both to gain new insights using raw data and to create models that can be used to analyze data.

Smart Data often also uses Big Data and Fast Data mechanisms. A transition from Big Data to Smart Data is also often desired.

**Related Macro-trends**

User Profiling, Cybersecurity, Digital Twin, Predictive Analytics, AI Assistant, Augmented & Virtual Reality

### *Macro-trend: Digital Twin*

A digital twin is a virtual representation of a material object including all the processes that exert some kind of influence on it. The concept is based on the approach of mirroring products, systems and processes including all their interactions at the digital level in the form of a dynamic simulation. Digital twins can also refer to intangible goods, such as in the planning of large-scale projects like the construction of factory site.

**Industry at the forefront**

Industry is a pioneer here and uses digital twins to mirror individual components or entire plants. This serves to simulate the ongoing operation. A permanent exchange and matching of the real object's data, collected by sensors, with the digital copy enables a realistic simulation of reality. In combination with smart software, production cycles can be simulated, real plants optimized, and predictions made about potential disruptions.

**Digital twin for X**

This concept can also be found in environmental protection and the health sector where it is used to simulate biospheres or complicated operations. In future, everyone could have their own digital twin. Trained using individual data, such a twin will enable predictions on future health status.

### *Macro-trend: Predictive Analytics*

Predictive Analytics seeks to predict future situations and scenarios. For this purpose, algorithms evaluate historical and recent data. The aim is to use personnel and other resources as efficiently as possible. In future, predictive intelligence will increasingly be used with regard to human behavior. Based on the evaluated data, the software will be able to predict which steps specific users will take next. This will help to pave the way for automated decision-making.

**Prescriptive Analytics**

Prescriptive Analytics goes one step further and provides recommendation for action in addition to the probabilities of certain scenarios taking place. This enables automated decision-making. It works by using algorithms to analyze large amounts of data from a wide range of sources. Artificial intelligence, simulations, statistical methods, and probability calculations are all used here.

**Impact analysis**

The aim is to find out what impact the various recommendations for action will have on the overall result and what steps should be taken or avoided to achieve a certain result. The important thing is that the underlying data is sufficient and valid.

### *Mega-trend: Virtualization*

High-performance and versatile input devices, multisensory enhancements and the growing number of cheap, accurate sensors are opening up new possibilities in the virtual world. The demand for and

development of technologies is increasing due to the digitization of analog activities and their remote implementation.

Covid-19 has brought about a wave of development in virtual platforms and digital tools that facilitate virtual collaboration and support flexible, agile ways of working. In industry, thanks to advanced sensors, complex simulations are possible with digital twin technology, and these simulations are also being used in environmental protection and in the health sector. Virtualization technology is also becoming a fixture of our daily lives and is changing, for example, how we shop, consume culture, or see a doctor (Remote X).

Augmented, mixed and virtual reality are bringing about a fusion of the digital and analog in everyday life. This involves a high degree of personalization, enables us to interact virtually with people and content, and provides memorable experiences. The multisensory enhancement of virtual content, such as with olfactory or haptic elements, is giving rise to a whole new level of immersion that can be used for virtual training, in the health sector and in the gaming industry.

**Related Macro-trends**

Digital Twin, Virtual Collaboration, Remote X, Simulated Senses, Augmented and Mixed Reality, Virtual Reality

*Macro-trend: Digital Twin. (This macro-trend is also mentioned for the mega-trend "Smart Data" and is described in the related paragraph above.)*

### *Mega-trend: Artificial Intelligence*

Artificial Intelligence (AI) applications are becoming increasingly prevalent in our everyday lives. Research is advancing at lightning speed. At the same time, the potential dangers associated with AI-based processes are become increasingly clear.

Digital personal assistants and smart speakers, such as Apple HomePod, Amazon Echo and Google Assistant, are taking over our homes and workplaces. Virtual assistants support people in their day-to-day work or personal lives. At the same time, more and more AI systems are taking the decision-making out of people's hands (predictive analytics). As a result, AI Trustability is becoming a critical factor in whether the technology is accepted. Many algorithms reinforce preconceptions developed at the development stage. AI is becoming increasingly creative and emotional. Creative AI is used in the film industry, for example, while Emotion AI aims to interpret human behavior.

Neural networks or Deep Learning make the algorithms capable of learning. In cognitive computing, human thought processes are simulated, so complex problems can be solved independently. However, universal artificial intelligence, or strong AI, is probably some years off. Initially, AI applications are only solving concrete problems. But progress – including in neuromorphic hardware, where processors replicate the functions of human neurons – is bringing us a step closer.

**Related Macro-trends**

Neuromorphic Hardware, AI Assistant, Cognitive Computing, Creative AI, Predictive Analytics, Emotion AI, AI Trustability

*Macro-trend: Predictive Analytics. (This macro-trend is also mentioned for the mega-trend "Smart Data" and is described in the related paragraph above.)*

### 4.3. PESTEL Analysis

| Factors | ESRIUM-related analysis |
|---|---|
| **Political** | Poor traffic management or high efforts for road maintenance negatively impacts traffic participants as well as the overall society. Traffic congestion is clearly linked to increased fuel consumption, carbon dioxide emissions and air pollution, which are an environmental and societal threat.<br>The Sustainable Development Goals of the United Nations (UN SDGs) set the scene for future political agenda settings as well as individual goals of countries: Relevant UN Sustainable Development Goals which are contributed to by the ESRIUM project are:<br>• Goal 3 - Good health and well-being: Ensure healthy lives and promote well-being for all at all ages<br>• Goal 9 - Industry, innovation, and infrastructure: Build resilient infrastructure, promote inclusive and sustainable industrialization and foster innovation<br>• Goal 13 - Climate action: Take urgent action to combat climate change and its impacts<br>The project is furthermore in line with the EU 's Green Deal goals of improving air quality (green deal expected benefit: fresh air, clean water, healthy soil and biodiversity) and investing in the resilience of the EU's industry (green deal expected benefit: globally competitive and resilient industry).<br>ESRIUM further drives digitalization (e.g., digital twin of the road wear situation and its forecast). The EU has long been the driver of digitalization (see the Data Act and other initiatives) and ESRIUM can take the concept to an area (e.g., managed infrastructure) where it had lower penetration.<br>The tense situation in Ukraine will further drive cost savings in areas (like managed infrastructure) where traditionally a lot of manual labor and expensive, highly trained human resources were used. This sad situation opens up the possibilities ahead of cost saving initiatives (and it makes the ESIRUM business case and proof of cost savings even more important). |
| **Economic** | With GNSS-based precise road sensing and AI-based algorithms like in ESRIUM, predictive maintenance activities can help to reduce severe road damages and therefore maintenance costs for road operators. This helps most of the publicly owned road operators to reach their goal on effective resources management (internal maintenance costs, external negative environmental impact and therefore increased costs).<br>GNSS-based applications like in ESRIUM are highly welcome for Europe's economic players (industry, service providers, etc.). All these stakeholders can benefit from Europe's investment in its global navigation satellite system.<br>ESRIUM will need to adopt efficient development methods and tools as the planned architecture and components are not cheap and complex to implement.<br>The newly proposed sensor solution can introduce an avalanche of cost savings in the road infrastructure maintenance area.<br>The business model of the ESRIUM components is not homogenous thus components shall be optional and replaceable - further driving cost savings in the project and the industry. |

| | |
|---|---|
| **Social** | With regards to the social environment of ESRIUM there is no direct impact visible for precise sensing and the followed road maintenance services of road operators. A possible indirect impact could be increased road safety by better maintaining European roads and reduce negative environmental impact by reducing traffic jams caused by long-term roadworks. However, this is not the focus of ESRIUM.<br>Privacy of shared information - following the EU regulations and directives - need to be considered if data is shared from car fleets (even if that is the re-use of state-owned fleets like post cars) and sensors of private vehicles and drivers. |
| **Technological** | Technological developments almost always have been a driver for further innovations. Sensors are crucial for development of innovative projects such as ESRIUM. The sensors in a car's proximity include LIDAR, Radar, and visual cameras. Advancement in sensors and IoT devices will for sure drive the ¨road-wear¨ layer and can bring further advancements and innovations.<br>Continuous advancement in artificial intelligence and 5G are also driving demand and assist in adopting technologies as the ESRIUM system. Expecting that connected and automated vehicles can be guided in a more precise way and benefit from more frequent updates of a “road wear” layer, the expected costs without changing the overall survey method (staying on products like RoadSTAR) would be too high for a full coverage of the entire network, which would be necessary for any automation efforts. Thus, the emergence of autonomous vehicles will push advancements and demands for updated ¨road wear¨ layers.<br>Having digital twins (concept and sample implementations) widely available can make the implementation cheaper (e.g., via clever make-or-buy decisions).<br>ESRIUM makes use of the European Satellite Systems; it needs to consider though GNSS vulnerabilities.<br>ESRIUM can drive standardization of road damage data in different areas like C-ITS, OpenDrive, NDS.Live, TPEG and others; making a new road damage model commonly available and re-used by the standards. Decorating the road damage information with a time scale (for prediction purposes) and information on deeper roadbed quality makes these standards even more widespread and opens up new use cases for them.<br>Sensor data collection and sharing is standardized via SENSORIS; data distribution channels next to C-ITS can be used to publish the road surface information. |
| **Legal** | Regulations and legal framework are a key driver for deploying solutions such as ESRIUM, since those raise liability, safety, and data protection concerns. Efforts by the European Union have been done to stablish a standard framework for roads and ITS in Europe, such as the ITS Directive, which can be considered a push factor to help ESRIUM to a successful market entry. The goal of this tool is to coordinate deployment of ITS across all member states in order to increase safety, including regulations on multimodal information, ticketing services, communication between vehicles and infrastructure, automated mobility and commands that all EU countries must be involved in data collection for providing real time services and information about accidents or damages on the road. Hence, a more structured legal framework is relevant for ESRIUM services to be efficiently deployed in their ecosystem. |
| **Environmental** | Changing demand and environmental issues can be another driver for new solutions as ESRIUM. Road transport is focused on providing a safer, greener, and more sustainable system for all road users. The efficient use of existing road infrastructure, |

| | |
|---|---|
| | combined with increasing mobility demands by providing mobility as a service and the overall increasing demand for the delivery of goods, indicate that road operators have to look into more efficient ways to operate and maintain their existing road networks. The Road Safety Directive and Vision Zero (also for emissions) pushes the industry to find sustainable and smart solutions.<br>The use case of routing traffic to less damaged and more resistant road surfaces also reduces particulate matter in the air and along with it, air pollution.<br>Together with the above routing use case and by implicitly reducing air pollution the project is greatly in line with the green deal expected benefits. |

*Table 11: PESTEL analysis result.*

## 4.4. Competitive Analysis

### 4.4.1. Existing Solutions

In every country there are different norms and standards regarding the road surface.

Compliance with these standards is also measured and certified differently in each country, which means that there are different solutions and focal points for measuring the road surface in each country and different competitors who carry out these measurements. Many of these measurements are still carried out in analog form or have been digitized bit by bit for years. These are the forerunners of a future digital twin.

| Competitors | Predictive maintenance | Inspection | V2X | Inventory | Digital Twin |
|---|---|---|---|---|---|
| Omicron | + | + | + | + | + |
| ROADSCANNERS | + | + | | + | + |
| LEHMANN + PARTNER | + | + | | + | + |
| IWS Messtechnik | | + | | | |
| AIT RoadSTAR | | + | | + | |
| Intents Mobi | | + | | + | |
| ROMDAS | | + | | + | |
| Ricoh | | + | | + | |
| EyeVi | + | + | | + | + |
| HAL24K | | + | | | |
| eagle eye | + | + | | + | + |
| 3D Mapping Solutions | + | + | | + | + |
| Greenwood | | + | | + | |
| NIRA Dynamics | + | + | + | + | + |
| Pathway | | + | | + | |

| | | | | | |
|---|---|---|---|---|---|
| **Deighton** | + | + | | + | |
| **ARRB** | | + | | + | |
| **ESRIUM** | + | + | + | + | + |

Most of ESRIUM's competitors descended from these existing vendors. Some are already partially digitally mature; some are still very analogue. Depending on the degree of digital maturity, there are also the possibility of solutions. Whether initially just simple measurement of inventory such as inspection. If there are further new solutions such as, predictive maintenance, V2X and the full expansion, a fully comprehensive digital twin which covers everything and will enable digital simulations of all kinds in the future. Table 12 shows the various providers and their variety of solutions. This competitor analysis is a supporting and complementary analysis between the solutions on the market and the Porter's Five Forces analysis.

In the market there are 2 main divisions of the competitors (Professional/ Semi-Professional) and these start and mainly concern data generation. These 2 different types of data collection and data sources then enable or hinder the possibilities of further data processing (AI) and that is crucial for the further course and their business models.

**Professional Competitor: (roughly comparable to ESRIUM)**

Competitors with professional sensors use a wide variety of high-precision, certified sensors and produce standardized, qualitatively certified data whose standards are recognized.

| Advantages | Disadvantages |
|---|---|
| • Very high data accuracy.<br>• Combination of many scanning parameters<br>• Future in-depth processing of the data possible | • Expensive Sensors (Hardware) from € 75,000- |

*Table 12: Cost-benefit of professional competitor.*

**Semi-Professional Compeditor:**

Most commercially available smartphones are used for data acquisition, with the optical and GPS sensors serving as the main data source. Other sensors such as acceleration and complement the data.

| | Advantages | Disadvantages |
|---|---|---|
| **Vialytics**<br>**Vaisala**<br>**RoadCare**<br>**TotalPave**<br>**RoadBounce** | • Very cheap hardware approx. € 1,500. -<br>• Very easy to assemble | • Low data accuracy which is attempted to be compensated by the SW algorithm<br>• Low number of sensors<br>• Use only in the best weather conditions<br>• High error rate<br>• Not a long technical service life |

*Table 13: Cost-benefit of semi-professional competitor.*

According to the motto "garbage in garbage out", no professional benefits and business models can be offered with semi-professional data acquisition. The smartphone solution providers are no competition for ESRIUM and can be neglected.PA

**Comparison regarding personnel costs for data collection:** The costs of data acquisition (personnel costs) are currently approximately the same for both variants.

1-2 people drive the route in a vehicle. In the future, ESRIUM will measure autonomous vehicles (Level 4) and reduce personnel costs.

**Data evaluation:** Regardless of the data collection, software algorithms process the data and generate the required benefits and business models. Most competitors limit themselves to the collection and evaluation.
Complete integration into the existing system of the road operator, as with ESRIUM, is only offered by very few competitors.

Note that updating the AI based detection of road wear features needs the collection of a new set of ground truth data and retraining the AI detector, which implies high costs. Actually, the update is nearly the same effort and cost as the initial development of the detector, as it includes the same efforts for data collection, ground truth labelling retraining and optimization.
Taking this into account, we would see an update like buying a new software licence of the “Road Wear Feature Detection Software – Licence” (calculated with €20.000,-) as a one-time payment.
The amortisation time was calculated with 5 years, because we believe that there will not be massive changes in the types of different road damages and their appearance. Its most likely if new materials for road surfaces might be used in the future or if new types of damages are accruing to due climate change. Anyway, an update of the “Road Wear Feature Detection Software – Licence” including an Up-to-date AI based detector, could be bought by customers at any time and on demand.
A yearly optimization of the detector based on performance evaluations of detection results will be included in calculated cost position “Road Wear Feature Detection Software – maintenance” (€3.000,- per year). Also, changes to the official road wear classification scheme (meta data) could be added to detectable road wear types and classes without any extra cost within the yearly maintenance fee.

**Customers:**
All professional Competitor want existing road operator as customers. With ASFINAG and NLS in ESRIUM as project members, we have a clear know-how and reference customer advantage over other providers. We can present an existing, working solution and start a pilot project immediately and gain experience in real operation.

**Prices:**
The current manual analogue recording of the existing infrastructure of the road operator is very personnel and time intensive and therefore very expensive. The costs for recording and added value with a digitized solution are definitely cheaper and therefore the price of the provider is not decisive.

Some Semi-Professional Smartphone solution providers have fixed, inflexible standardized offers and offer costs per kilometer. e.g. https://vialytics.com/ from € 100,-/ KM.

The price differences of professional competitors are not decisive for the customers at the moment. Due to the individual solutions and offers, prices are hardly comparable. The offers and their solutions are too individual.
The currently still small number of providers and the high demand of the customers prevent a price war.

### 4.4.2. Porter's Five Forces Analysis

The following figures provide a very first Porter’s 5-forces analysis for the ESRIUM business cases. This analysis is based on the feedback of ESRIUM project partners (P= partner) who rated the risks on a scale from low to high.

| Partners' response | Bargaining power of buyers | Threat of substitute products or services | Bargaining power of supplier | Threat of new entrants | Rivalry among existing competitors |
|---|---|---|---|---|---|
| P1 | High | Low | High | Medium | Low |
| P2 | High | Low | High | Medium | Medium |
| P3 | Medium | Low | Low | Medium | Medium |
| P4 | Low | Low | Low | Medium | Low |
| P5 | High | Medium | Low | Medium | Low |
| P6 | Medium | Medium | Medium | High | Medium |
| P7 | Medium | Low | Medium | Medium | Medium |

*Table 14: Porter's Five Forces Analysis risk result.*

Figure 8 presents some lessons learnt out of the internal rating.

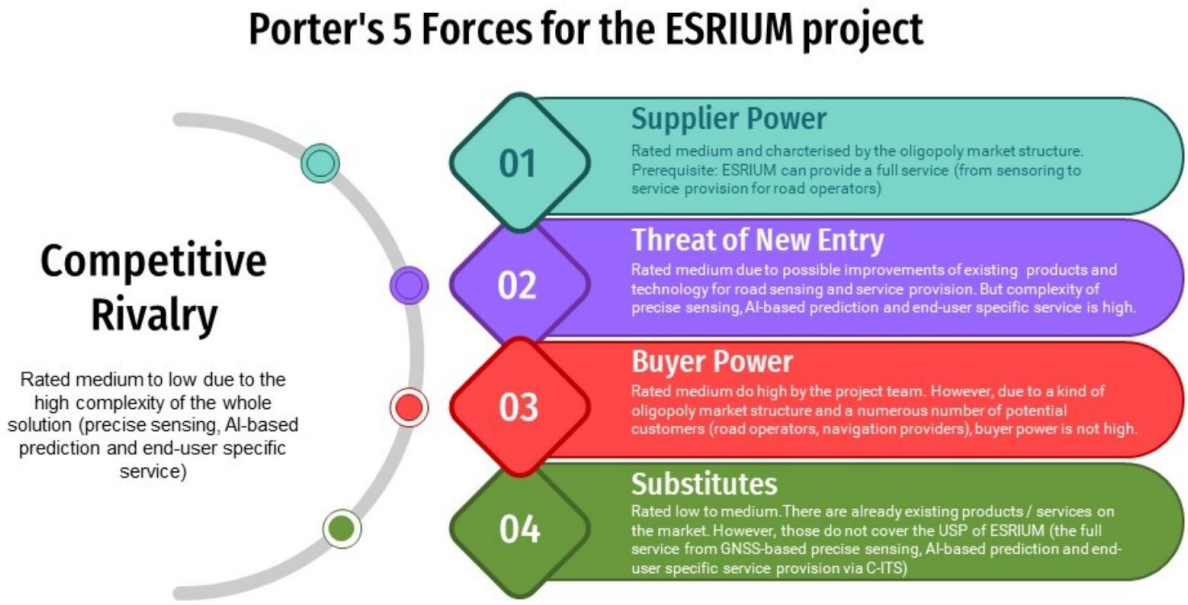


*Figure 8: Porter's Five Forces Analysis for ESRIUM.*

### 4.4.3. Existing and Emerging Business Models

The purpose of collecting, processing and analyzing road condition data is traffic safety. This knowledge can be used in a direct and an indirect way to achieve the purpose; these are the two types of customers of a road quality service:

- The indirect way is the traditional solution when the road operator collects the data in the best quality available, analyzes it and use the results to optimize road maintenance works and to avert the most safety critical road damages.
- The direct way is sharing road condition information (e.g. pothole warnings) with traffic participants (e.g. fleet operators, drivers).

Currently these two use cases of road condition data usage are usually operated absolute separated by different actors:

- The service providers for road operators are typically 3rd party (or in-house) specialists with high expense, high quality equipment. Their service is then delivered via proprietary means and many times via manual labor and human specialists (e.g. manually tagging road service problems and executing statistical analysis based on previous experience and regulations. These types of activities are country and municipality-specific, their coordination is done via international information sharing means (congresses, white papers, closed communities of experts etc).
- The service providers for traffic participants are typically smartphone or PC apps, with cheap, utilizing the input of built-in sensors (of the mobile phone or maybe of the properly equipped vehicles). The delivery of the service is either via a smartphone or a PC app; sometimes delivering the raw input data, or more often using an aggregating cloud service that filters, summarizes, and generalizes the raw input. The service can be free of charge (like Waze) or a pay-per-use business model for more advanced users (like fleet operators, routing service providers or truck drivers).

What is common among the existing business models is that the data collection, distribution and delivery pipeline is dedicated to that given service provider; there is no (or rare) sharing and aggregating of input data of different sources.

The emerging business models (e.g., competitors of ESRIUM) are a step further in sharing input data of different sources: they describe themselves as *"Intelligent and proactive infrastructure asset management"* (*roadscanners.com*). The services use multiple input sources and automatic post processing of the data with some level of prediction. So far there seems to be no database or input source sharing between these businesses, so they rely heavily on their own sensors, applications, data distribution channels and cloud services. The delivery of the data is usually not via standards, but via their own implementation.

| | Sevice provider | Solution | Customer | Goal |
|---|---|---|---|---|
| A | **Road detector specialist**<br>- 3rd party supplier<br>or<br>- the road operator itself | **Complex solution**<br>- from survey<br>- through data processing<br>- to analysis | **Road Operator** | **Road maintenance optimization** |
| B | **Community network**<br>- generally by smart phone apps | **Minimal solution**<br>- only position of road damage<br>- no other info<br>- no analysis<br>- no guarantee | **Community network and Smartphone app service provider** | **Support traffic safety** |
| **Emerging solutions** | **Data collection**<br>- smart phone sensors/apps<br>- vehicle sensors<br>- dedicated instruments installed on the vehicle<br>**Data processing and service**<br>- 3rd party supplier | **Complex automated solution optimized for big data processing** | **Road Operator and V2I service providers** | **Road maintenance optimization and Support traffic safety** |

*Figure 9: Existing and emerging business models*

Rating the current and the emerging solutions along the axles of

- Processes
  - Automation
  - Quality
- Service
  - Reliability
  - Accuracy
  - Price
- Data
  - Data amount
  - Data freshness
  - Update frequency

Some can see how the emerging solutions bite into every aspect of the current business models.

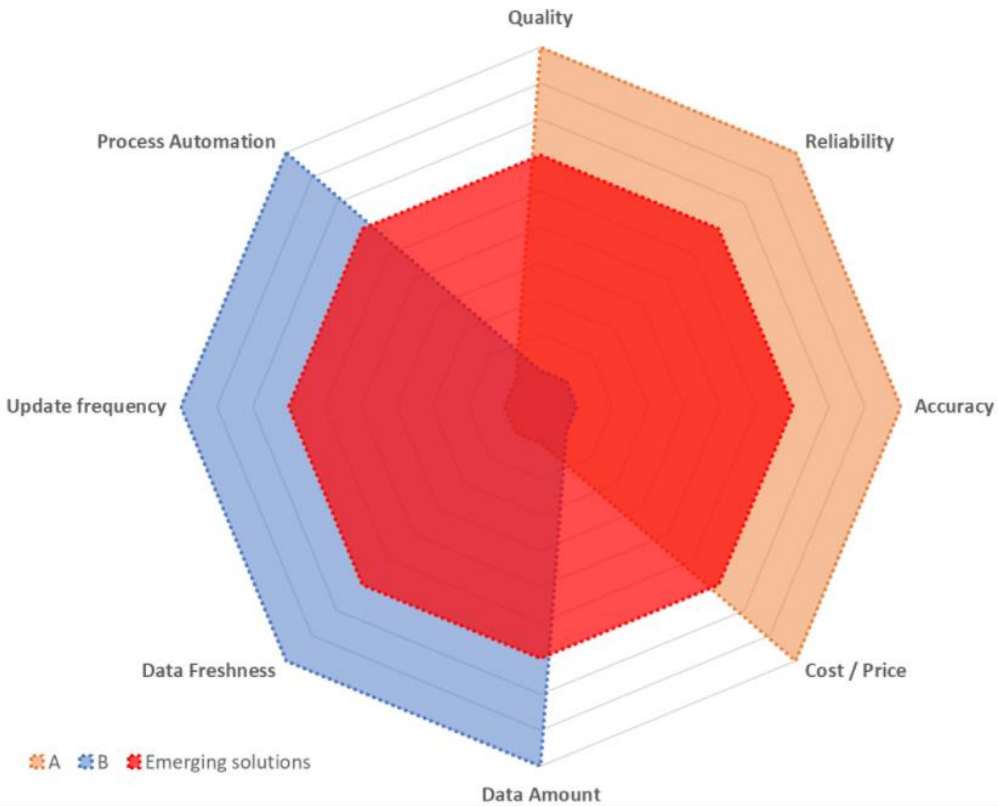


*Figure 10: Existing and emerging business diagram.*

As a summary, the existing and emerging business models so far got to the point of offering proprietary, but end-to-end services.

The key benefit of an ESIRIUM implementation can be along the lines of standardization, thus making the market of

- sensors (existing, or cheap, new, maybe even private vehicle built-in)
- mobile data input (manual or sensor based)
- data distribution (to highway operators, municipalities, and traffic participants)
- and data postprocessing (manual or automatic)

into open markets where solutions emerge and compete with each other, bringing the cost of road ware data down. Along the lines of these future, emerging components ESRIUM also delivers a turnkey, e2e solution as a proof of the concept of standard road ware data.

### 4.5. Market Potential

In this section, we perform market analysis and provide information on the Total Available Market (TAM), including asset management market, global total road network in km and by region, as well as price by km. A section for Serviceable Available Market (SAM) is provided including information about EU market and potential revenue per European country and its total road network. Finally, Serviceable Obtainable Market (SOM) section includes a list of possible targeted countries with specific characteristics such as technology maturity, large budgets and the potential revenue that could be reached within the first 5 years.

#### 4.5.1. Global Market

In 2019, The **Asset Management Market** (AMM) worth $3,463 million and is forecasted to achieve $7,529 million by 2027 with a CAGR of 10.3% between 2020 to 2027, according to MarketsandMarkets Analysis. North America is the leader of asset performance management market due to large adoption of Internet of Things (IoT) and Artificial Intelligence (AI). Moreover, IT budgets have been increasing in the region because of digital transformation of businesses characterized by the impact of cloud computing and AI on daily operations. Other regions expected to gain larger shares are Asia-Pacific and Europe. This represent an opportunity to ESRIUM since everyday more regions and businesses are employing Asset Management Systems for their services and operations.

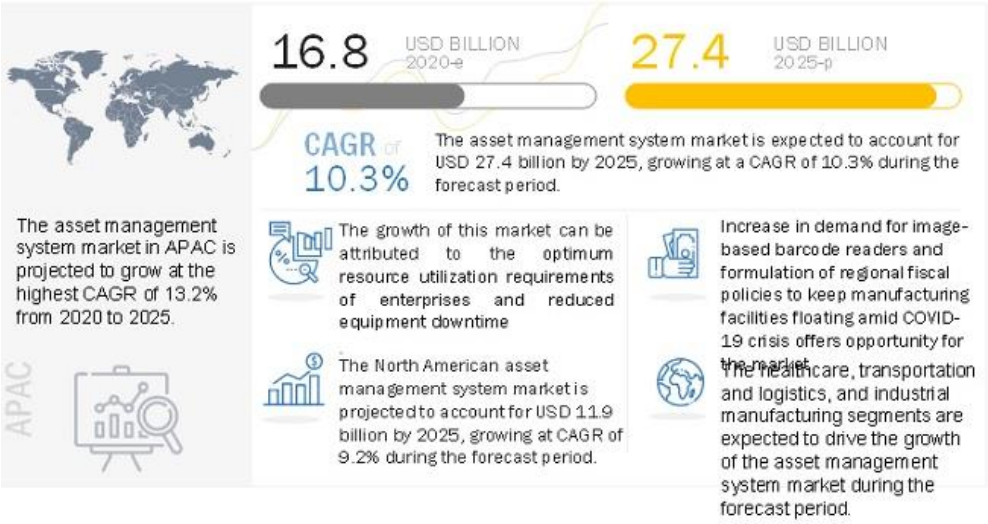


*Figure 11: Market forecast asset management system[4].*

Moreover, according to Industry Arc, the **Digital Map Market** will reach $29.67 billion by 2025, increasing at a CAGR of 13.81 percent between 2020 and 2025. In 2018, North America had the largest share of the market with 27% of the market. APAC and Europe also had important (but less) market share. The usage of digital maps to collect geographic information systems is comprising a wide range of sectors from automotive to fleet management, construction, and aerial intelligence.

A really important component in ESRIUM is the data collected from the **mobile mapping**. The mobile mapping market is experiencing tremendous growth in the use of laser scanning and positioning technologies. Recent advances in LiDAR technology have allowed mapping specialists to analyze

[4] MarketsandMarkets

natural and built-up regions with greater flexibility and precision. Global Market Insight predicts the mobile mapping market to grow to $65 billion in 2026 from a baseline of $20 billion in 2019. In 2019, Europe accounted for more than a quarter of the worldwide mobile mapping market, accounting for more than 25% of revenue. The European industrial demand is defined by the rapid development of self-driving cars and an increasing demand for location-aware technology (Global Market insights, 2020). According to the EGNSS agency, around three billion mobile applications already rely on location data. Furthermore, numerous EU states, particularly Germany, Italy, and the United Kingdom, are significantly relying on mapping tools for defense purposes. The advancements and market growth of mobile mapping will positively impact the market for ESRIUM as we be relying on the data gathered from Lidar sensors and cameras.

Moreover, as the road-wear layer provided by ESRIUM can contribute to the **HD maps**, we have investigated the market for HD maps. Following to the most updated report of Emerging Research, the HD maps for autonomous cars global market was valued at USD 1.58 billion in 2020 and is forecasted to reach USD 16.51 billion by 2028 at a steady CAGR of 34.3 percent.

The **autonomous cars market** is also expected to grow in the coming years. The worldwide autonomous vehicle market is expected to be worth $54.23 billion in 2019 and $556.67 billion by 2026, growing at a CAGR of 39.47 percent from 2019 to 2026 according to Allied Market Research. Also, advancements in connected and cooperative vehicles can open new opportunities and markets to ESRIUM. All these market trends will have a direct impact on the market size for the road damage maps and ¨road-wear¨ layers. While this is our current understanding of the market, further analysis will be performed in WP6 and during the project cycle including competitive analysis.

The **ITS market** has been value at 20.6 billion euros in 2020 and is expected to reach 27 billion euros by 2026, with a CAGR of 5.11% over the period. United States, Germany and India have been increasing their budgets in ITS and creating laws to make road telematics mandatory for the safety of their rods. Additionally, North America has the largest market share, being the most advanced region on levels of ITS and Asia Pacific is growing at the highest CAGR over 2021- 2026. For the European region, a market size of 14 billion euros for 2022 was estimated. The development of ITS is fundamental for the deployment of ESRIUM's technologies, thus areas with highest ITS levels may be more prone to adopt road-wear mapping earlier.

Moreover, the total **market for road-wear mapping** could be estimated by taking into consideration the global road network, as well as the price per kilometers.

According to an extensive study made by the IRS World Road Statistics, the Global Road Network by 2018 covers **32 million of kilometers**. Based on estimations made on 2.5, the price per km will be **10 euros** approximately, thus if we multiply this amount by the Global Road Network length, the global market for road-wear mapping is estimated to worth **320 million of euros**.

Moreover, we have identified the total length in km of each region in the world, namely United States, Latin America, Europe, Asia, Africa, and the Middle East. However, for Latin America, Asia, Africa and the Middle East, we have only taken into account major highway networks across regions, such as the Pan-American Highway (from US until Argentina), the Asian Highway Network (including India, Sri Lanka, Pakistan, China, Iran, Japan, South Korea, Nepal and Bangladesh), the Trans-African Highway network (connecting important regions like Cairo, Tripoli, Algiers, Dakar, Lagos, N'Djamena, Djibouti, Lobito, Mombasa, Beira, Gaborone, Windhoek and Cape Town) the Road Network in MENA countries (described by Statista). On the other hand, the total road network for the United States covers both rural and urban roads in the 50 states, following the 2018 report of the Federal Highway Administration. Moreover, European road network covers motorway, paved and unpaved roads for 46 countries.

Since we have only considered major networks, the following table describes a general and simple estimation of the total market size for each region. Furthermore, as a general assumption, it has been considered that the road maps are being updated 2 times each year:

| Region | Total Road Network (km) | Total Market size (in euro) |
|---|---|---|
| **United States** | 6,733,023.758 km | 134,660,475.16 euros |
| **Latin America** | 30,000 km | 600,000 euros |
| **Europe** | 8,513,717 km | 170,274,340 euros |
| **Asia** | 140,479 km | 2,809,580 euros |
| **Africa** | 56,683 km | 1,133,660 euros |
| **Middle East** | 925,57 km | 18,511,400 euros |

*Table 15: Market Size by Region.*

Following the information provided Table 15, Europe has the largest road network, followed by the United States, reaching a market size of 170,274,340 euros and 134.660.475,16 euros respectively, representing the largest shares of the total market for road wear mapping.

### 4.5.2. Serviceable Available Market: EU market

The scope of this deliverable has been on European countries. The EU market represents an excellent opportunity for ESRIUM's solution since it covers a total of **8,513,717 km**, which represents **approximately 26% of the total global road network**. Furthermore, the market for road-wear mapping in Europe is estimated to be valued at **85,137,170 euros,** every time mapping is done. If we follow our previous assumption, that mapping is done 2 times each year, the market for Europe will be estimated at 170,274,340 euros. Thus, the potential revenue depends on the number of times the road-wear map is updated, meaning that if the mapping is done once a year, then the total kms are multiplied by 10 euros, but if the procedure is done twice a year, then the total kms are doubled, hence when multiplied by the price, we get a higher revenue. Clearly, the more often the mapping is performed, the more revenue ESRIUM can get.

Furthermore, Europe has been developing efforts to expand their technology levels across the region, specifically growing Intelligent Transport System technologies for road maintenance and management. Coordinated actions and government regulations at EU level has been undergoing to deploy a continuous and harmonized cross border services for travel information and traffic management. For instance, in 2010 the European Commission launched the Directive 2010/40/EU which has been reviewed every 5 to 3 to establish a framework for the deployment for ITS in the road transport section and keep track of EU members progresses on ITS. National reports of ITS progresses can be found on the European Commission website. On the other hand, as we mentioned before, European ITS market was forecasted to reach a market size of 14 billion euros by 2022. Countries like UK and Germany dominated the scene for road telematics.

In addition, the next table shows an estimation of road-ware mapping market size by European country. Following the same procedure as before, depending on the total km of each country and assuming mapping is done twice a year, market sizes are shown in Table 16.

| # | Country | Motorway | Paved | Unpaved | Total (km) | Total euros (revenue) |
|---|---|---|---|---|---|---|
| 1 | Albania | 323 | 12,920 | 5,080 | 18,000 | 360,000 |
| 2 | Andorra | 0 | 198 | 71 | 269 | 5380 |
| 3 | Armenia | 0 | 7,558 | 234 | 7,792 | 155,840 |
| 4 | Austria | 2,249 | 200,000 | - | 200,000 | 4,000,000 |
| 5 | Azerbaijan | 99 | 29,210 | 29,931 | 59,141 | 1,182,820 |
| 6 | Belarus | 815 | 94,797 | - | 94,797 | 1,895,940 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 7 | Belgium | 1,763 | 120,514 | 33,498 | 154,012 | 3,080,240 |
| 8 | Bosnia and Herzegovina | 205 | 19,426 | 3,500 | 22,926 | 458,520 |
| 9 | Bulgaria | 830 | 43,649 | 440 | 44,089 | 881,780 |
| 10 | Croatia | 1,318 | 26,958 | - | 26,958 | 539,160 |
| 11 | Cyprus | 254 | 8,564 | 4,442 | 13,006 | 260,120 |
| 12 | Czech Republic | 1,292 | 130,671 | - | 130,671 | 2,613,420 |
| 13 | Denmark | 1,205 | 74,558 | - | 74,558 | 1,491,160 |
| 14 | Estonia | 115 | 10,427 | 47,985 | 58,412 | 1,168,240 |
| 15 | Finland | 863 | 51,016 | 27,146 | 78,162 | 1,563,240 |
| 16 | France | 11,882 | 1,028,446 | - | 1,028,446 | 20,568,920 |
| 17 | Georgia | 129 | 7,854 | 12,570 | 20,424 | 408,480 |
| 18 | Germany | 12,917 | 644,480 | - | 644,480 | 12,889,600 |
| 19 | Great Britain | 3,557 | 344,000 | 54,350 | 398,350 | 7,967,000 |
| 20 | Greece | 2,311 | 107,406 | 9,594 | 117,000 | 2,340,000 |
| 21 | Hungary | 1,715 | 76,075 | 123,492 | 199,567 | 3,991,340 |
| 22 | Iceland | 0 | 4,782 | 8,108 | 12,890 | 257,800 |
| 23 | Ireland | 1,224 | 91,145 | 5,457 | 96,602 | 1,932,040 |
| 24 | Italy | 6,758 | 487,700 | - | 487,700 | 9,754,000 |
| 25 | Latvia | 0 | 20,131 | 53,461 | 73,592 | 1,471,840 |
| 26 | Liechtenstein | 0 | 380 | - | 380 | 7,600 |
| 27 | Lithuania | 0 | 13,584 | 8,242 | 21,238 | 424,760 |
| 28 | Luxembourg | 152 | 2,899 | - | 2,899 | 57,980 |
| 29 | Malta | 0 | 2,704 | 392 | 3,096 | 61,920 |
| 30 | Moldova | 0 | 8,835 | 517 | 9,352 | 187,040 |
| 31 | Montenegro | 0 | 7,141 | 621 | 7,762 | 155,240 |
| 32 | Netherlands | 2,808 | 139,295 | - | 139,295 | 2,785,900 |
| 33 | North Macedonia | 242 | 14,182 | 4,549 | 14,182 | 283,640 |
| 34 | Norway | 664 | 75,754 | 18,116 | 93,870 | 1,877,400 |
| 35 | Poland | 1,706 | 292,134 | 131,863 | 423,997 | 8,479,949 |
| 36 | Portugal | 2,992 | 71,294 | 11,606 | 82,900 | 1,658,000 |
| 37 | Romania | 912 | 68,551 | 17,840 | 86,391 | 1,727,820 |
| 38 | Russia | 1,232 | 1,063,908 | 412,000 | 1,507,751 | 30,155,020 |
| 39 | Serbia | 925 | 30,171 | 15,248 | 45,419 | 908,380 |
| 40 | Slovakia | 496 | 38,085 | 5,676 | 43,761 | 875,220 |
| 41 | Slovenia | 623 | 38,985 | - | 38,985 | 779,700 |
| 42 | Spain | 17,109 | 683,175 | - | 683,175 | 13,663,500 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 43 | Sweden | 2,050 | 579,564 | - | 579,564 | 11,591,280 |
| 44 | Switzerland | 1,824 | 71,454 | - | 71,454 | 1,429,080 |
| 45 | Turkey | 3,523 | 177,550 | 249,356 | 426,906 | 8,538,120 |
| 46 | Ukraine | 199 | 166,095 | 3,599 | 169,496 | 3,389,929 |
| | | | Total | | 8,513,717 | 170,274,340 |

*Table 16: Market Size by European Country.*

### 4.5.3. Serviceable Obtainable Market: Target market for the first 5 years

Based on the previous analysis made on this deliverable, the possible target market is comprised of a list of European countries with specific features such as high ITS levels, large road networks, robust road maintenance budgets, and high average daily traffic/proportion of Heavy Goods Vehicle, which represent an opportunity for ESRIUM to commercialize its services.

With this information, we can continue to assess how to deliver ESRIUM's solution across Europe in the first 5 years. It is important to highlight that the potential revenue depends on the number of times the road-wear map is updated. We assume at least 4 times road wear map update per year, meaning that the total kms targeted are multiplied by 4, and then multiply by the estimated price (10 euros), we obtain the target market size. This procedure is emphasized in Table 18 and Table 19.

Austria will be the first client to be approached. ASFINAG as one of the project partners is the main road operator in Austria and is managing 2249 km. Being a partner of the project makes ASFINAG an ideal client to be approached. The second country to target is Norway, being a country with high technology maturity and large maintenance budgets. Not only do the aforementioned features make the country a remarkable possible client, but also the fact that their National Road Authority, NPRA, manages 55,352 km of national roads that represent 60% of the total Norwegian network, makes Norway an interesting target for ESRIUM to deploy its technology, gaining more than half of the market for road-wear mapping in the country.

| Country | Target Road operator | Total Km covered by the target road operator |
|---|---|---|
| **Austria** | ASFINAG | 2249 km |
| **Norway** | NPRA/VEGVESEN | 55352 km |
| **Denmark** | Vejdirektoratets | 1660 km |
| **Sweden** | Trafikverket | 100000 km |
| **Finland** | TIEH/Finnra | 78137 km |
| **Belgium** | Vayla | 78000 km |
| **The Netherlands** | Rijkswaterstaat | 5800 km |
| **Germany** | Autobahn | 13200km |

*Table 17: Target countries and clients for the first 5 years after commercialization of the ESRIUM solution.*

Followed by Austria and Norway, it is expected to cover the Danish market by the second year, as well as the Sweden market. In the third year and fourth year, we estimate to cover Finland, Belgium, and the Netherlands. Finally, ESRIUM's technology could reach the German market by the fifth year. By the end of the period, it is estimated to cover 1,337,592 kms and assuming a price of 10 euros per km of mapping, we get **44.4 million euro of total target market for the first 5 years**.

| | Y1 | Y2 | Y3 | Y4 | Y5 |
|---|---|---|---|---|---|
| **Austria** | 8996 | 8996 | 8996 | 8996 | 8996 |
| **Norway** | 221408 | 221408 | 221408 | 221408 | 221408 |
| **Denmark** | | 6640 | 6640 | 6640 | 6640 |
| **Sweeden** | | 400000 | 400000 | 400000 | 400000 |
| **Finland** | | | 312548 | 312548 | 312548 |
| **Belgium** | | | | 312000 | 312000 |
| **The Netherlands** | | | | 23200 | 23200 |
| **Germany** | | | | | 52800 |
| **Total** | **230,404** | **637,044** | **949,592** | **1,284,792** | **1,337,592** |

*Table 18: Target market in km.*

| | Y1 | Y2 | Y3 | Y4 | Y5 |
|---|---|---|---|---|---|
| **Total market in million(euro)** | 2.3 € | 6.3 € | 9.5 € | 12.8 € | 13.3 € |

*Table 19: Total target market in Euro for the first 5-year.*

### 4.6. SWOT Analysis

In the table below, we have listed the results of the internal workshop we organized to discuss the strengths, weaknesses, opportunities, and threats to the ESRIUM commercialization.

| | Positive | Negative |
|---|---|---|
| | **Strengths** | **Weaknesses** |
| **Internal** | • Mostly built on existing open standards and technologies<br>• Flexible architecture<br>• High accuracy<br>• ESRIUM provides full-service chain<br>• Usage of the European GNSS<br>• Fast sensing process of road surface<br>• Adaptability to country-specific details<br>• Data delivery can also be flexible<br>• Concept with high configurability<br>• One stop shopping<br>• Includes several “vendors”<br>• Cheap solution for sensor system<br>• Usage of European Satellite Systems<br>• Based on potential customer needs<br>• Market access available<br>• Friendly customer consortium<br>• Flexibility of components<br>• Regular updates<br>• Increase planning efficiency | • Road wear data processing is only semi-automatic<br>• Complex data chain<br>• No market-ready product yet<br>• Necessary amount of data<br>• Based on needs of one road operator<br>• Network dependency<br>• No clear USP of the ESRIUM system<br>• Open impact of ESRIUM services |

| | Opportunities | Threats |
|---|---|---|
| External | • Trends in our favor (chapter trend analysis)<br>• Need of cheaper and more efficient road maintenance and traffic safety enhancement<br>• Full coverage of services from data collection through processing and interpretation to end user provision<br>• Increasing importance of SDGs and Green deal topics for public road operators<br>• Possible integration of multiple input sources<br>• Digitalization / Artificial Intelligence<br>• Solve the EGNSS issue<br>• Licensing model<br>• Digital Twins are widely applicable<br>• Increased demand for AVs<br>• Few/no competitors<br>• Social impact<br>• Various data distribution channels<br>• Cost reduction and safety increase<br>• Novel EU regulations regarding implementation of ITS on roads (ITS Directive) | Mobile phone or car sensor-based solutions can be cheaper<br>• Mobile phone or car sensor-based solutions can provide much more data<br>• The system currently covers the possible problems of and gives solutions for two regions and one customer<br>• Costs for the ESRIUM solution are too high<br>• C-ITS on-board units (WLAN ITS-G5) are missing in most of the vehicles (passenger cars, trucks)<br>• The high accuracy of ESRIUM is not necessary for road maintenance<br>• Substitution of the system<br>• Different user needs and requirements<br>• Car based sensor data ingestion is standard<br>• No common road damage classification<br>• No really safety-relevant road damages in Europe<br>• Narrow market<br>• Economic recession<br>• Reliance on GNSS<br>• Regulations regarding liability since will imply more accountability from road operators |

*Table 20: ESRIUM solution SWOT Analysis.*

### 4.6.1. Strengths

**Using standards:** ESRIUM will use the following standards and well-known formats for interfaces and processes:

- ISO/TS 19321 C-ITS IVI to provide routing information for the vehicles,
- ETSI TS 103 301 to provide GNSS position correction data,
- OpenDrive to provide high definition basemap,
- JSON, GeoJSON and Datex II to share road condition data,
- NDS Live and TPEG2 to provide navigation related services to the end users.

Using standard through the whole system makes ESRIUM structure very flexible and easier if any component needs to be changed or replaced. At the same time, having the full spectrum of components (from sensors to AI) makes ESIRUM and end-to-end solution, with understanding of the needs and implementation options of all subcomponents.

**Design for modularity:** Our data model and data distribution system can be built on existing standards in a way that multiple raw input data ranging from mobile phone sensors (and even as an extreme case manual input from traffic participants) to ESRIUM's own sensor and more expensive existing road quality

measurement systems can be used, even mixed. Similarly, the post processing phase of the raw data can be ESRIUMs own semi-automatic solution, our own AI solution; or the integration of existing post processing services let them be the involvement of human experts (as that is the case in many countries).

**Accuracy**: All the detection and processing technologies aim the highest achievable accuracy from the sensor elements to the data interpretation and provision.

**Fast sensing process of road surface:** The European market of road operators is though converging, but there are still differences identified country-by-country. Some of the countries or municipalities even have legal rules driving sensor accuracy and how post processing of the data is supposed to be performed. Instead of forcing a change of these legislations (though that can be the long-term goal) ESIRUM can adapt sub-components to these regional needs while the underlying data model and unaffected components can remain the same.

The delivery of the road quality data can be flexible too; delivering to the road operators in their own expected format and to the traffic participants via other means (e.g., as traffic data, via NDS volatile layer, NDS.Live Tiles services or SmartLayerPath services).

**Concept with high configurability:** ESRIUM states a difficult problem aggregating several approaches. There are various vendors that have to be customized individually but any product in this field needs customization.

**One stop shopping:** From the customers view this is desirable because by paying one fee (per km or annually) they get a white solution based directly on their needs (necessary to have this customization).

Includes several “vendors” (= somebody who sells something): There are several partners engaged in ESRIUM but there will be only one face selling the complete product ensuring the desired one stop shop for a complex product (e.g., complex issues of map creation etc.). ESRIUM service includes the full service from sensing, AI-based data processing and map provision. Customers do not need several service partners for their road maintenance service (including c-its link to end users). Moreover, Usage of the European GNSS helps to be independent from international GNSS

**Economic solution for sensor system:** Currently available sensor systems for monitoring street conditions (e.g., RoadSTAR) are quite expensive. In comparison to that the ESRIUM sensor platform is much smaller, and the individual components are more affordable.

**Usage of European Satellite Systems:** All services of ESRIUM are based on the authenticated position which is a feature of Galileo ensuring the desired robustness.

Based on potential customer needs: By having ASF in the consortium ESRIUM has all the insights needed in order to build the system (based on the needs of a potential customer). This results in several mitigating factors due to getting feedback of needs directly. It is to mention that ASF is not isolated. They are in close contact to DACH (and know exactly what is going on there) and thus, are able to represent more than one customer.

**Market access available:** Norway is also quite advanced, and they are adapting their road map very often. This is based on a sensing system mounted on coast services using a laser system to detect damages and to detect the condition of fences on the sides of the road. It looks like other countries are outpacing Austria, but Austria was the first country deploying C-ITS stations allowing for much higher accuracy than any other system. ASF is one of the innovation leaders in Europe (ASECAP, CEDR) and can open the market. They have a strong network in Europe and will help to convince others. In addition, ASF is the only road operator who is actually ingesting sensory stating into the CER platform in Europe.

**Friendly customer consortium:** ASF will be the first paying customer being a very good starting point and since the position of ASF in road operators is really good, they can function as model for others.

Flexibility of components: All components are flexible and can be used for different purposes. Especially the data acquisition done in ESRIUM can be used as a layer for digital twins.

**Regular updates:** The sensing system can be mounted on existing road operator vehicles saving costs for new vehicles. In this way the speed in sensing and providing map data increases significantly in comparison to available solutions (e.g., 4 years cycle for RoadSTAR). In fact, the time frame of the whole

procedure of sensing and providing the system with a map is very short (ESRIUM provides a fast processing and updating). Note that it is still to decide if the product will be competing with RoadSTAR or if it will add new services on top of it.

**Increase planning efficiency:** Regular updates and the available prediction service will increase the planning efficiency and management of resources of road operators. What they get out of the project is that their planning efficiency can be increased. This is not a topic of actually reducing maintenance but allowing for a better planning when fixing holes which is especially a matter of resources (people and machines) being real money.

### 4.6.2. Weaknesses

**ESRIUM data chain is based on project partners expertise and capabilities** that causes a more complex data chain than the optimal. Moreover, there is no market-ready product yet and it is still a long way for a commercial product (TRL9)

**Upscaling:** The system currently covers the possible problems of and gives solutions for two regions and one customer; upscaling of the current prototype could take a long time

**Necessary amount of data:** ESRIUM is not a fixed product (usage of the shelf) and needs to be customized for each customer. Thus, it needs a lot of implementations and is not easy to use. In addition, the requirement here is: "Give us as much data as we need than we can give you a solution that works" because the data aggregation by AI needs a critical mass and it takes approximately 6 months - to collect enough data that the algorithms works - for the customer to see actual results. An AI solution is based on a lot of road kilometres (actually the whole country) while the RoadSTAR works on the first kilometre.

Based on needs of one road operator: The system is really focused on ASF but it needs to be customized for each road operator. A real in-depth market analysis is still pending since due to time and money constraints during the proposal phase in the initial business plan the analysis was only done within our own stakeholder group and it was not looked outside.

**Network dependency:** The high positioning accuracy using RTK requires a well-developed dense CORS network, but this might not be available in certain countries or areas. The stations have to be rather dense since the density plays an important role to reach the 1cm accuracy because despite the fact that a high accuracy can be achieved without RTK it will never reach the 1cm. This may not be necessary for all applications we are targeting but this accuracy is one of ESRIUMS USPs. Especially ASF demands, as outcome of the project, for the RTK accuracy to be included in a digital twin. This information has to be precise enough to tell vehicles when and how to change lanes.

**No clear USP of the ESRIUM system:** The current business model is not homogenous since profit and non-profit providers are included in the consortium. In addition, it is still not clear what services will finally be provided. It will be important to evaluate what is available and what is the need in order to define a USP. That is, the service level of ESRIUM has to be fixed until the end of the project. Until then it will be clearer what the impact of this high precision services can be (e.g., What can they save? Does this result in less time for construction services?). It is mandatory to manage the business expectations on the same level as the technical expectations. For this it is necessary to create a transparent and easier adoptable unified business model but the complexity of the business value chain in the project is huge. This topic will be discussed in several exploitation workshops in order to clarify the following points: (1) How to use results and how to align our expectations in money making? (2) Who is interested in commercializing the product? There are profit and non-profit organizations involved with different cost structures, marketing, selling, and licensing models; (3) There are many realistic solutions. Is e.g., the creation of a spin-off organization the best option?

**Open impact of ESRIUM services:** The impact of ESRIUM services to traffic safety, efficiency, environmental issues (reducing construction sites) is not yet clear since no other customers were considered yet. The system does not comply with different systems of different road operators because every county uses their own system (even national, regional, local). This mandatory analysis of what can

be saved at construction sites will be done in WP5 to quantify the impact on traffic safety transforming the current weakness into a strength by the end of the project.

### 4.6.3. Opportunities

**Need of cheaper and more efficient road maintenance and traffic safety enhancement**

**Increase in demand for one-stop shop services:** ESRIUM can provide full coverage of services from data collection through processing and interpretation to end user provision

**Increasing importance of SDGs** and Green deal topics for public road operators helps to bring new innovative solutions to the market (including predictive maintenance)

**Digitalization / Artificial Intelligence:** It is very important to follow trends and digitalization is definitively a very strong trend. Consequently, the digitalization of the road wear map is a very good argument since nobody has seen the benefit of AI in the traffic environment yet.

**Solve the EGNSS issue:** EGNSS is the main driver for the internal sponsor of ASF. It is that important because any system that touches automated driving assistance is based on positioning. There is no endgame on the precise positioning (location system) up to now and ASFs strategy is to insource their open demands if the industry cannot provide (license) it. As they did with the C-ITS. The goal is to find out how this should be implemented and if it is possible to tender out that somebody builds the stations they need (or integrate it to stations they have) to provide correction signals so that ASF controls the complete operation of sending out the correction signals. If ASF develops this by themselves, they can never do it as efficient and precise and 24h as industry but they can control the whole state with one system and can build upon that in order to gradually get better. ASF wants to know the hands-on solution and if they can provide a solution like that for industry to then realize ADAS systems on their roads.

**Licensing model:** New positioning services are appearing all the time. That is, high accuracy positioning can be achieved with other services than RTK (e.g., PPP, Galileo HAS) even some that have no contact to reference stations. Especially Galileo may be used in the future (it is free) enabling a broadcast for everybody. Since ESRIUM is not dependent on RTK, any other positioning solution can support it, it is always possible to switch to new and better services. These services are simple data streamers or data bases and do not rely on information where the data comes from (no data rights issues).

**Digital Twins are widely applicable:** ESRIUM is based on a lot of different components making it quite flexible to use. These individual parts may be reusable for other applications because those components are not that closely connected. The digital twin trend is in favor of ASF as the demand for digital twins is increasing. New solutions may arise in the next year that can be exploited due to the flexibility of the ESRIUM system and ESRIUMs data acquisition builds the basis for those digital twins. The road wear/surface may simply result in a new layer providing additional information that could be very beneficial.

**Increased demand for AVs:** The more automated vehicles are on the roads, the more HD maps becomes relevant and ESRIUM provides an additional layer on top of it.

Few/no competitors: ESRIUM is one of the first players and there is not much competition yet. That is, there are currently no other companies that were able to get the market, thus, the timing is very good.

**Social behavior:** Users tend to consider dangerous road damage information to adapt their driving behavior. This trend is becoming more relevant since people are more cautious about their safety. ESRIUM will result in an additional sensibilization of traffic participants. Thus, there is not only the business and the technical impact but also a strong social related impact. One key element is humans' interaction in the traffic. Drivers like to know if there is a potentially threatening pothole in front and then drive more cautiously (e.g., slow down). The question is how this social impact can be sued for the evaluation of the system.

**Various data distribution channels:** In the future other data distribution channels may be available next to C-ITS allowing to deliver information to radio broadcast or cellular communications. The more

information goes through the better services can be expected. The core business here is what driving experience can be achieved concerning not only traffic safety but also conveniences.

**Cost reduction and safety increase:** The goal of the ESRIUM system is to reduce maintenance costs and emissions while increasing safety. This impact was not measured yet but if the consortium is able to provide quantified data for reducing costs, maintenance efforts and emissions while increasing traffic safety this will be become a strength.

**New regulations**: On the other hand, regulations regarding implementation of ITS on the roads by the European Commission represents an opportunity for ESRIUM since more advanced infrastructure and technology ready artefacts will be available. This type of regulations will push the implementation of new technologies like ESRIUM into the market since Member States will need to comply with a minimum level of ITS.

### 4.6.4. Threats

**Mobile phone or car sensor-based solutions** can be cheaper and can provide much more data

**Costs**: Cost for the ESRIUM solution are too high for replacing existing solutions for sensing and road maintenance management

**C-ITS on-board units**: (WLAN ITS-G5) are missing in most of the vehicles (passenger cars, trucks) and therefore the C-ITS communication link of road operators based on that technology to their customers is currently not the best

**The high accuracy of ESRIUM is not necessary for road maintenance**

**Substitution of the system:** It may be possible to substitute the ESRIUM system with more competitive and cheaper systems. That is, existing players might simply copy system components resulting in better and cheaper solutions by other companies and despite the fact that the consortium is working on a very complex system it will not be possible to avoid that other copy it.

**Different user needs and requirements**: The ESRIUM solution is currently very focused on Austria and its usage by ASF while other (European) countries may have different needs. Thus, it is necessary to find a commonality.

**Car based sensor data ingestion is standard:** The goal of SENSORIS (with participation of all OEMs) is to standardize data perceived from on board sensors resulting in a common data ingestion interface. This approach may compete with ESRIUM one day. Not in accuracy but millions of vehicles using the interface may have similar impact. The original idea was to update the HD map with every single possible data (static and dynamic) but in this was it may also be possible to get road damage data resulting in a thread to the sensor platform.

**No common road damage classification:** The road damage classification is not commonly defined. That is, there is no unified classification of damages, and each road operator does his own classification which is something the consortium of ESRIUM cannot control.

**No really safety-relevant road damages in Europe:** There are no safety related damages in Austrian road networks or in Europe in general. ESRIUM detects upcoming damages in an early phase, so the question is if small issues are really safety related. Despite the fact that the range in Europe is broad all European motorways are in a good quality. Most critical are deep potholes and ruts but there is no existent safety classification or threshold. Also, areas with problem zones for aqua planning are relevant. This classification issue is to be discussed with a traffic safety expert. Detection of changes before they get critical relates to passive safety (like safety belts) but it is also a matter of reliability (if there is a pothole, why not fix it?). The idea is to use available information to raise the driver's awareness and to avert reliability (insurance companies do not pay if road is properly marked). It is the responsibility of the stakeholder how to use it, if they share it as a thread, or if they use it as liability issue (balance between benefit and. necessity). ESRIUM just provides information being more a matter of better planning and efficiency in shortening construction works (other point in focus). In addition, it creates awareness of

damages and knowledge when they get critical such that maintenance can be optimized following importance of damage.

**Narrow market:** The current market is narrow, only having RoadSTAR and Scrim as the main providers in the DACH region. Scrim not as good as RoadSTAR but Germany wanted to open the market and the SCRIM system definitively has to be monitored. The upcoming market may be broad but is not foreseeable at the moment. The aim of ESRIUM is to use some holes for road operators (owner of C-ITS infrastructure) and road users such as the road operators can use the outcome for traffic/road safety and provide it to road users (even charge it).

**Economic recession:** Economic recession might be a thread as it is for all businesses.

**Reliance on GNSS:** The reliance on only one high-accuracy positioning solution is critical in case of failure, since there are several possibilities of GNSS dysfunctions (RFI, jamming, spoofing, etc.). This is due to the vulnerability of the GNSS system itself but is a common threat for all applications. Everybody (the whole society and our current lifestyle) relies on the availability of GNSS; counting not only for the positioning but also for the timing. Jamming and spoofing is becoming more and more popular, especially in conflicts like wars. There are so many vicious applications nowadays that it is unknown what they can provide or what they could do.

**Liability regulations:** From interviews conducted for D2.5, insights about liability concerns could be collected. Interviewees highlighted their concerns regarding liability and legal issues since routing recommendations imply accountability from the road administrations; hence, as more regulations to provide a legal framework are made, more efforts by road operators to abbey rules, which could hinder the adoption of ESRIUM solution if it means extra obligations for them. As an example of efforts to regulate liability issues concerning Artificial Intelligence and IoT, the European Commission has launched in 2021 a proposal for legislations related to AI damages in order to set harmonized rules in Member States. Nevertheless, it is expected to have a much more formal regulation for liability topics concerning damages produced by AI related technologies in the future; therefore, governments' accountability for implementing technologies similar to ESRIUM will increase, which could mean less interest on investing on solutions based on AI and IoT.

## SECTION 5: CONCLUSION

This deliverable's goal is to assess the business environment by learning about existing market solutions and challenges. In this deliverable, we give an analysis of the market and business ecosystem for ESRIUM solutions, as well as review and benchmark current approaches, estimate the market potential of ESRIUM technologies and services, and examine current stakeholders' business models. Its goal is to assist in the development of an exploitation plan for the various stakeholders involved. As part of this task, an ESRIUM-related trend selection on megatrends and related macro-trends was performed. With the key words predictive maintenance, C-ITS, GNSS, digital map, Smart Road Infrastructure the following four mega-trends were identified: Intelligent Infrastructure, Smart Data, Virtualization, and Artificial Intelligence. Furthermore, corresponding macro-trends were described and set the scene for further business analysis like SWOT, PESTEL and Porter's Five Forces.

In SECTION 1:, we elaborate the ESRIUM solution for green road maintenance and road safety including four business cases. Then based on ESRIUM's value chain (explained in deliverable D2.4), we illustrate the role of key stakeholders and project partners in creation of the road wear mapping.

We clarify the methodology used for assessment of market ecosystem in SECTION 2:. First, we perform a desktop research and literature review for state of art analysis to reach a comprehend perspective of current challenges and approaches in the road maintenance related industries. Then to validate our findings internally we run internal workshop to get inputs from partners about market needs. At the end, we obtain external feedbacks through online survey and peer-to-peer interviews to coherent our results.

In SECTION 3:, we analyze and benchmark current approaches in details including the importance of road asset management in road administrations, the benefits of adopting of the current system to the modern data collection and AI-based platforms, the current challenges in European road networks and EU efforts for road improvement, technology level in road monitoring and finally country-based analysis considering their roads length, technology, and budget.

In SECTION 4:, we elaborate the ESRIUM business ecosystem using different tools to find its market position. we identify ESRIUM target market, potential customers, and countries by using various tools and frameworks such as SWOT, PESTEL, Porter's Five Forces analysis. The analysis findings of each tool is insightful:

The PESTEL-Analysis outlined a variety of issues to be considered when providing a valid marco-economic picture for ESRIUM. Just to highlight two of them without putting them into one category of the analysis: SDGs and EGNSS. The sustainability goals of the UN directly impact political, social, and environmental market characteristics. As we outlined in the chapters above especially the following goals strongly impacts ESRIUM macro-economic surrounding: SDG3 - Good health and well-being: Encourages well-being by guaranteeing a healthy life to all people indistinctively of their ages, SDG9 - Industry, innovation, and infrastructure: Construct resilient, inclusive, sustainable infrastructure to reach a greener industrialization and promote innovation, and SDG13 - Climate action: Take urgent action to combat climate change. The second issue to be mentioned here is the EGNSS factor. The usage of EGNSS - the European global satellite navigation system technology is a very strong driver for European industry and infrastructure provider to strengthen resilience in their daily maintenance tasks.

The main outcome of Porter's Five Forces analysis for ESRIUM is a medium risk surrounding. Within the internal analysis no high risk from the following five areas were identified: Bargaining power of buyers, threat of substitute products or services, bargaining power of supplier, threat of new entrants, and rivalry among already available competitors in the market. The high complexity of the whole ESRIUM solution and the very innovative end-to-end solution were the main drivers for this analysis.

Market potential was studied in sub-section 4.5, covering Total Available Market (TAM), referring to the global market for road-wear mapping, which is estimated at 320 million of euros. Serviceable Available Market (SAM), considering European market with a market size of 85,137,170 euros approximately. Finally, Serviceable Obtainable Market (SOM) which takes into consideration targeted European countries with technology maturity and large budgets. The estimation for the first five years is a market size of 44.4 million euros covering 1,337,592 kms of targeted countries, namely Austria, Norway, Denmark, Sweden, Finland, Belgium, the Netherlands, and Germany. As we have mentioned before, market size will increase every time road-wear mapping is done, thus, the more mapping is done, more potential revenue can be reached.

A detailed SWOT analysis was performed including the opinions of ASF, ENI, VIF, JRD, FGI and EVO. During an extensive discussion the topics were not only listed and elaborated but also moved to their proper allocation. In that way the consortium resulted in a common understanding of the four business classes. It is to mention that certain threads and weaknesses may evolve to being a strength or an opportunity during the remaining course of the project.

The competitor analysis has shown that there are hardly any competitors who can map so many technical possibilities in such a high interval density as ESRIUM. There is currently no competitor recognizable who can offer a daily updated digital twin for road operators at acceptable costs in the next few months until the end of the project.

Finally, we assess the existing business model and try to estimate the potential ESRIUM market at the global, European, and country specific level.

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## SECTION 7: ATTACHMENT

### 7.1. PESTLE Analysis

This section briefly describes the strategic management tool "PESTLE analysis" which is used to provide an ESRIUM-related PESTLE analysis in chapter 4.3.

"PESTLE analysis, which is sometimes referred to as PEST analysis, is a concept in marketing principles. Moreover, this concept is used as a tool by companies to track the environment they're operating in or are planning to launch a new project/product/service, etc. PESTLE is a mnemonic which in its expanded form denotes P for Political, E for Economic, S for Social, T for Technological, L for Legal, and E for Environmental. It gives a bird's eye view of the whole environment from many different angles that one wants to check and keep a track of while contemplating a certain idea/plan." (https://pestleanalysis.com/what-is-pestle-analysis/)

### 7.2. SWOT Analysis

*"A strengths, weaknesses, opportunities, and threats (SWOT) analysis has become a fundamental tool for organizations to evaluate their position in the market and is widely used to analyze the internal and external environments of organizations during times of indecision (Rozmi et al., 2018; Wu, 2020). The four components identify either internal or external considerations. Strengths refer to the internal elements of an organization that facilitate reaching its goals, while weaknesses are those internal elements that interfere with organizational success. Opportunities—external aspects that help an organization reach its goals—are not only positive environmental aspects but also opportunities to address gaps and initiate new ctivities. Threats, on the other hand, are aspects of the organization's external environment that are barriers or potential barriers to reach its goals (Aldehayyat & Anchor, 2008; Fleisher & Bensoussan, 2003; Lee & Lin, 2008; Shrestha et al., 2004).*

*The SWOT matrix can be summarized as follows:*

- *SO strategies: taking advantage of opportunities.*
- *ST strategies: avoiding threats.*
- *WO strategies: introducing new opportunities by reduction of weaknesses.*
- *WT strategies: avoid threats by minimizing weaknesses."*

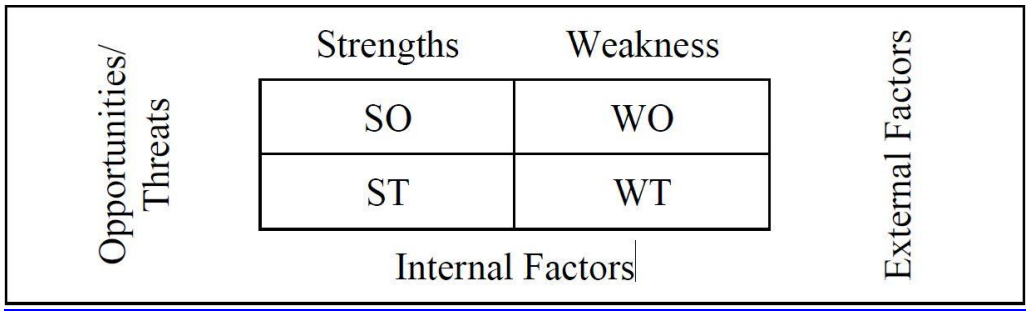


*Figure 12: SWOT Matrix, (Benzaghta, 2021).*

### 7.3. Porter's Five Forces Analysis

This section provides basic information on Michael Porter's Five Forces to set the scene for further ESRIUM-respective strategic analysis (section 4.4.2). To help the reader to get familiar with Michael Porter's ideas, we start with the original text published in the Harvard Business Review in 1979.

"*The essence of strategy formulation is coping with competition. Yet it is easy to view competition too narrowly and too pessimistically. While one sometimes hears executives complaining to the contrary, intense competition in an industry is neither coincidence nor bad luck.*

*Moreover, in the fight for market share, competition is not manifested only in the other players. Rather, competition in an industry is rooted in its underlying economics, and competitive forces exist that go well beyond the established combatants in a particular industry. Customers, suppliers, potential entrants, and substitute products are all competitors that may be more or less prominent or active depending on the industry.*

*The state of competition in an industry depends on five basic forces, which are diagrammed in the Exhibit. The collective strength of these forces determines the ultimate profit potential of an industry. It ranges from intense in industries like tires, metal cans, and steel, where no company earns spectacular returns on investment, toward mild in industries like oil field services and equipment, soft drinks, and toiletries, where there is room for quite high returns."*


*Figure 13: Porter's Five Forces (1979).*

Following the original input from Michael Porter we could conclude that Porter's Five Forces is a business analysis model helping to explain why various industries are able to sustain different levels of profitability. Before analyzing the ESRIUM-related use cases and business areas we want to provide you with a short definition of the five forces itself (Harvard Business School, Institute for Strategy & Competitiveness):

- Threat of substitute products or services
- Bargaining power of supplier
- Bargaining power of buyers
- Threat of new entrants
- Rivalry among existing competitors

**Threat of substitute products or services**

A substitute is another product or service that meets the same underlying need that the industry's product meets in a different way. Videoconferencing is a substitute for travel. Email is a substitute for express mail. The threat of a substitute is high if it offers an attractive price-performance trade-off versus the industry's product, especially if the buyer's cost of switching to the substitute is low.

**Bargaining power of supplier**

Companies in every industry purchase various inputs from suppliers, which account for differing proportions of cost. Powerful suppliers can use their negotiating leverage to charge higher prices or demand more favorable terms from industry competitors, which lowers industry profitability. If there are only one or two suppliers of an essential input product, for example, or if switching suppliers is expensive or time consuming, a supplier group wields more power.

**Bargaining power of buyers**

Powerful customers can use their clout to force prices down or demand more service at existing prices, thus capturing more value for themselves. Buyer power is highest when buyers are large relative to the competitors serving them, products are undifferentiated and represent a significant cost for the buyer, and there are few switching costs to shifting business from one competitor to another. They can play rivals against each other – especially if an industry's products are undifferentiated, it's inexpensive to switch loyalties, and price trumps quality. There may be multiple buyer segments in a given industry with different levels of power.

**Threat of new entrants**

The threat of new entrants into an industry can force current players to keep prices down and spend more to retain customers. Actually, entry brings new capacity and pressure on prices and costs. The threat of entry, therefore, puts a cap on the profit potential of an industry. This threat depends on the size of a series of barriers to entry, including economies of scale, to the cost of building brand awareness, to accessing distribution channels, to government restrictions. The threat of entry also depends on the capabilities of the likely potential entrants. If there are well established companies in the industry operating in other geographic regions, for example, the threat of entry rises.

**Rivalry among existing competitors**

If rivalry is intense, it drives down prices or dissipates profits by raising the cost of competing. Companies compete away the value they create. Rivalry tends to be especially fierce if:

- Competitors are numerous or are roughly equal in size and market position
- Industry growth is slow
- There are high fixed costs, which create incentives for price cutting
- Exit barriers are high
- Rivals are highly committed to the business
- Firms have differing goals, diverse approaches to competing, or lack familiarity with one another

### 7.4. Road network in Europe (km), 2019

| # | Country | Motorway | Paved | Unpaved | Total (km) |
|---|---|---|---|---|---|
| 1 | Albania | 323 | 12,920 | 5,080 | 18,000 |
| 2 | Andorra | 0 | 198 | 71 | 269 |
| 3 | Armenia | 0 | 7,558 | 234 | 7,792 |
| 4 | Austria | 2,249 | 200,000 | - | 200,000 |

| | | | | | |
|---|---|---|---|---|---|
| 5 | Azerbaijan | 99 | 29,210 | 29,931 | 59,141 |
| 6 | Belarus | 815 | 94,797 | - | 94,797 |
| 7 | Belgium | 1,763 | 120,514 | 33,498 | 154,012 |
| 8 | Bosnia and Herzegovina | 205 | 19,426 | 3,500 | 22,926 |
| 9 | Bulgaria | 830 | 43,649 | 440 | 44,089 |
| 10 | Croatia | 1,318 | 26,958 | - | 26,958 |
| 11 | Cyprus | 254 | 8,564 | 4,442 | 13,006 |
| 12 | Czech Republic | 1,292 | 130,671 | - | 130,671 |
| 13 | Denmark | 1,205 | 74,558 | - | 74,558 |
| 14 | Estonia | 115 | 10,427 | 47,985 | 58,412 |
| 15 | Finland | 863 | 51,016 | 27,146 | 78,162 |
| 16 | France | 11,882 | 1,028,446 | - | 1,028,446 |
| 17 | Georgia | 129 | 7,854 | 12,570 | 20,424 |
| 18 | Germany | 12,917 | 644,480 | - | 644,480 |
| 19 | Great Britain | 3,557 | 344,000 | 54,350 | 398,350 |
| 20 | Greece | 2,311 | 107,406 | 9,594 | 117,000 |
| 21 | Hungary | 1,715 | 76,075 | 123,492 | 199,567 |
| 22 | Iceland | 0 | 4,782 | 8,108 | 12,890 |
| 23 | Ireland | 1,224 | 91,145 | 5,457 | 96,602 |
| 24 | Italy | 6,758 | 487,700 | - | 487,700 |
| 25 | Latvia | 0 | 20,131 | 53,461 | 73,592 |
| 26 | Liechtenstein | 0 | 380 | - | 380 |
| 27 | Lithuania | 0 | 13,584 | 8,242 | 21,238 |
| 28 | Luxembourg | 152 | 2,899 | - | 2,899 |
| 29 | Malta | 0 | 2,704 | 392 | 3,096 |
| 30 | Moldova | 0 | 8,835 | 517 | 9,352 |
| 31 | Montenegro | 0 | 7,141 | 621 | 7,762 |
| 32 | Netherlands | 2,808 | 139,295 | - | 139,295 |
| 33 | North Macedonia | 242 | 14,182 | 4,549 | 14,182 |
| 34 | Norway | 664 | 75,754 | 18,116 | 93,870 |
| 35 | Poland | 1,706 | 292,134 | 131,863 | 423,997 |
| 36 | Portugal | 2,992 | 71,294 | 11,606 | 82,900 |
| 37 | Romania | 912 | 68,551 | 17,840 | 86,391 |
| 38 | Russia | 1,232 | 1,063,908 | 412,000 | 1,507,751 |
| 39 | Serbia | 925 | 30,171 | 15,248 | 45,419 |

| | | | | | |
|---|---|---|---|---|---|
| 40 | Slovakia | 496 | 38,085 | 5,676 | 43,761 |
| 41 | Slovenia | 623 | 38,985 | - | 38,985 |
| 42 | Spain | 17,109 | 683,175 | - | 683,175 |
| 43 | Sweden | 2,050 | 579,564 | - | 579,564 |
| 44 | Switzerland | 1,824 | 71,454 | - | 71,454 |
| 45 | Turkey | 3,523 | 177,550 | 249,356 | 426,906 |
| 46 | Ukraine | 199 | 166,095 | 3,599 | 169,496 |
| | | | Total | | 8,513,717 |

*Table 21: Road network in Europe (km) 2019[5].*

## 7.5. Financing of Maintenance and Contracts

| Country | Institution and financing | Amount (millions) | Km | Duration of contracts |
|---|---|---|---|---|
| **Austria** | ASFINAG – financed through tolls, capital markets and issuance of bonds (does not receive any subsidies) | EUR 844 (in 2018) | 2249km | - |
| **Belgium (Flanders)** | AWV – financed by the government | EUR 782 in total:<br>420 – investments<br>170 – maintenance<br>The rest for construction/operational costs | 7000 km | N/A |
| **Denmark** | DRD – financed by the government<br>Sund & Baelt Holding A/S (PPP: Public - Private Partnership) - financed through state loans | DKK 3050 in total: (409,82 euros)<br>DKK 1,404 - construction<br>DKK 1,213 – maintenance<br>DKK 433 – other services | 1600 km<br>34 km | N/A |
| **Estonia** | ERA – financed by the government and external sources (EU funds and road/state fees) | EUR 300 (2018)in total: from state revenues<br>65 – operating costs from which 60% (39 million) used for maintenance of roads<br>179 – investments<br>56 – public transport grants<br>In addition: EUR 22 from EU funds | 16608 km | N/A |
| **England** | HE – financed by the government<br>External service providers | £15 billion (2015-2020) (17,84 euros) | 6920.179 km | Long-term Design Build Finance Operate |

[5] Road Networks in Europe

| | | | | |
|---|---|---|---|---|
| | Midland Motorway Group (M6 Toll) | | 43.45 km | commissions : 25-30 years |
| **Finland** | FTIA – financed by the government | EUR 903 (2019) in total:<br>290 – investments<br>613 – operation, maintenance, traffic control and state subsidies for private roads | - | N/A |
| **France** | Association Professionnelle Des Sociétés Françaises Concessionnaires Ou Exploitantes D'autoroutes Et D'ouvrages Routiers (ASFA) - 26 private companies | In the last 10 years: EUR 20 billion invested | 9193,3 km | Contracts are reviewed every 5 years |
| **Germany** | Federal Ministry of Transport and Digital Infrastructure – financed by federal tax funds and tolls<br>Autobahn GmbH – private company (Federal government is the sole shareholder)<br>Toll Collect GMBH | EUR 132 Billion (2016-2030) in total:<br>67 – maintenance<br>53 – extension and construction<br>12 – additional investments | 13,000km<br>50,948.5 km | N/A<br>Since 2021<br>- |
| **Hungary** | Hungarian Public Roads - financed by the government and EU funds | HUF 89 billion (0,24 euros) | 32,000 km | Since 2005 |
| | Concession Company, AKA Alföld Concession Company Ltd | | 1259 km | Since 1994 |
| **Iceland** | IRCA – financed by the government | EUR 260 in total:<br>89 – road investments<br>71 – maintenance<br>39 – services<br>26 – public transport subsides<br>26 – harbors, ferries, lighthouses<br>9 – operations and research | - | N/A |
| **Ireland** | TII – funding agent, distributes funding to local authorities | ITIA collected EUR 177 in toll revenues (2020) | 325,9 km (ITIA) | N/A |

| | | | | |
|---|---|---|---|---|
| | ITIA: Irish Tolling Industry Association – 9 companies (PPP projects) | | | |
| **Italy** | ANAS – financed by the government and EU funds | EUR 29.9 billions (long term investment)<br>15.9 - maintenance | 26,500 km | N/A |
| | Associazione Italiana Società Concessionarie Autostrade E Trafori (AISCAT) - 18 companies | AISCAT collected EUR 3694,50 in toll revenues (2020) | 4835,4 | |
| **Lithuania** | LRA | EUR 577.8 (from which EUR 41.1 comes from EU funds) | - | N/A |
| **Luxembourg** | Administration des Ponts et Chaussées - annual government budget | EUR 400 (2019) | 837 km | N/A |
| **Netherlands** | N.V. Westerscheldetunnel – 1 company | N.V. Westerscheldetunnel collected EUR 28,70 in toll revenues (2020) | 24 km | - |
| **Norway** | NPRA – national funds | NOK 60.3 billion (2018) (6,05 euros)<br>from which NOK 2.7 billion for maintenance | - | N/A |
| **Poland** | GDDKIA - financed by the government and EU funds | EUR 3-4 billion<br>0.5-0.6 - maintenance | 19,400 km | N/A |
| | POLSKIE AUTOSTRADY KONCESYJNE (PAK) - 4 companies | PAK collected EUR 292,90 in toll revenues (2020) | 468 | Until 2037 -<br>Autostrada Wielkopolska S.A |
| **Portugal** | Associação Portuguesa Das Sociedades Concessionárias De Auto-estradas Ou Pontes Com Portagens (APCAP) - 24 companies | APCAP collected EUR 918,31 in toll revenues (2020) | 3636,1 | 30 years |
| **Slovenia** | SIA – financed by the government | EUR 290 (2018)<br>62.6% - maintenance and management | - | N/A |
| | DARS – partly financed by state | EUR 260 (2018)<br>18.1% - maintenance and management | 623,3 km | Since 1994 |

| | | | | |
|---|---|---|---|---|
| | budget (concession contract) | | | |
| **Spain** | DGC | EUR 1,913 in total<br>958 – maintenance and operation | - | N/A |
| | Asociación de Empresas Constructuras y Concesionarios de Infrastructuras (SEOPAN) - 16 companies | SEOPAN collected EUR 1023,35 in toll revenues (2020) | 1879,4 km | 40 years: construction concessions: (could be extended until 46 years)<br>20 years:<br>operation concessions |
| **Sweden** | Swedish Transport Administration | SEK54 billion in total (5,10 euros)<br>SEK19.5 billion - operation, maintenance, and traffic control | - | N/A |
| **Switzerland** | FEDRO | CHF4.2 billion in total (4,02 euros)<br>CHF1.5 billion - operations and the performance of maintenance work on the network | - | N/A |

*Table 22: Financing of Maintenance and Contracts.*

## 7.6. ASFINAG core data

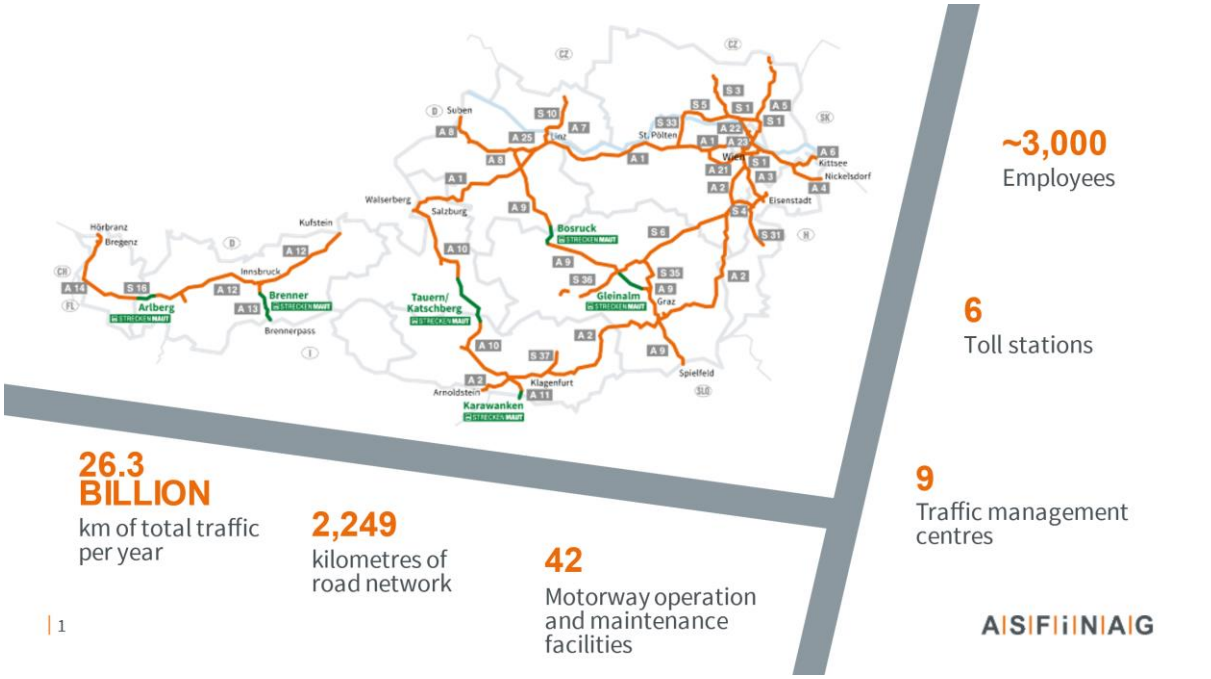


*Figure 14: ASFINAG Core Data.*