

European Association of Remote Sensing Companies

Sentinel Benefits Study (SeBS)

A Case Study

# Motorway Maintenance in Portugal



Client:	ESA
Client Representative:	Alessandra Tassa
Date of Delivery:	30/07/2024
Version:	Final Report
Author(s):	Júlia Caufapé / Dáire Boyle (EARSC)
Reviewer	Alessandra Tassa (ESA)

Version	Date	Comment
1 <sup>st</sup> Issue	26/06/2024	
2 <sup>nd</sup> Issue	23/07/2024	
3 <sup>rd</sup> Issue	24/07/2024	
4 <sup>th</sup> Issue	30/07/2024	

**For more information contact:**

- EARSC: [info@earsc.org](mailto:info@earsc.org)
- ESA: [Alessandra.Tassa@esa.int](mailto:Alessandra.Tassa@esa.int)

Funded by the EU and ESA – ESA Contract Number: 4000119743/17/I-SBo.

The views expressed herein can in no way be taken to reflect the official opinion of the European Space Agency or the European Union.

## Table of Contents

<b>Setting the Scene .....</b>	<b>6</b>
<b>Executive Summary .....</b>	<b>7</b>
<b>1 Introduction &amp; Scope .....</b>	<b>9</b>
1.1 The Context of this study.....	9
1.2 What is the case all about?.....	9
1.3 How does this case relate to others? .....	9
1.4 More About the Study.....	9
1.5 Acknowledgements.....	10
<b>2 Roads in Portugal .....</b>	<b>11</b>
2.1 The Portuguese Road Network .....	11
2.1.1 Policies and Strategies .....	12
2.2 Geohazards and common issues around ground movement .....	14
2.2.1 Climate change considerations.....	14
2.2.2 Floods and landslides .....	14
2.2.3 Earthquakes and landslides .....	17
2.2.4 Soil erosion and wildfires .....	17
2.2.5 Coastal erosion .....	18
2.3 Social and environmental considerations.....	19
2.3.1 Flora and fauna considerations.....	21
2.3.2 Vegetation along roads considerations .....	21
2.4 Infrastructure monitoring techniques.....	22
2.5 Informed decisions, coordinated actions and effective interventions.....	22
2.5.1 What decisions .....	22
2.5.2 What data .....	23
2.5.3 Limitations of conventional methods.....	24
<b>3 The Use of Sentinel Data .....</b>	<b>25</b>
3.1 How can satellites help with ground movement monitoring?.....	25
3.1.1 Advantages.....	28
3.1.2 Limitations.....	28
3.2 Copernicus and the Sentinels .....	29
3.3 The Spotlight Service.....	31
3.3.1 Vegetation monitoring along motorways.....	33
3.3.2 Future Evolution of the Service .....	34
<b>4 Understanding the Value Chain .....</b>	<b>36</b>
4.1 Description of the Value Chain .....	36
4.2 The Actors.....	36
4.2.1 Tier 1: Service Provider – Spotlight .....	36
4.2.2 Tier 2: Primary User – Egis.....	38
4.2.3 Tier 3: IMT & NorScut.....	38
4.2.4 Tier 4: Citizens & Society .....	40
4.2.5 Other Beneficiaries .....	41
<b>5 Assessing the Benefits .....</b>	<b>42</b>
5.1 Overview .....	42
5.2 Benefits along the Value Chain .....	43

5.2.1	Tier 1: Service Provider – Spotlight .....	43
5.2.2	Tier 2: Primary User – Egis .....	43
5.2.3	Tier 3: IMT & NorScut .....	45
5.2.4	Tier 4: Citizens & Society .....	50
5.2.5	Other Beneficiaries .....	52
5.3	Summary of Benefits .....	52
5.3.1	Economic .....	52
5.3.2	Environmental .....	54
5.3.3	Regulatory .....	54
5.3.4	Entrepreneurship & Innovation .....	54
5.3.5	Science and Technology .....	55
5.3.6	Societal .....	55
5.4	Synoptic overview .....	55
<b>6</b>	<b>Key Findings and Final Thoughts .....</b>	<b>57</b>
6.1	Key findings .....	57
6.2	The Impact of Sentinel Data .....	57
6.3	Widening the Perspective .....	57
6.4	Final Thoughts .....	58
	<b>Annex 1: References and Sources .....</b>	<b>60</b>
	<b>Annex 2: General Approach and Methodology .....</b>	<b>61</b>
	<b>Annex 3: About the Authors .....</b>	<b>64</b>

## List of Figures

Figure 1: Summary of Benefits along the Value Chain .....	8
Figure 2-1: Comparative road densities .....	12
Figure 2-2: Landslide in Curral das Freiras, in Madeira, February 2010 .....	15
Figure 2-3: Frequency of landslide events per month for the DISASTER database timelines .....	16
Figure 2-4: Important hydrological natural disasters in mainland Portugal 1865-2015 .....	16
Figure 2-5: Important earthquakes in the Portuguese mainland .....	17
Figure 2-6: Soil vulnerability map .....	19
Figure 3-1: Illustration of passive versus active remote sensing .....	26
Figure 3-2: Active and passive sensors used for remote sensing .....	26
Figure 3-3: Current Sentinel satellites .....	29
Figure 3-4: Sentinel-1 and Sentinel-2 satellites .....	30
Figure 3-5: General view of A24 on the Spotlight platform .....	31
Figure 3-6: Part of the A24 with areas of severe subsidence represented by red dots .....	32
Figure 3-7: The three points on the identified slope where rapid acceleration was identified .....	33
Figure 3-8: Identification of unhealthy trees via the Spotlight platform .....	34
Figure 4-1: The value chain for Motorway Maintenance in Portugal .....	36
Figure 4-2: The Spotlight team .....	37
Figure 4-3: NorScut also provide tourist information pertaining to the A24 .....	40
Figure 5-1: Benefits along the value chain .....	42



Figure 5-2: Tolls and pricing along the A24 .....48  
Figure 6-1: Delivering value across the full range of dimensions .....57

## List of Tables

Table 5-1: Benefits Assessment by Category.....52  
Table 5-2: Summary of economic benefits.....53  
Table 5-3: Summary of benefits for each tier .....56  
Table A2-1: Definitions for the benefit dimensions ..... 61  
Table A2-2: The ranking of the benefits ..... 62  
Table A2-3: Complete list of indicators considered within SeBS analyses ..... 63

## Setting the Scene

It's a hot day in June 2022 in the municipality of Viseu, and Vin Diesel and Michelle Rodriguez are running through their lines; [the filming of the 10<sup>th</sup> Fast and Furious \("Fast X", 2023\) movie is about to start.](#)

Even though this is the 10th film in the saga, they still get nervous and excited when filming begins. As the director urges them to get into position, Jason Momoa invites the cast and crew to take in the beautiful scenery that northern Portugal has to offer before shouting "Action!". As they all look around, Vin can't help but notice a visible crack in the road ahead where they are supposed to be speeding along. While he's quietly telling Michelle about it, the production assistant overhears them and makes a scene out of his own panic. At this point, everyone is thinking that the production team should have checked the area more carefully, especially as they closed off this part of the A24 motorway for the shoot.

While they're discussing how to proceed, Dwayne "the Rock" Johnson suddenly recalls the project his daughter Ava did on her last year of school abroad a few years ago about satellites and the Copernicus programme.

Dwayne and his then-wife Dany Garcia sent Ava to Barcelona, Spain for her senior year of school, because they wanted her to improve her Spanish, given her mother's Cuban heritage. In Barcelona, there's the famous science museum [CosmoCaixa](#), which she visited on a school trip. It was there that she first learned about and became fascinated with satellite data and Earth Observation.

Although this was already 4 years ago, and Dwayne merely skimmed through her report (as parents typically do), he remembers being particularly surprised by the satellites' abilities to detect ground movement and support motorway maintenance. Ever since his colleagues filmed "The Fast and the Furious: Tokyo Drift (2006)" in Japan, they learned the hard way how due to belonging to a seismically active region, Tokyo is particularly vulnerable to geological hazards such as landslides or ground rupture. They had to relocate a few times in the shooting of the 2006 film, which proved both inconvenient and costly. Hence, when Dwayne read Ava's report, he couldn't help but think of his colleagues in Tokyo all those years ago.

Suddenly, "The Rock" calmed everyone down as he explained his thought process. The solution is simple, he continued, all we have to do is contact the people in charge of maintaining the motorway and ask them to check which parts of the A24 are free of ground movement and therefore safe for us to film. They will be able to point out safe locations using satellite data.

"Wow, who knew Dwayne was such a scientist?!", exclaimed Michelle mockingly. "Don't thank me, thank Ava and her passion for space.", Dwayne replied with a grin on his face.

*Whilst the character in this story is entirely fictional, the situation is inspired by real events based on our knowledge gained through the case interviews.*

## Executive Summary

This report demonstrates the benefits of using Copernicus Sentinel data to detect subsidence and potential geohazards along motorways. It is set in northern Portugal, along the A24 motorway, and shows how governments, road authorities, concessionaires and, in turn, Portuguese citizens can benefit from the use of satellite data.

Remote sensing techniques are increasingly being used to provide precise data on ground subsidence and vegetation monitoring. Satellites detect surface changes, offering vital information for highway infrastructure management in Portugal. Via the use of Copernicus data, the stakeholders can more effectively identify potential ground and infrastructure movements and assess the health of vegetation near motorways to better anticipate forest fires or treefall. Given Portugal's elevated risk of wildfires due to high temperatures and dry weather, these advancements are crucial for risk management.

In the north-east of Portugal, the A24 is a 157 km long mountainous motorway running from Chaves in the north to Viseu in the south. It was concessioned to the Portuguese State and NorScut in the year 2000. The operation and management of the motorway is carried out by Egis, an international construction engineering consultancy, while major repairs are handled by the Portuguese Road Authority (IMT)/NorScut.

This case focuses on how Spotlite's Sentinel-based service enables Egis to more efficiently locate and examine potentially hazardous areas along the A24 motorway and optimise on-site checks and associated maintenance costs. Spotlite's regional knowledge and experience in forest fire risk mitigation was a key factor in Egis' choice of service provider. Accordingly, IMT and NorScut benefit from accurate road condition assessments, risk allocation, and cost reductions.

The quantified economic benefits range from **€125,000/year** to **€180,000/year** for the studied case of the A24, and from **€2.5 million/year** to **€3.6 million/year** when extrapolated to the whole country (all figures explained in chapter 5). They are derived from the commercial data costs saved by Spotlite, the savings related to optimised on-site maintenance and vegetation checks by Egis, and the reduced likelihood of several types of threats to road infrastructure for IMT/NorScut.

Possibly the greatest benefits manifested in this case are societal, as this case highlights the key benefits for public infrastructure. Ensuring key pieces of infrastructure are maintained safely reduces the chances of road accidents and minimises road closures, thereby keeping infrastructure open and available for both citizens and commerce.

The benefits within each tier of the value chain are shown in the figure below:



Figure 1: Summary of Benefits along the Value Chain

## 1 Introduction & Scope

### 1.1 The Context of this study

The analysis of the case study “*Motorway Maintenance in Portugal*” is carried out in the context of the “[The Sentinel Economic Benefits Study](#)” (SeBS). This study is looking to develop cases showing how EO-derived products based on data generated by one or more Sentinel satellites deliver value to society and citizens. The [Sentinel](#) satellites form a crucial part of EU’s [Copernicus Programme](#), providing space-based observations on a full, free and open basis. Data coming from the Sentinels –together with other data collected by contributing missions and ground, sea or airborne instruments– is used to support key economic or societal areas such as agriculture, insurance, disaster management, climate change monitoring, etc. Sentinel data are thus a key component of the [Copernicus Services](#), and a crucial source used by companies to deliver products and services helping different users across the globe.

### 1.2 What is the case all about?

This report presents the advantages of utilising Copernicus Sentinel data to identify subsidence and possible geohazards along the A24 motorway in northern Portugal.

The report demonstrates the ways in which governments, road authorities, concessionaires, and Portuguese citizens benefit from satellite data. The A24 motorway, which is managed by Egis and maintained by the Portuguese Road Authority (IMT), extends for 157 km from Chaves to Viseu.

Spotlite’s specialisation in satellite data has enabled Egis to efficiently identify sites that are most at risk of ground motion, forest fires, or tree fall, thus optimising on-site inspection routines and associated costs. Consequently, IMT and NorScut have benefited from the provision of accurate road assessments, risk allocation, and cost savings.

### 1.3 How does this case relate to others?

As part of the SeBS project, the ground monitoring component of this portfolio case is closely linked to the case studies “[Ground Motion Monitoring in Norway](#)” (2020) and “[Highways Management in Italy](#)” (2022). Sentinel-1’s InSAR data have also been deployed for ground motion monitoring in the case “[Infrastructure Monitoring in the Netherlands](#)”. All of these cases involve monitoring the land surface for motion risks and mapping for forest, water, and soil management.

For the other component that the service provider was looking at, which was vegetation monitoring, they used the optical imagery from Sentinel-2. Many other portfolio cases have used this satellite data, including in [Croatia](#), [Estonia](#), and [France](#), covering agriculture, food production and environmental monitoring.

### 1.4 More About the Study

Each case study analysed in SeBS, focuses on products and services which use data coming from Sentinel satellites, measuring the impact of that product or service throughout the value chain. The starting point is the primary user of the satellite data, followed by a step-by-step analysis whereby

the operations of beneficiaries in each subsequent link of the value chain are analysed, all the way down to citizens and society.

In this process, the main aim is to understand and demonstrate the value which is generated using satellite-based Earth Observations (EO) and particularly the data coming from the Copernicus Sentinel satellites. Each case study thus underlines the causal relationship between the use of Copernicus Sentinel satellite data and benefits resulting from their use, including increased productivity, more efficient and environmentally friendly operations, economic gains and improved quality of life, among others. The evaluated and demonstrated benefits can be used by:

- **Decision makers:** Having access to a portfolio of concrete cases where the benefits from the operational use of Sentinel data in decision making are clearly articulated, helps decision makers not only to justify future investments but also to direct them towards areas that most matter in their country or organisation.
- **Users:** Moving beyond a vague idea of how EO services can support more effective operations requires a concrete understanding of the benefits they can actually bring in similar cases. In this regard, it is both numbers and stories that can resonate with users and attract them to explore further or deeper uses of EO in their operational activities.
- **Service providers:** Solid argumentation around the economic and environmental benefits stemming from the use of EO, coupled with powerful storytelling, can become an effective marketing tool for service providers seeking to promote their solutions and for EARSC to promote the sector.

In the framework of this project, 20 case studies will be developed with reports to be published on each one.

## 1.5 Acknowledgements

We would like to thank the following people for taking the time to talk to us. In particular:

**Martino Correia** – Spotlite

**Richard Lengrand** – Egis

**Emefa De Souza** – Egis

**Luís da Silva** – Egis

## 2 Roads in Portugal

This chapter presents general information about the current and historic roads in Portugal, as well as the deterministic landscape and policy characteristics of the road infrastructure. The possible issues and challenges faced by road authorities and civil society are also identified in this chapter. Namely, ground movements, infrastructure failures, maintenance challenges, etc.

### 2.1 The Portuguese Road Network

The majority of Portugal's terrain is mountainous, particularly to the north of the Tejo (Tagus) River, which divides the country in half. Although the north has coastal plains, the land quickly rises into hills and deep river valleys. The highest point in continental Portugal is the mountain range Serra da Estrela, which reaches an altitude of 1,993 m above average sea level. In the south of the country there are the Alentejo and Algarve regions, known for their agricultural landscapes and tourist developments, respectively. In between these regions you can find several ranges of hills, some of which reaching 900 m of height.

The network of roads and motorways in Portugal has a total length of 11,217 km, which ranks the country 128<sup>th</sup> in the world<sup>1</sup>. However, these results should be seen in the context of the country's population density, as higher densities usually require more extensive and efficient road networks to manage traffic and transport needs. Portugal's current population density of 114.4 inhabitants per km<sup>2</sup> is approximately 5% higher than the EU27 average<sup>2</sup>.

The Baseline project<sup>3</sup>, which aimed to produce values for Road Safety KPIs (Key Performance Indicators) in EU Member States, led to the definition of a performance indicator related to road infrastructure and safety. This indicator represents the percentage of the road network length of roads with either opposite traffic separation (by barrier or area) or with a speed limit equal to or lower than 70 km/h in relation to the total road network length. Portugal's motorway KPI value is 100%, as all motorways have median separations. It is important to note that this only implies that there are no/limited opportunities for head-on or crossing crashes and that the design is of highest standard. Additionally, World Data provides numerical statistics on road safety, indicating that with an average of 8.2 fatalities per 100,000 inhabitants per year, road traffic is considered relatively safe compared to the EU figure of 5.8 in the EU, and the global figure of 16.9.

The project's report on the KPI Infrastructure, released in 2023, included a number of valuable insights<sup>4</sup> which can assist in the process of policymaking, in improving the safety of the roads, and in assessing where to allocate investments.

---

<sup>1</sup><https://www.worlddata.info/europe/portugal/transport.php#:~:text=The%20network%20of%20roads%20and,also%20be%20taken%20into%20account>

<sup>2</sup>[https://ec.europa.eu/eurostat/databrowser/view/DEMO\\_R\\_D3DENS\\_custom\\_672158/bookmark/table?lang=en&bookmarkId=48e7b1e4-7d8d-45db-8717-b7bfd36182a0](https://ec.europa.eu/eurostat/databrowser/view/DEMO_R_D3DENS_custom_672158/bookmark/table?lang=en&bookmarkId=48e7b1e4-7d8d-45db-8717-b7bfd36182a0)

<sup>3</sup><https://www.baseline.vias.be/>

<sup>4</sup><https://www.baseline.vias.be/storage/minisites/baseline-kpi-infrastructure.pdf>

We will now examine the most relevant road safety performance indicators in Portugal which relate to the roads’ infrastructure.

The infrastructure quality is considered to be very high in comparison to other EU countries. This is assessed by the road users who have given it a 6 in a scale from 1 to 7.

The World Bank defines road density as the ratio of the length of the country’s total road network to its land area<sup>5</sup>. Portugal’s road density is calculated to be approximately 80% lower than the EU average, but its motorway density is significantly higher by 120%. You can refer to the following table extracted from the Portuguese National Road Safety Profile sourced by EUROSTAT<sup>6</sup>.

	Portugal	European Union
<b>Motorways</b>	33 km road/1000 km <sup>2</sup>	15 km road/1000 km <sup>2</sup>
<b>Total</b>	155 km road/1000 km <sup>2</sup>	918 km road/1000 km <sup>2</sup>

**Figure 2-1: Comparative road densities**

Given all of the above, it is of critical importance to invest in and promote continuous road monitoring and innovation in the sector.

The A24, which is the subject of this study, is a two-lane mountainous motorway of 157 km. It has 26 interchanges, 3 of which lead to service areas. The road has 1069 slopes, 86 of which are reinforced. It links Chaves to the north and Viseu to the south<sup>7</sup>.

In the year 2000, NorScut entered into a concession agreement with the Portuguese State for the A24<sup>8</sup>. The routinary operations and management of the road are subcontracted to Egis, while major repairs are carried out by IMT (Instituto da Mobilidade e dos Transportes – the Mobility and Transport Institute in English), the grantor, when necessary.

IMT provide estimated figures on the number of vehicles that use the A24 each quarter. Roughly 1.7 million vehicles were recorded across the entire length of the A24 in 2023<sup>9</sup>.

### 2.1.1 Policies and Strategies

In order to understand how Portuguese transport policies were developed and their impact on the country’s society and economy, it’s important to look at the historical evolution of the road network and the policies that have addressed the problems encountered in managing the roads.

Before the spread of motorisation, Portugal’s land transport network was mainly complementary to river transport. Travel within the country was limited to very small areas and, until the second half of the 18<sup>th</sup> century, it was mainly on foot, via the river, and with the help of animals.

<sup>5</sup><https://databank.worldbank.org/metadataglossary/world-development-indicators/series/IS.ROD.DNST.K2#:~:text=Road%20density%20is%20the%20ratio,Source>

<sup>6</sup>[European Road Safety Observatory National Road Safety Profile - Portugal](https://www.eurostat.ec.europa.eu/tgm/table?table=sdgs-08-10)

<sup>7</sup><https://www.meridiam.com/assets/norscut-highway-portugal/>

<sup>8</sup>[http://www.norscut.com/subcanais\\_n1.asp?id\\_canal=132&id\\_subcanal\\_n1=220](http://www.norscut.com/subcanais_n1.asp?id_canal=132&id_subcanal_n1=220)

<sup>9</sup><https://www.imt-ip.pt/sites/IMTT/Portugues/InfraestruturasRodoviaras/RedeRodoviaria/Paginas/Relatorios.aspx>

In the 19<sup>th</sup> century, the road network was characterised by the highest density of roads along the coast, with a decreasing density towards the interior of the country, following the distribution of the main population clusters. Recent initiatives by public bodies have aimed to enhance travel and mitigate the impact of interiority and regional asymmetries. Until the 1960s, the Portuguese government had a number of concerns about the development of land transport, including contract concessions, project financing, and the impact of road construction on agriculture. Over the years, the government encountered problems related to the inefficiency of investment in transport, which led to social inequalities, especially between urban and rural areas. There was also a lack of information systems on the functioning of the sector, which is essential for optimal government intervention.

In conclusion, the fact that the road network is a legacy of the past reflects the desire to connect densely populated areas, to support growth in other areas, to respond to strategies for the transformation of the national territory, and to satisfy the mobility needs that arise.

### Policies and Strategies

The National Risk Assessment (NRA) is overseen by ANEPC (Autoridade Nacional de Emergência e Proteção Civil – the National Authority for Emergency and Civil Protection in English). This consists of promoting the survey, forecasting, analysis, and evaluation of natural hazards in roads<sup>10</sup>. The risks considered in this report are those of both natural origins i.e., landslides, earthquakes and falling trees as well as human-induced risks such as road accidents and fires.

ANEPC implements the policies that relate to prevention and preparedness, with the most pertinent categories for this study being Territorial planning and Monitoring, alert and warning<sup>11</sup>. The Basic Law on Civil Protection focuses on preventing and mitigating risks and accidents, falling in Territorial planning section. Further, their policy on Land Use, complemented by the Portuguese Basic Law on Civil Protection, aims to ensure safety in land occupation and increase resilience to extreme climate events by defining mandatory land use practices and measures. On the other hand, through the Monitoring, Alert and Warning category, they ensure the dissemination of all information on risks and measures to overcome them to all citizens, in accordance with Decree Law No. 2/2019.

Moreover, seeing the findings presented in Baseline's report on KPI Infrastructure, it is recommended they are taken into consideration as they would be a valuable addition to Portugal's policy framework. Currently, Portugal is one of the few EU countries (29%) that doesn't invest in upgrading high-risk sites. Surrounding other infrastructure-related policies, Portugal is very aligned with the majority of the EU member countries and their standards. These policies include required audits to new road infrastructure, road inspections, design standards, etc.

---

<sup>10</sup>[https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/national-disaster-management-system/portugal\\_en](https://civil-protection-humanitarian-aid.ec.europa.eu/what/civil-protection/national-disaster-management-system/portugal_en)

<sup>11</sup><https://prociv.gov.pt/pt/prevencao-e-preparacao/missao/enquadramento/>

## 2.2 Geohazards and common issues around ground movement

In terms of natural hazards, Portugal is most vulnerable to landslides and floods<sup>12</sup>. The landslides that have taken place in Portugal over the years have been mostly triggered by earthquakes or rainfall<sup>13</sup>. However, there are other problems, such as coastal erosion and soil erosion, with the latter likely to occur and have an impact on road management. Related to this is the fact that, as a Mediterranean country, Portugal is in a region that's prone to forest fires, which have been empirically shown to be a key factor in soil erosion, with the highest risk of erosion in north-central Portugal, i.e., our study area<sup>14</sup>.

### 2.2.1 Climate change considerations

According to the [World Bank's Climate Change Knowledge Portal](#), Portugal is vulnerable to the effects of climate change through extreme events associated with lack or excess of **rainfall** and **heat waves**. In turn, the frequency and magnitude of **landslides** are expected to continue to increase with climate change, largely due to an increase in extreme rainfall (*Haque et al., 2016; Auflič et al., 2023*). Likewise, the most common triggers for ground subsidence are extreme weather events (e.g. heavy rainfall or floods), industrial activities, and earthquakes.

Rising sea levels are also a threat to Portugal's **coastline**, where a significant proportion of the population lives. Moreover, by the end of the 21<sup>st</sup> century, global **temperatures** in Portugal are expected to rise by 1.5°C to 2°C above pre-industrial levels<sup>15</sup>.

Lastly, **wildfires** in Portugal are expected to increase in frequency and severity due to climate change impacts, including extreme weather conditions, fuel load (amount of combustible material available) and continuity (uninterrupted presence of combustible material), and land cover and management practices<sup>16</sup>.

Overall, climate change is intensifying several geohazards in Portugal, including landslides, floods, and wildfires. The following sections will explore these geohazards and related issues in detail, focusing on their causes, impacts, and implications for Portugal (see section 3.3.2 for more information on climate change).

### 2.2.2 Floods and landslides

Floods in the central and northern regions of the country –the latter of which including the A24 motorway– have caused 85.2% of the natural disasters over the last 150 years, with landslides accounting for the remaining 14.8%. During this period, 1,658 cases have been identified and

---

<sup>12</sup><https://revistas.rcaap.pt/finisterra/article/view/33142/24023#:~:text=Geohazards%20are%20concentrated%20primarily%20in,%2C%20flash%20floods%2C%20and%20landslides>

<sup>13</sup>Zêzere, J. L., *LVIII*(124), 2023, pp. 7-27

<sup>14</sup><https://www.mdpi.com/2571-6255/6/7/254>

<sup>15</sup>Carvalho, D., 2024

<sup>16</sup>[OECD - Taming Wildfires in the Context of Climate Change – The case of Portugal](#)

included in the DISASTER database (Zêzere *et al.*, 2020). This has resulted in over 1,000 deaths and has left around 40,300 people homeless.

Floods are most likely to develop gradually along the prominent rivers Tagus, Douro, Mondego, ... caused by the abundance of the winter rain accumulation. The Porto and Douro valleys, as well as the Coimbra and Mondego valleys, are where most flooding occurs. Also, due to its favourable natural conditions and dense population, the western Portugal region (from Setúbal to Porto) is especially vulnerable to both natural disasters.

In more recent events, on the island of São Miguel of the Azores archipelago, heavy rainfall in 1997 caused over 1.000 shallow landslides, which resulted for some of the slides to produce debris flows and even 29 casualties. Likewise, in 2010, the Madeira archipelago experienced a number of similarly triggered landslides that caused 45 deaths.

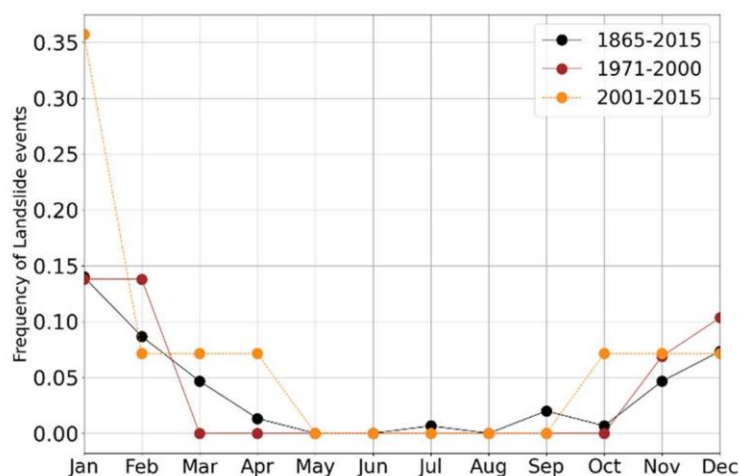


**Figure 2-2: Landslide in Curral das Freiras, in Madeira, February 2010<sup>17</sup>**

In the mainland, many of the landslides that have transpired have also been caused by strong storms and flooding. All of these 302 events between 1865 and 2015 are too recoded in the DISASTER database (Pereira, *et al.*, 2017; Zêzere *et al.*, 2020), and they took place where there is greater topographic variation, in the centre and north of the country. In these regions landslides are more likely to happen due to the steeper slopes and differences in elevation.

---

<sup>17</sup>Source: [NBC News](#)



**Figure 2-3: Frequency of landslide events per month for the DISASTER database timelines<sup>18</sup>**

Figure 2-3 depicts which months are most likely to experience landslides due to flooding, taking into account 3 different time periods. We can see that the 3-time frames are consistent and show a higher frequency between November and February, with a maximum in December and January. This is in line with the rainy season in Portugal, which usually takes place in autumn and winter.

Date	Event type	Affected Districts	Fatalities	Injured people	Evacuated people	Displaced people
2001 26-27 Jan	F + L	1, 3, 6, 9, 10, 13, 17, 18	6	5	402	570
1997 2-9 Nov	FF + UF	2, 8, 14, 15	11	22	141	134
1983 18-19 Nov	FF + UF + L	11, 14	18	0	255	3 239
1979 5-16 Feb	F + FF + L	5, 6, 11, 13, 14, 17	8	3	4244	14 322
1967 25-26 Nov	FF + UF	11, 15	522	330	304	885
1941 15-17 Feb	F + FF	11, 15	33	0	109	0
1940 2-6 Jan	F + UF + L	4, 7, 11, 14, 15, 17	7	3	35	1 043
1909 20-28 Dec	F + FF + UF + L	1, 3, 4, 5, 6, 9, 10, 11, 13, 14, 15, 16, 17, 18	37	4	679	478
1904 9-12 Feb	F + L	1, 3, 13, 17	27	1	1	3
1865 25-26 Nov	F + FF	11	21	0	0	0

Event type: F - Flood; FF - Flash flood; UF - Urban flood; L - Landslide.

Portuguese Districts: 1 - Aveiro; 2 - Beja; 3 - Braga; 4 - Bragança; 5 - Castelo Branco; 6 - Coimbra; 7 - Évora; 8 - Faro; 9 - Guarda; 10 - Leiria; 11 - Lisboa; 12 - Portalegre; 13 - Porto; 14 - Santarém; 15 - Setúbal; 16 - Viana do Castelo; 17 - Vila Real; 18 - Viseu.

**Figure 2-4: Important hydrological natural disasters in mainland Portugal 1865-2015**

Currently, floods are controlled by releasing water from dams, although this is a risky practice because when the water level exceeds the maximum capacity limit, extensive discharges are needed to avoid further damage.

<sup>18</sup>Source: [Araújo et al. \(2022\)](#)

### 2.2.3 Earthquakes and landslides

Scientific research has shown that although Portugal is in a rather low seismicity area, it has experienced large earthquakes in the past (before there were instruments to meaningfully record ground motion data)<sup>19</sup>. Via empirical investigation, a ground motion prediction model and equations (GMPEs) have been developed<sup>20</sup>. The results show that softer soils are more susceptible to attenuation (loss of signal strength) at lower frequencies, making them less prone to ground motion. Conversely, stiffer soils are proven to increase in signal strength, hence amplifying ground movement at higher frequencies. In the case of northern Portugal, it has been demonstrated that the soil consists of low stiffness, which is consistent with the literature<sup>21</sup>.

When talking about the Portuguese islands, historically, the most notable landslide occurred in Vila Franca do Campo (in São Miguel Island), in the year 1522. Serious ground subsidence transpired as a consequence of a strong earthquake (measuring around 6.2 on the Richter scale) which resulted in 3000-5000 deaths. More specifically, these debris flows originated in the hills above, in preceding fluvial channels, which then spread across the town and into the ocean, covering an area of 4,5 km<sup>2</sup>.

Now diving into continental Portugal and continuing with earthquake-induced landslides, researchers have found 28 of these over almost 1,600 years (*Vaz & Zêzere, 2016*), with magnitudes ranging from 4 up to 8.7, mostly in central and southern Portugal.

Year	Month	Day	Name	Source location	Magnitude Mb/Mw	Tsunami intensity (K)
1969	02	28	Horseshoe EQ	Horseshoe Abyssal Plain	7.5/-	III
1964	03	15	Guadalquivir Bank EQ	Gulf of Cadiz	6.2/-	
1909	04	23	Benavente EQ	Lower Tagus Valley	-/6.0	
1858	11	11	Setúbal EQ	South of Setúbal	6.8/-	
1856	01	12	Sotavento EQ	SW Iberian margin	6.0/-	
1761	03	31	North Atlantic	Gloria Fault Zone	7.5/-	VI
1755	11	01	Lisbon EQ	SW Iberian margin	-/8.5 - 8.7	XI
1722	12	27	Tavira EQ	Offshore Algarve	6.5/-	VI
1719	03	06	Portimão EQ	Offshore (?) Algarve	7.0/-	
1531	01	26	Vila Franca de Xira EQ	Lower Tagus Valley	7.1/-	VII
1512	01	28	Lisbon EQ	Lower Tagus Valley	6.3/-	
1356	08	24	North Atlantic	Gloria Fault Zone	7.5/-	
1353			Silves EQ	Offshore Algarve	6.0/-	
1344			Benavente EQ	Lower Tagus Valley	6.0/-	
382			Cape S. Vicente EQ	SW Iberian margin	7.5/-	VI
63 BC			Portugal and Galicia EQ	W Iberian margin	8.5/-	VII

Figure 2-5: Important earthquakes in the Portuguese mainland (*Vaz & Zêzere, 2016*)

### 2.2.4 Soil erosion and wildfires

By empirically analysing the relationship between different types of land use and the type of vegetation covering them (see sections 2.3.1 and 2.3.2), scientists have been able to extract valuable insights on how much of the soil is washed away by rainwater and can thus cause ground

<sup>19</sup>[https://www.researchgate.net/publication/253471141\\_New\\_Ground\\_motions\\_relations\\_for\\_Portugal\\_Mainland\\_using\\_a\\_stochastic\\_finite\\_fault\\_modeling](https://www.researchgate.net/publication/253471141_New_Ground_motions_relations_for_Portugal_Mainland_using_a_stochastic_finite_fault_modeling)

<sup>20</sup><https://fenix.tecnico.ulisboa.pt/downloadFile/1970719973966060/15.10.2015%20-%20extended%20abstract.pdf>

<sup>21</sup>[https://www.researchgate.net/publication/282175950\\_Ground\\_Stiffness\\_Evaluation\\_Using\\_the\\_Soil\\_Stiffness\\_Gauge\\_SSG](https://www.researchgate.net/publication/282175950_Ground_Stiffness_Evaluation_Using_the_Soil_Stiffness_Gauge_SSG)

subsidence<sup>22</sup>. This study (*Roxo et al., 2023*) focussed on the southern Portuguese area around the Serra de Mértola and consisted of 58 years of sampled data, supported by airborne and NASA Landsat imagery. The aim was to identify the most frequent effects between 3 variables in 3 defined transition scenarios. The variables were land use consequences, land cover changes, and vegetation response to soil erosion. The transitions were abandoned land, land being used for farming or animal pasturing, and intermediate scenarios. The study's findings highlight the strong correlation between the changes in land use and land cover with soil erosion, especially through the conversions between abandonment and farming or pasturing use.

In the context of southern European countries, with Portugal being a particularly notable case, forest fires represent a serious environmental risk. They are widely considered to be one of the main causes of land degradation and desertification (*Lourenco et al., 2012*). As they tend to alter hydrological processes (e.g. precipitation and infiltration), they make the affected landscape more vulnerable to flooding and erosion. In addition, the risk of runoff, which is the flow of water from rainfall or snowmelt across land cover, can also lead to ground erosion and flooding. In more extreme cases, and particularly in hilly areas (such as the A24 region), fires are likely to lead to debris flows and flash floods. To mitigate these risks and decrease raindrop impact on soil and reduce canopy rainfall storage, it is essential to maintain vegetation cover. This is why it is crucial to prevent and analyse forest fires.

### 2.2.5 Coastal erosion

The Portuguese coastline, with its beaches, cliffs, and low rocky shores, extends for 830 km (*Zêzere, 2023*). Coastal erosion has been very present since the late 1800s, especially in the north of Portugal, where about 20% of the coastline has receded at a rate of about 7 m per year, resulting in a significant amount of 1,220 ha between 1958 and 2016. The abundance of sedimentary rocky cliffs along the coastline, both on the peninsular side and on the islands, implies dangerous outcomes such as rockfall, landslides or the formation of sinkholes. An example of the destruction of infrastructure due to coastal erosion was in Espinho, a bit further south of Porto. The area that encompasses Espinho and Mira is one of the most commonly affected within the country's mainland. Articles show that the reasons for this are the lack of continuous and systematic coastline monitoring, the lack of strategic management by authorities with different scopes, and the underestimation of coastal erosion and its potential infrastructural damage (among others)<sup>23</sup>. Similarly, the sandy beaches have an annual erosion rate of 7.4 mm, which is heavily influenced by human activity, i.e. dam construction, dredging practices, engineering and mining interventions (like port construction), heavy urban development due to tourism, etc.

---

<sup>22</sup><https://oceanservice.noaa.gov/facts/subsidence.html#:~:text=Subsidence%20can%20also%20be%20caused,process%20known%20as%20loess%20deposits>

<sup>23</sup><https://www.climatechangeport.com/portugal/coastal-erosion/>

## 2.3 Social and environmental considerations

Soil degradation includes (but is not limited to) phenomena that result in a deterioration of soil quality and/or soil health, caused by either natural or anthropogenic factors. It unfortunately poses many negative impacts on nature, biodiversity, and ecosystems (Cano-Díaz et al., 2023), which in turn, have negative returns on production and the sustainability of the water quality. This paper examines and integrates several soil threats (including hydrogeological and erosion risks) to assess their distribution across the country and to quantify their vulnerability or sensitivity to them. The key findings using the combined assessment of the variables illustrate a rather concerning situation, with 58% of the terrain resulting in soil with a moderate vulnerability, 32% with low vulnerability, and 10% with high vulnerability. The following map (Figure 2-6), extracted from the paper, supports the establishment of informed decisions on land use and management, as well as the creation of national and international policies that prioritise its sustainable use.

In the special report of the Intergovernmental Panel on Climate Change (IPCC) in 2012<sup>24</sup>, the signs and warnings of climate change were already present and of vital importance. The UN intergovernmental body stressed that, as a consequence of climate change, landslides have increased notably over the

previous 100 years and will continue to do so. Following this, and still from a European perspective, Goriano et al. (2017) analysed the available literature and historical data on environmental issues related to ground motion and their potential causality, focusing on IPCC report's emphasis on temperature increases and higher precipitation frequency and intensity in the Mediterranean. Consequently, they test and confirm the hypothesis that an expected increase in rainfall will result in a higher number of landslides due to hydrological causes. Although this study was carried out in the south of Italy (in Calabria), it could account for other parts of Europe, as the methodology and high-resolution projections are replicable. As for how society is included in this study, Calabria's population is also considered in how exposed they will be in the future to these geohazards and how that will impact individuals. A sizeable increase in the landslide-exposed population is predicted through the study's model, a rise of approximately 67%. The insights of this study allow

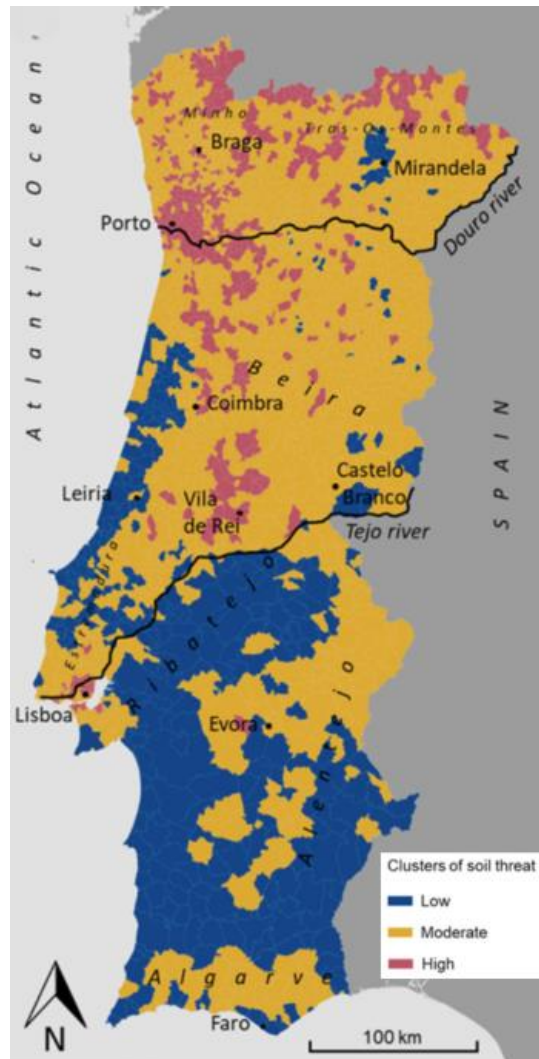


Figure 2-6: Soil vulnerability map

<sup>24</sup><https://doi.org/10.1017/CBO9781139177245>

us to believe that, in the long and medium run, there is a need not only for infrastructure management and monitoring, but also for an improvement and focus on the current risk management and mitigation strategies.

Accordingly, the [Directive on the Resilience of Critical Entities](#) entered into force last January 2023, and will be definitively adopted by the Member States by October 2024. Consistently aligned with this case's direction and necessary initiatives, the Directive's purpose is to strengthen the EU's critical infrastructures and the bodies or entities that oversee them in order to promote security in all senses against geohazards. The Directive naturally also targets many other critical infrastructures and bodies, for instance, those that manage public health emergencies, or those dealing with terrorist attacks or national threats and sabotage. Hence, the Directive covers many identified sectors – energy, banking, drinking water, digital infrastructure, public administration, and space, to name a few.

It is important to note that the 2022 Council Recommendation on strengthening the resilience of critical infrastructure has already been adopted by the Member States. This was prompted by the EU's desire to have a seamless adoption across the Union, which in turn was triggered by the calls received for additional measures in response to the acts of sabotage against critical infrastructure.

However, in this report we will focus on the identified sector of transport, as it is the most critical for the future of road infrastructure monitoring and safety. The Directive requires Member States to identify the national critical bodies and to implement specific national strategies to assess the risk of their infrastructure. Relatedly, performing risk assessment and carrying out the necessary measures is also specified. Finally, in an international and cooperative spirit, it is also provided that the Member States support and assist each other across sectors and industries in order to enhance European security and risk response capabilities. In the transportation sector, the Directive places emphasis on overseeing that the road infrastructure is protected from natural and human-made threats. As a continuation of the European Critical Infrastructure (ECI) Directive, which came into force in 2008, transport operators will have to comply with the required Operator Security Plans and appoint Security Liaison Officers, thus ensuring stronger accountability and cooperation.

A key general environmental consideration is the fact that the A24 motorway passes through areas that belong to the Natura 2000 Network, which is a network of conservation areas designed by the European Commission for the protection of biodiversity in the EU. The sites within Natura 2000 are designated under the [Birds and the Habitats Directives](#)<sup>25</sup>. Most notably, the Habitats Directive identifies positive conservation measures, i.e., through the implementation of management plans and measures and by addressing ecological requirements. Preventative measures and safeguards are also included in the Directive.

The companies involved in this report are not accountable for the network's monitoring, but by undertaking diligent, up-to-date, and preventive roadside vegetation management, they indirectly contribute to the environmental maintenance and protection of Natura 2000. This is also supported

---

<sup>25</sup><https://www.eea.europa.eu/themes/biodiversity/natura-2000/the-natura-2000-protected-areas-network>

by the monitoring and preventive measures taken when it comes to forest fire management. To make Natura 2000-related information available to all stakeholders in the value chain, the European Environment Agency (EEA) maintains an annually updated, publicly accessible EU database on Natura 2000, and hosts, among other tools, the [Natura 2000 network online map viewer](#).

### 2.3.1 Flora and fauna considerations<sup>26</sup>

When designing, building, and maintaining road infrastructure, a few factors need to be taken into account to ensure that flora and fauna do not suffer.

The companies in charge of this need to focus from an early stage on contributing to the achievement of the SDGs by reducing their environmental footprint. The installation of photovoltaic panels in maintenance centres and tunnels to guarantee the production of energy for their own consumption has proven successful, both environmentally and socially (and therefore economically).

During the operation and maintenance phase of the motorway, in order not to be delayed for environmental reasons (due to European directives on environmental aspects), it is highly recommended that exploratory work be carried out on the entire motorway and that tolls be introduced. Failing to implement these may result in the need to deviate from the initially planned route. This was the case for the A24 road operator, NorScut.

### 2.3.2 Vegetation along roads considerations<sup>27</sup>

The expansion of linear infrastructure inevitably results in the loss and fragmentation of habitats. It is therefore vital to maintain green spaces alongside these infrastructures in order to preserve biodiversity. This is intensified in environments where human activities have negatively impacted natural landscapes. Some examples of linear infrastructures include roads, railways, powerlines, and pipelines.

To guarantee the ecosystem services and mitigate the adverse effects of linear infrastructures on biodiversity, the project LIFE LINES (Linear Infrastructure Networks with Ecological Solutions) was established (2015-2020). Its goal was to facilitate the development of a green infrastructure that provides refuge for plants and animals and ensures their safe passage around these structures.

In accordance with the Portuguese legislation (Decreto-Lei n. 124/2006), which supports the Forest Fire Defence System, vegetation management should be carried out with frequent cutting to maintain a low layer of herbs. Due to the high risk of forest fires in the country, a firebreak of typically 10 m is required in Portugal between vegetation and road infrastructure<sup>28</sup>.

---

<sup>26</sup><https://capmagellan.com/o-caminho-que-percorre-um-panorama-sensacional-a-a24-e-a-alianca-entre-seguranca-e-respeito-pela-natureza/>

<sup>27</sup><https://lifelines.uevora.pt/wp-content/uploads/2022/05/Guiao-LINES-PLANTAS-200dpi-ENG-maio-2022.pdf>

<sup>28</sup><https://intapi.sciendo.com/pdf/10.2478/ffp-2023-0020#:~:text=A%202%2Dm%2Dwide%20firebreak,%2C%20bushes%2C%20shrubs%20and%20trees>

## 2.4 Infrastructure monitoring techniques<sup>29</sup>

Maintaining a careful and efficient maintenance of a country's road network is vital for society's benefit. According to the World Bank, road networks handle more than 80% of all passenger traffic and over 50% of all freight and consignments.

Typically, administrating and overseeing the assets of roads involves monitoring, assessing, and implementing repair or replacement decisions.

The purpose of this section is to outline the traditional (and then current) methods of road condition monitoring practice. To this end, the paper that's currently being analysed and used as source (*Radopoulou and Brilakis, 2016*) focuses on the traditional monitoring techniques and their shortcomings. In 2016, 99% of the data collection data and analysis was manual, and it was in the process of evolving into a more automated process.

The traditional process is as follows: In the first stage, road operators can collect data either manually or automatically. The latter approach involves the use of specialised vehicles such as a Road Surface Profiling Vehicle (RSPV), equipped with laser scanners, high-resolution cameras, inertial measurement units, etc. The use of automated methods, however, can be costly. The initial investment required for the acquisition of specialised vehicles is estimated to be a minimum of €422,000. This tends to result in the performance of manual techniques being used for many kilometres. Conversely, the manual data collection approach consists of the accredited surveyors inspecting the infrastructure by foot or motorised vehicles while looking for issues on the road. Once they detect one, they assess the site and analyse whether this could be addressed. Later, they need to input the gathered information throughout the process into the surveying authorities' database. This has proven to be inefficient, as it is subjective, labour intensive, and very time consuming. In the second stage, they examine the data to detect potential defects and execute severity assessments, which is also subjective and laborious. Finally, the Road Condition Index (RCI) is computed in order to classify each road based on national standards to then be able to take high-level maintenance or rehabilitation decisions.

Looking into several assessment criteria (accuracy, applicability, cost, and contribution), the paper concludes that none of the (to date) automated surveying methods tackle all the limitations the manual techniques pose in a cost-effective and holistic way.

## 2.5 Informed decisions, coordinated actions and effective interventions<sup>30</sup>

### 2.5.1 What decisions

What kind of information will be useful to the road planners and builders to improve their decisions, and how can satellites help? Which decisions can be influenced and improved? This depends on the phase of the project.

---

<sup>29</sup><https://www.sciencedirect.com/science/article/pii/S2352146516304434>

<sup>30</sup>SeBS: "Highways Management in Italy"

In the case of Portugal, satellite data was not used in the planning, design and construction of the A24 motorway, as this began over 24 years ago. In addition, it was only after these three phases that the primary user, Egis, began working with the Sentinel data service provider, Spotlite. This means that satellite data were only used in this study during the operational phase, which consists of the continuous maintenance of the infrastructure. Nevertheless, we will explain which decisions would benefit from the use of satellite data throughout the different phases.

**Planning phase:** The decisions taken here prepare the business case for the proposed road development. A key decision at this stage is to select the route and obtain regulatory approvals. Understanding the stability of the proposed route and avoiding areas of historic vulnerability can avoid future problems. The use of InSAR provides a unique means of understanding the extent and speed of any movement. It can also identify the level of risk due from rockslides. The ground motion map will provide easy access to this information which would not otherwise.

**Design phase:** Decisions made at this stage relate to the type of road construction method to be used. Design decisions can be made knowing where the ground is moving and, most importantly, how fast it is moving in the different parts of the proposed route.

**Construction phase:** Activities during the construction process can themselves cause ground movement. Decisions made during this phase relate to detailed engineering and construction tasks. These include the safety of both the project and the design. Monitoring for unexpected ground movements can indicate unforeseen problems (e.g. consequences of drilling through impermeable layers) or foreseen problems (settlement of ballast or deposited materials).

**Operational phase:** It concerns the long-term stability of the road. As in the area of northern Portugal where the A24 motorway is located, unexpected consequences can be detected, and new conclusions may be drawn. Knowledge of ground movements can help in decisions on the timing of maintenance works.

## 2.5.2 What data

InSAR ground motion maps are almost unique in what they can offer, and road management can benefit from ground motion information in several ways:

- Historical mapping of movement can help planners determine the best routes to take to avoid unstable areas. Information on any ground movement that may have occurred before a road was built, during construction or after the work has been completed is extremely useful.
- Mapping movement at rates of a few millimetres per day or per week can identify where construction is causing instability. Measured over longer periods of time, these can identify stresses that are building up and could cause tunnels or bridges to fail. Due to the nature of ground movement and maintenance requirements, revisit times typically need to be in the order of weekly to monthly<sup>31</sup>.
- In terms of spatial resolution requirements for road infrastructure monitoring, typically 1 m to 100 m resolution will suffice<sup>31</sup>.

---

<sup>31</sup>[Copernicus Report on Road and Automotive User Needs and Requirements](#)

- The rate of movement is important as an indicator in some situations. Very precise measurements of movement, possibly using corner reflectors, can be used to improve construction methods, for example to determine when ballast or landfill has settled.

As such measurements become available, the safety of the road system can be improved.

### 2.5.3 Limitations of conventional methods

In terms of measuring ground motion, conventional methods are very limited. Alternative methods do exist to measure the movement of the ground surface, but these are either less accurate, more expensive or limited in area covered. In particular:

- Traditional surveys cover a limited area and are labour intensive. They can be carried out with high accuracy and close spatial sampling but require a lot of time to measure movement regularly. In fact, without the support of satellite data, traditional field surveys for the A24 typically require roughly 120 person days per year.
- Overflights or similar aerial applications using LiDAR (Light Detection and Ranging) remote sensing technology are expensive and therefore not suitable for regular measurements, although the accuracy and spatial resolution are excellent. However, these LiDAR sensors collect relatively sparse data over larger areas more efficiently than static terrestrial LiDAR scanners.
- Augmented GPS measurement requires significant investment in equipment and therefore staff training. In addition, its accuracy can be compromised if the signal is obstructed (e.g. in tunnels or mountainous regions) or if the system is of lower accuracy (e.g. consumer GPS devices). Other thematically similar SeBS cases previously carried out in [Norway](#) and [Italy](#) support this limitation of the satellite-based navigation system.

In reality, due to the limitations of more conventional methods, ground motion is rarely investigated by road designers. Knowledge of the geology and where problems are likely to occur are mainly used as a guide. Satellite-based InSAR has the potential to be a key tool to be used by road designers and engineers.

## 3 The Use of Sentinel Data

### 3.1 How can satellites help with ground movement monitoring?

Remote sensing techniques are increasingly harnessed to provide timely and precise data across various aspects related to ground subsidence and vegetation monitoring. Copernicus data can enable the extraction of valuable insights that aid in the identification of potential ground and infrastructure movement as well as the health of vegetation, in this case trees, close to highways.

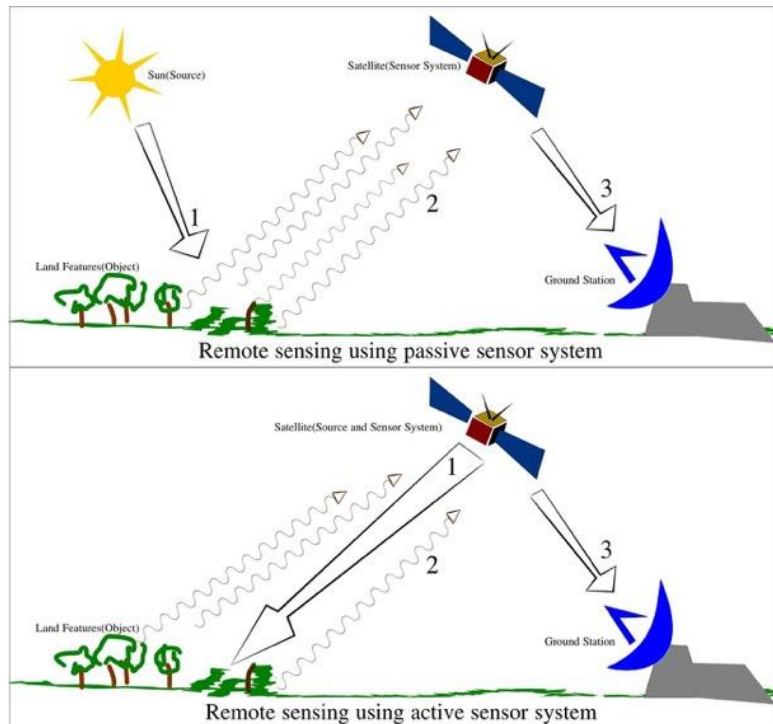
Before delving into the specific ground motion and monitoring services examined in Portugal, it's essential to grasp how satellites can detect changes on the Earth's surface, providing invaluable information to entities involved in overseeing highway infrastructure management.

Broadly speaking there are two main classes of Earth Observation satellites<sup>32</sup>:

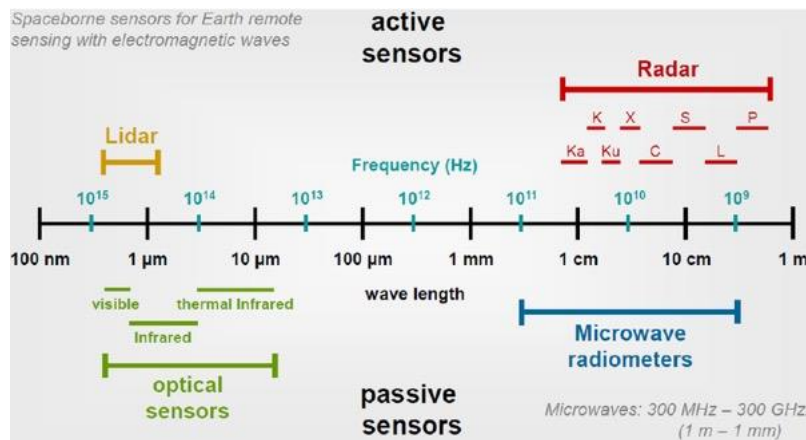
- Those carrying **passive sensors** able to detect the sun's energy as it is reflected from the Earth's surface. These "optical" satellites are affected by cloud coverage (as it hinders solar radiation) and can only observe during daytime. Typically used sensors in this category are radiometers (incl. imaging and Spectroradiometers) and spectrometers.
- Those carrying **active sensors** capable of emitting their own energy (in the form of electromagnetic radiation) to illuminate the scene (and objects therein) they observe. Such satellites send a pulse of energy from the sensor to the object and then receive the radiation that is reflected or backscattered from that object. Typically used sensors in this category are radar, scatterometer and LiDAR. Satellites carrying such sensors – for example Synthetic Aperture Radar (SAR) satellites – are unaffected by cloud coverage.

---

<sup>32</sup>[Overview of passive and active instruments on board earth observation satellites](#)



**Figure 3-1: Illustration of passive versus active remote sensing<sup>33</sup>**



**Figure 3-2: Active and passive sensors used for remote sensing<sup>34</sup>**

As seen in Figure 3-1, active and passive sensors emit/collect electromagnetic signals of different wavelengths. In practice, different materials on the Earth’s surface reflect electromagnetic waves in a different manner. These reflectance differences allow Earth Observation (EO) satellites to distinguish between buildings/infrastructure, grasslands, water surfaces, forests etc. When more than two wavelengths are used, the separation among objects is even more evident. Thus, satellites equipped with multispectral sensors (i.e. utilising different bands of the spectrum) can provide data that allow the quantitative classification of different types of land cover in a given scene.

<sup>33</sup>[Dall \(2017\)](#)

<sup>34</sup>[Lefevre, F & Tanzi, Tullio. \(2014\)](#)

In all cases, the data collected by EO satellites is transmitted via radio waves to properly equipped ground stations. There they are translated into a digital image that can be displayed on a computer screen. Each satellite image is composed of pixels and each of these pixels represents a square area on the image that is a measure of the sensor's ability to resolve (or "see") objects of different sizes. The higher the resolution the greater the ability of the sensor to discern smaller objects, but also the narrower the strip of land that can be surveyed by the satellite.

### **Measuring ground movement**

A SAR system emits microwave pulses (with a wavelength ranging from few centimetres to few tens of centimetres) and records the echoes from each pulse. The time taken for the echo to arrive provides the distance between the satellite and the measurement point on the ground. The energy that is reflected or scattered back from the ground provides important information on the surface. Since microwave radiation penetrates the atmosphere with negligible absorption, SAR is capable of operating during all weather conditions and at night. These properties for all-weather and night-day acquisitions, make this technology very appealing for Earth surface monitoring purposes.

A technique known as InSAR (Interferometric Synthetic Aperture Radar) is intensively used for the measurement of ground and structure deformations. The key data processing technique used as part of InSAR is typically referred to in literature as Multi-Temporal Interferometry (MTI). MTI has shown, in the last two decades, strengths and capacities in terms of wide area coverage (several tens of thousands of square kilometres) over long periods (several years). With MTI, successive SAR images are compared so that the distance between known points are compared. When these have changed, the radar can detect this. The basis of MTI-InSAR is that the radar can measure to high precision when a point on the ground has moved closer or further away from the radar. If the radar is carried on-board a satellite, it is hence useful for measuring vertical displacements; but note that it is unable to measure any lateral movements. As the radar signal hits the ground, the intensity of the energy reflected is determined by the nature of the ground surface. If this is strong and stable from one image to another (which may be taken days, months or even years apart, then changes in (the phase of) the signal enable the vertical distance to be measured.

### **Measuring plant properties**

The most common for measuring plant properties entails the measurement of the Normalised Difference Vegetation Index (NDVI) from passive or optical sensors. NDVI quantifies vegetation by measuring the difference between near-infrared (which vegetation strongly reflects) and red light (which vegetation absorbs). Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. But it absorbs more red and blue light. Calculations of NDVI for a given pixel always result in a number that ranges from minus one (-1) to plus one (+1). By using NDVI and taking advantage of various plant properties, such as the fact that different plants sprout, grow, and shed leaves or flowers at different times of the year can allow researchers to discern invasive species from native species and track how these plants are spreading. This remotely sensed information can also be validated via in-field inspections to ensure detection techniques are accurate. Knowledge of the distribution of this index across a given area, allow stakeholders concerned with the monitoring of tree health to make informed decisions on what interventions

may be needed where and when. To ensure EO data's suitability in various applications, in-situ data can also be used to validate the remotely sensed data.

### 3.1.1 Advantages

The most important advantages of satellite-based ground movement and vegetation monitoring applications include:

- The **capability to acquire data anywhere in the world**, and for the SAR technique, unrestricted by weather conditions. Satellites offer a **robust source of near-real-time<sup>35</sup> information** to aid biodiversity monitoring.
- The ability to generate **consistent, comparable, and relatively objective** (i.e., not depending on individual interpretation/observation) information, collected **systematically on multiple scales, from local to regional to nation-wide**.
- The capability to **supply regular, detailed updates on ground movement or vegetation status** on a local, regional, or national basis. By combining different satellites, this can be even done daily offering an invaluable resource to data users.
- Satellite images offer spatially continuous data coverage of an entire area, with no further interpolation required, in contrast to ground-based discrete sampling. As such, they can serve as a basis for interpolation of information gathered in situ.
- Finally, whilst EO satellite data are a complementary data source to in-situ data (as well as airborne data, socio-economic data, and model outputs) in most countries, they **can be the only reliable source of information in countries lacking the ground infrastructure**.

### 3.1.2 Limitations

When compared to alternatives such as on-site or aerial surveys, satellite-based ground motion and vegetation mapping presents the following limitations:

- Resolution and active sensor limitations – spatial resolution may not be high enough to detect the required data at small scales or sensors may not be capable/suitable for certain applications.
- Non-daily revisit times for high resolution, non-commercial optical satellites – However, in the application of based ground motion and vegetation monitoring, daily revisit times are generally not necessary.
- Possibility of gaps in data availability due to cloud cover for optical data.

On-site surveys can offer certain information such as the detection of small cracks in infrastructure which cannot as of yet be fully replicated with either satellite or aerial remote sensing.

---

<sup>35</sup>[“Near real-time” has a different meaning based on the application being studied. In the context of agriculture, near real-time is understood to be a few days. For a comprehensive overview on this we recommend a recent publication by Defourny et al. \(2019\)](#)

Until a few years ago, another potential limitation was the cost of acquiring satellite data. That has progressively changed, first thanks to Landsat<sup>36</sup>, and then with the advent of the Sentinel era – producing vast amounts of data under the Copernicus full, free and open data policy.

### 3.2 Copernicus and the Sentinels

The service studied is based on the use of both Sentinel-1 and Sentinel-2 data coming from the European Copernicus programme, so we shall start with a simple overview of the programme to place the services into context.

Copernicus is an [EU flagship programme](#)<sup>37</sup>. Copernicus started out as GMES (Global Monitoring for Environment and Security) with the goal of meeting European geo-information needs. At its heart is the most complete, operational satellite system in the world; owned by the EU and operated by ESA and EUMETSAT and currently comprising six types of satellites, see figure below.



**Figure 3-3: Current Sentinel satellites**

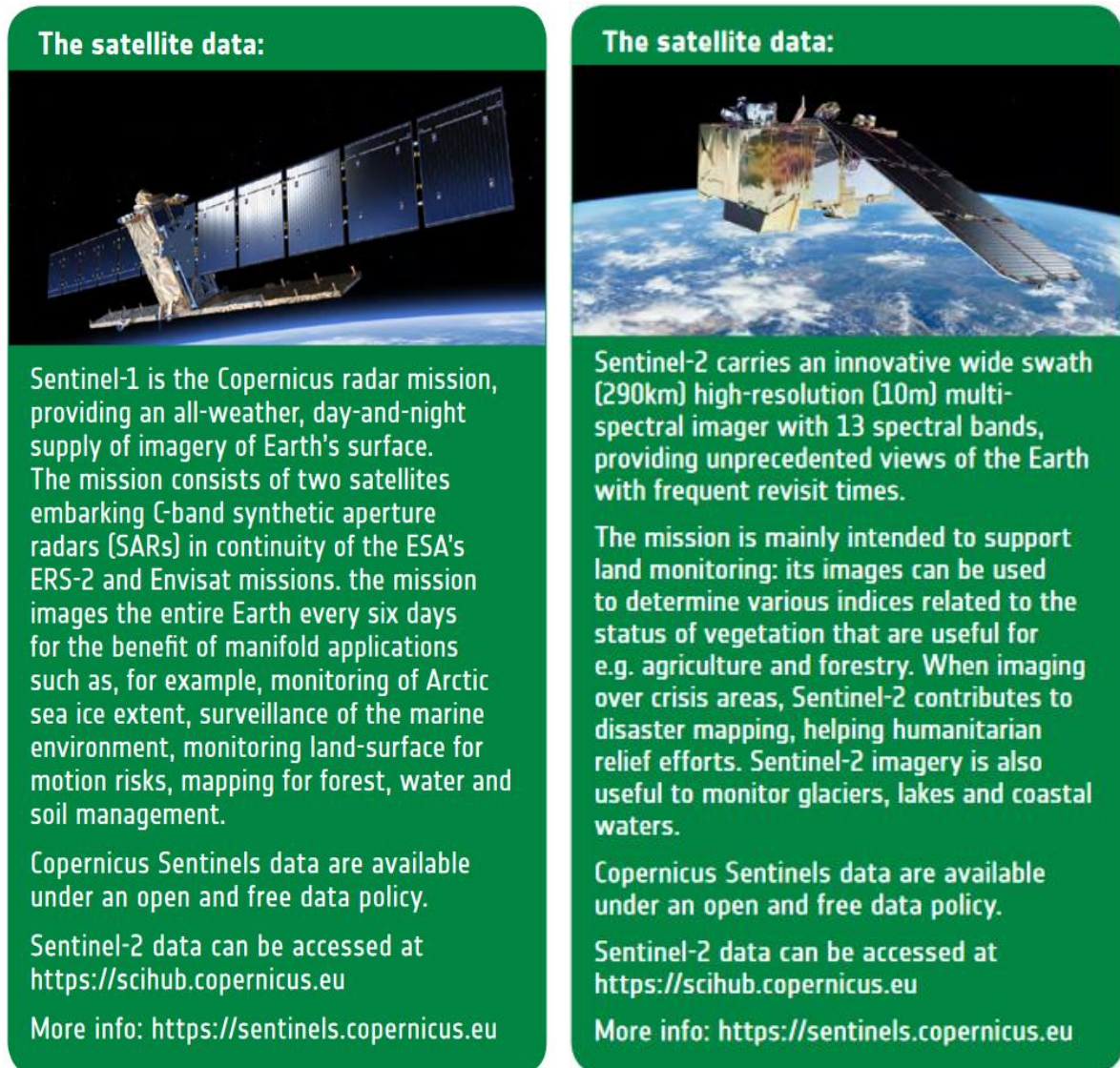
This case is defined by both [Sentinel-1](#)<sup>38</sup> and [Sentinel-2](#)<sup>39</sup> (see the information boxes below).

<sup>36</sup><https://www.usgs.gov/core-science-systems/nli/landsat>

<sup>37</sup><https://www.copernicus.eu/en>

<sup>38</sup><https://sentinel.esa.int/web/sentinel/missions/sentinel-1>

<sup>39</sup><https://sentinel.esa.int/web/sentinel/missions/sentinel-2>



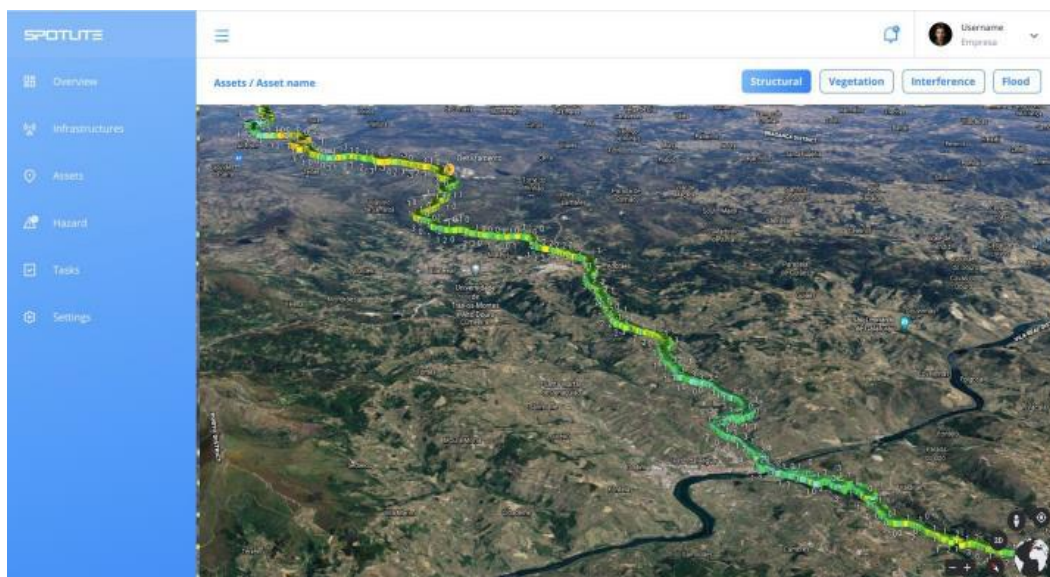
**Figure 3-4: Sentinel-1 and Sentinel-2 satellites**

Sentinel-1 carries a Synthetic Aperture Radar (SAR) operating in C-band. Sentinel-1 provides high-reliability data with a short revisit time, global coverage and rapid data dissemination to support operational applications. As already discussed, SAR is an effective and important technique in monitoring ground movement because its quality does not depend on weather conditions, cloud cover or day/night light coverage. Sentinel-1 SAR can be used to complement optical and NDVI data which is derived from Sentinel-2 (this will be further discussed in the following paragraph).

Sentinel-2 is a wide-swath, high-resolution, multi-spectral imaging mission. Sentinel-2 carries an optical instrument payload that samples 13 spectral bands: four bands at 10 m, six bands at 20 m and three bands at 60 m spatial resolution. Normalized difference vegetation index (NDVI) is a simple graphical indicator that can be derived from Sentinel-2 data which helps to assess vegetation health based on how the vegetation reflects light at certain frequencies. Sentinel-2 helps infrastructure managers to monitor tree health over time.

### 3.3 The Spotlight Service

Several engineering solutions were adopted to aid [Egis Road Operation Portugal \(EROP\)](#) in their operations, which entailed the monitoring of several geotechnical structures, namely 145 support walls as well as imposing embankments, many of these with reinforcement infrastructures such as soil nails and engineered concrete coverings. The need to carry out adequate management and monitoring throughout the life cycle of these important assets led to the development of a mixed system based on periodic visual inspections and monitoring of different types, namely topographic and using inclinometers.



**Figure 3-5: General view of A24 on the Spotlite platform**

However, these types of monitoring imply the existence of equipment on the ground, which is limited to defined locations as well as certain data collection periods. Therefore, it was important to find monitoring methods that allowed for a geographic broader analysis, shorter periods between measurements and the ability to understand movements that occurred prior to the installation of physical monitoring systems. As a result, Egis called upon [Spotlite](#), a Portuguese remote sensing company to help them conduct analysis using a satellite-based monitoring system, whose implementation allowed for a much broader spatial analysis with reduced periodicities. This enabled the early detection of potential instabilities in the areas surrounding the motorway, particularly over areas that did not have local instrumentation installed.

Spotlite developed a satellite-based platform (also called Spotlite) which enables multi-risk monitoring of infrastructures. It allows for the identification of risks of different types, including ground subsidence, mapping and forecasting of floods and problems related to proximity of vegetation to given infrastructures. It also includes tools to assist in digital visualisation of structures and associated analysis data, using “Digital Twin” technology. Additionally, the platform allows the management of field data related to infrastructures, including their specific characteristics, associated photographs or images, areas of interest and the association of documents and/or files. With relevance to this case, the platform integrates MTI-InSAR techniques based on Sentinel-1 data

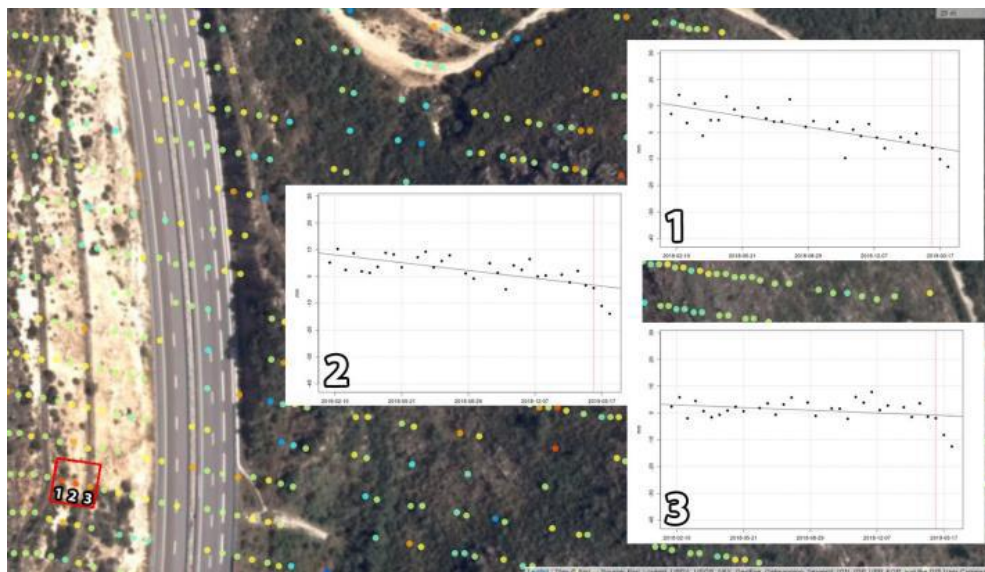
to monitor ground subsidence and uses Sentinel-2 data to monitor vegetation close to the motorway.



**Figure 3-6: Part of the A24 with areas of severe subsidence represented by red dots**

For the general analysis of the A24, more than 100,000 points were obtained along 157 km of motorway. In this stretch of road, eleven areas with cumulative displacement of between 2 and 5 cm were identified, which then were inspected, validated, and monitored by in-situ teams.

Further detailed analysis focused on a specific area of the A24, which is known to have previously been affected by a landslide on an embankment on the west side of the road. The area of the slope with the greatest instability was in the southern zone, which coincided with the location of the earlier landslide. More specifically, 3 points with rapid acceleration were noted (see image below) enabling timely interventions to be taken on the ground to avoid further issues.



**Figure 3-7: The three points on the identified slope where rapid acceleration was identified**

In 2023, further innovations were developed under a successful [ESA project](#) which created an online platform to monitor geohazards affecting transportation infrastructure using EO. These were implemented in Greece and Turkey, two other cases where Spotlite and Egis also collaborated.

### 3.3.1 Vegetation monitoring along motorways

Although this case primarily revolves around the monitoring of ground instability close to the A24 motorway, Spotlite also provides vegetation monitoring services close to the motorway. Trees that are unhealthy due to disease or drought present a heightened risk of falling and potentially damaging nearby infrastructure, disrupting service or injuring people. Moreover, Portugal is a Mediterranean country with high temperatures and low rainfall, making it highly susceptible to forest fires, which can put nearby motorway infrastructure at risk. These factors can impact vast areas, making them challenging to monitor effectively and in a timely manner.

Spotlite utilises Sentinel-2 imagery to monitor tree vitality, helping us to identify areas where trees have died or are dying. By using this data, they can assess tree health and take necessary measures to address any issues detected. Additionally, they can use remote sensing data to estimate tree height and analyse the potential impact radius of falling trees. This helps in identifying any potential dangers to the integrity of the infrastructure and the safety of its users.

Sentinel data provides Spotlite with a cost-effective solution for large-scale monitoring of vegetation conditions along the entire A24 motorway network. By using this data, they can quickly identify areas where vegetation vitality is decreasing and map diseased trees. Furthermore, it allows them to pinpoint individual trees that may pose a potential risk to the infrastructure. With this information, managers and operators can allocate resources to critical areas and ensure efficient resource utilisation.



**Figure 3-8: Identification of unhealthy trees via the Spotlite platform**

### 3.3.2 Future Evolution of the Service

In addition to the ground motion and vegetation monitoring services developed for the Spotlite platform, several other services are continuing to be developed.

The platform offers flood mapping and flood risk assessment tools, suitable to monitor and predict potential impacts of catastrophic floods over large areas. Historical analysis based on Sentinel data allows for the development of predictive flood risk assessment models, taking into account such factors as geomorphological characteristics of the terrain, land cover data and precipitation records.

Tools are being developed to detect third-party interference in critical infrastructure networks. Using Sentinel data, it is possible to quickly identify and locate the source of the interference, whether intentional or unintentional, on a network-wide scale. By detecting changes caused by illegal or unauthorised activity, management teams can quickly take appropriate action to ensure the integrity of the infrastructure. This can help reduce downtime, improve security and reduce the costs associated with repairing and replacing damaged or stolen equipment<sup>40</sup>. Although this Spotlite solution focusing on interference is currently under development, its key features will be the ability to change detection to locate sources of interference and the ability to alert and act as an early warning system.

Through virtual replicas of assets and infrastructures, or “Digital Twins”, Spotlite also provides 2D and 3D visualisation tools for asset information management. Integrating satellite and IoT sensor data, the service can provide a detailed understanding of the infrastructure behaviour, performance, and condition over time. Moreover, these comprehensive digital representations can

<sup>40</sup><https://www.spotlitedata.com/solutions/interference>

be used to improve maintenance operations, tasking, and management strategies, as well as optimising budgets.

Moreover, it is relevant to mention an important upcoming mission from which Spotlite will be able to leverage data in the future, namely, the [Copernicus Hyperspectral Imaging Mission for the Environment \(CHIME\)](#), expected to be launched in 2028. It is foreseen to bolster the Copernicus offering even further, particularly when it comes to monitoring of natural habitats. Each CHIME satellite will carry a Hyperspectral Imager (HSI) on board to support the monitoring, implementation, and improvement of a range of policies in the domain of raw material, food security, agriculture, and soil properties. HSI will have secondary applications that relate to biodiversity and ecosystem sustainability, forestry management, environmental degradation, lake/coastal ecosystems, water quality, and snow characteristics<sup>41</sup>.

Furthermore, while not specifically used by Spotlite in this case, it is pertinent to mention two of the six [Copernicus programme](#) services, namely the [Copernicus Emergency Management Service \(CEMS\)](#) and the [Copernicus Climate Change Service \(C3S\)](#).

CEMS provides a comprehensive solution for disaster risk management for natural and man-made hazards, integrating satellite data, in situ observations, models, and aerial data. CEMS's free and open data allows users and emergency management professionals to integrate these data into their preparedness, response, and recovery activities, thus protecting lives, assets, and the environment. The Early Warning and Monitoring component of CEMS is focused on the mitigation of droughts, forest fires, and floods. For the context of this report, we will focus specifically on CEMS's [European Forest Fire Information System \(EFFIS\)](#). Established in 1998, EFFIS supports forest protection services in the EU and neighbouring countries, providing EU institutions with up-to-date and reliable information on wildfires. In 2015, EFFIS became a component of CEMS. It offers several specific tools and applications for wildfire management, including the [Wildfire Risk Viewer](#) and [Firenews](#), to name a few.

C3S supports society by providing authoritative information on past, present, and future climate in Europe and the rest of the world, with the aim of supporting EU adaptation and mitigation policies by providing consistent and authoritative information about climate change. Through the [Climate Data Store \(CDS\)](#), they provide climate data and information on impacts on a range of topics and sectoral areas. The most relevant sectoral areas for this case are [Infrastructure, Transport and Associated Standards](#) and [Health](#).

---

<sup>41</sup><https://www.eoportal.org/satellite-missions/chime-copernicus#eop-quick-facts-section>

## 4 Understanding the Value Chain

### 4.1 Description of the Value Chain

This case study examines the benefits currently being obtained by the road infrastructure and safety sectors through the use of remote sensing Copernicus data. The combination of InSAR technology and the NDVI index provides a solution for monitoring ground subsidence and assessing vegetation properties. This enables the operationalisation and long-term maintenance of road quality and safety, enhancing the reliability and sustainability of transportation infrastructure, in a cost-effective way. Spotlite’s monitoring of the risks that arise around road infrastructure using satellite data provided Egis with the tools and knowledge to be able to examine this Portuguese motorway (A24) more efficiently, allocating hazardous sites within the infrastructure more effectively and reducing the number of on-site checks. Consequently, Egis was then able to implement a more effective maintenance strategy, while also reducing costs. In turn, the Portuguese Road Authority (IMT) and the concessionaire responsible for managing this motorway (NorScut) also benefit from a more comprehensive and accurate examination of the road’s condition, enabling a more precise allocation of risks and a reduction in costs for both them and society. Finally, the public benefits from a more efficient use of its money and its resources, as well as from better-organised roads with fewer closures or deviations, which leads to a safer transportation experience. This is graphically represented in the value chain below.

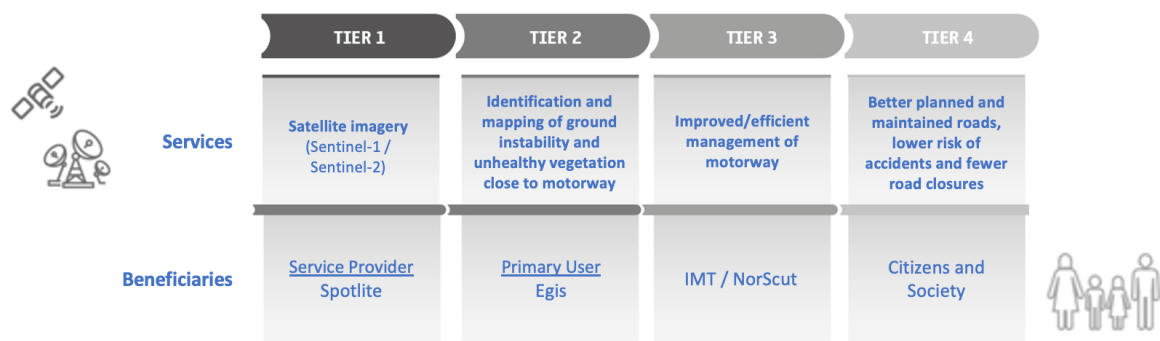
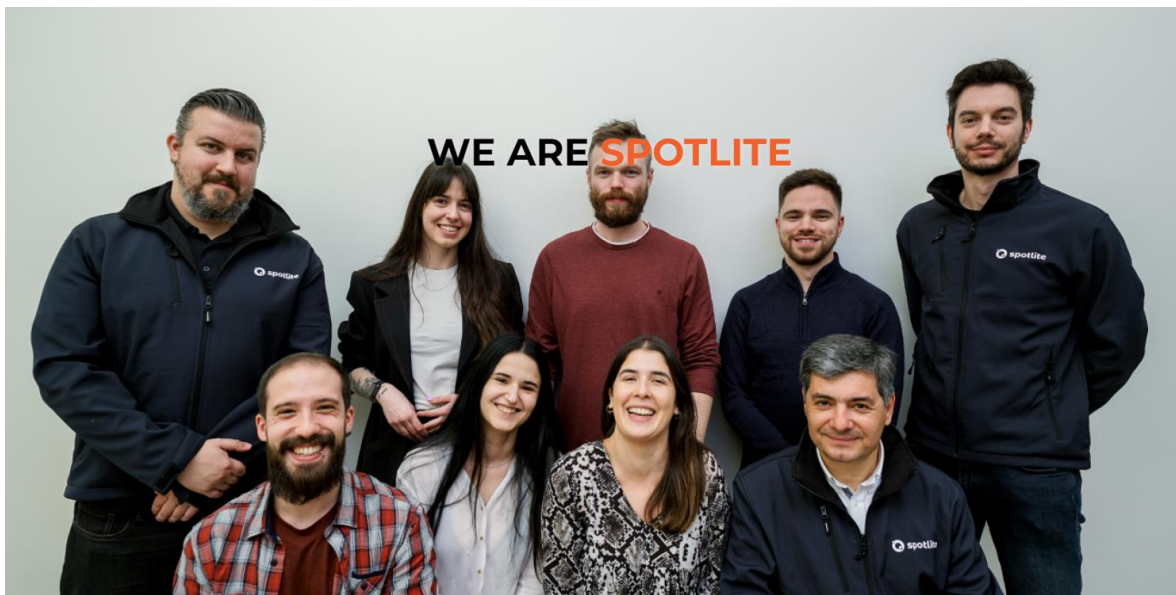


Figure 4-1: The value chain for Motorway Maintenance in Portugal

### 4.2 The Actors

#### 4.2.1 Tier 1: Service Provider – Spotlite

[Spotlite](#) is a Portuguese company specialising in infrastructure risk monitoring through the use of satellite imagery. It provides infrastructure managers and operators with analytics and tools for structural health assessment via remote sensing techniques, offering a resource for monitoring and maintaining critical infrastructure. In addition to assisting with the identification of necessary maintenance procedures due to ground subsidence or unhealthy vegetation, their services also enable the proactive assessment of infrastructure for early risk detection. The team is made up of approximately 20 employees.



**Figure 4-2: The Spotlite team**

The solution they offer consists of an innovative online risk monitoring platform and early-warning system designed to safeguard critical infrastructure. Based on satellite data, it provides analytics on multiple hazards for structural health assessment and asset management, with the aim of meeting the specific needs of different industries. Spotlite integrates satellite-based analytics with ground data, providing a comprehensive view of critical infrastructure. The platform combines the power of remote sensing from Earth Observation satellites with in-situ IoT sensor data, creating a holistic approach to monitoring and management. The result is a monitoring and management platform that helps organisations ensure the safety and reliability of their infrastructure. The product offers some key benefits, including high precision, continuous monitoring (near real time), the ability to consider historical data, and the capacity to collect and analyse data from virtually any location on the planet. While Spotlite also plays a role in the mining and energy sectors, its focus and impact are in the transportation sector, where it provides solutions for both railway and road systems.

In addition to analysing ground motion and vegetation, Spotlite's solutions also examine floods, interference, and digital twins. Focussing on ground subsidence, and in line with what was previously mentioned, Spotlite's solution involves the remote sensing technology InSAR. This consists of precisely detecting where there has been structural motion via radar waves on a network-wide scale. In terms of vegetation, Spotlite is able to monitor a series of key indicators, such as health, vitality, changes in the coverage, and, most importantly, potential encroachment (unauthorized extension or occupation) over safety corridors. The platform provides up-to-date data to be able the optimisation of vegetation management strategies in relation to infrastructure networks.

#### 4.2.2 Tier 2: Primary User – Egis

[Egis](#) is an end-to-end global consulting, engineering and operating firm specialising in mobility services, with a presence in 120 countries. They work with clients across the entire value chain and project lifecycle. With 19,500 employees, they create and operate smart infrastructures and buildings in response to climate change challenges, with the aim of achieving a more balanced, sustainable and resilient land use. Their team involves both engineers and operators, thus bringing their clients technical expertise and a holistic view of how green infrastructure, smart cities, and future transport work together.

Egis is headquartered in Guyancourt (France), and was founded in France over 90 years ago, around the time before the Second World War. Since then, the company has expanded its office spaces across every continent. Egis' strong regional presence allows them to gain a deep understanding of the challenges and constraints faced by each country, enabling them to adapt their approach to suit the unique context of each market. They collaborate with governmental entities, private road owners, and institutional investors.

Egis has a comprehensive presence across 9 core sectors, offering expertise in all aspects of transport, infrastructure, and the built environment. Some examples of their work are urban and transit, rail transport, and air transport. We will be focusing on their work in the field of road transport. Their support spans from designing major structures, connecting cities or collecting tools, in order to meet today's stakeholders' needs while laying the foundations for tomorrow's challenges. Their key expertise areas are project structuring and financing, road eco-design, integration of turnkey systems, toll collection and enforcement, and, most notably, operation and maintenance. They adopt a future-ready approach via systems thinking to prepare the infrastructure over time (considering the entire transportation network as an interconnected system), to accommodate changing mobility patterns, new technologies, and climate change.

Relevant to this case, Egis hired Spotlite to help them monitor issues relating to ground subsidence around the A24 motorway in Portugal. Egis is responsible for the operation and maintenance of the A24 motorway, and by carrying out regular inspections of various road assets, it is possible to identify any existing problems and the subsequent work required to resolve them.

#### 4.2.3 Tier 3: IMT & NorScut

##### **IMT - Instituto da Mobilidade e dos Transportes (Portuguese Road Authority)**

The [IMT - Instituto da Mobilidade e dos Transportes \(Portuguese Road Authority\)](#) is a governmental body integrated into the indirect administration of the Portuguese State, with administrative and financial autonomy. The IMT is a central body with jurisdiction over the entire national territory and has its headquarters in Lisbon. It is responsible for regulating and overseeing all aspects of transportation within the country, including road infrastructure. Its primary mission is to ensure the efficient, safe, and sustainable mobility of people and goods. IMT carries out responsibilities of the Ministry of Infrastructure in coordination with the Ministries of Internal Administration, Economy and Sea, Environment and Climate Action. IMT also integrates the responsibilities of SIEV (Sistema de Identificação Eletrónica de Veículos), relating to the operation and management of the country's

electronic vehicle identification system. This system has since given way to the national electronic toll service.

One of the key functions of IMT in road development is the planning and implementation of national transportation policies. The institute is involved in creating comprehensive transportation plans<sup>42</sup> that align with Portugal's economic, social, and environmental goals. These plans include the development of new road projects, the expansion of existing networks, and the integration of various transportation modes to enhance overall connectivity. IMT also plays a significant role in the regulatory aspect<sup>43</sup> of road development. It sets the standards and guidelines for the design, construction, and maintenance of road infrastructure. This includes ensuring that all road projects meet the necessary safety and quality requirements. By establishing these regulations, IMT aims to create a consistent and reliable road network that can support the country's mobility needs.

In addition to planning and regulation, IMT is involved in the funding and financing of road projects. The institute works in collaboration with other governmental bodies, local authorities, and private entities (see NorScut) to secure the necessary resources for road development. This includes managing public funds, coordinating with international funding organisations, and promoting public-private partnerships to leverage additional investment.

### **NorScut**

[NorScut](#) operates as a player in the development, construction, operation, and maintenance of transportation infrastructure, with a particular focus on highways. As a concessionaire, NorScut has been granted the rights by the government to manage certain infrastructure projects for a designated period. During this concession period, the company is responsible for various critical activities, ensuring the infrastructure's efficiency and safety. On December 30, 2000, the Concession Agreement was signed between NorScut and the Portuguese State (IMT) for the design, construction, financing, and operation of the future A24.

One of the primary roles of NorScut is in the development and construction phases of infrastructure projects. This involves meticulous planning and designing of roadways and associated structures to meet high standards. NorScut oversees the entire construction process, managing it to ensure projects are completed on schedule, within budget, and in accordance with quality specifications. This hands-on approach in the initial stages sets the foundation for long-term operational success. In addition to development and construction, NorScut is deeply involved in the operation and maintenance of the infrastructure it manages. Routine maintenance activities include regular inspections, repairs, and general upkeep to keep the infrastructure in optimal condition. Moreover, the company undertakes major rehabilitation efforts periodically, which involve extensive repairs and upgrades necessary to maintain the infrastructure's functionality and safety over time.

---

<sup>42</sup><https://www.imt-ip.pt/sites/IMTT/Portugues/InfraestruturasRodoviaras/RedeRodoviaria/Paginas/PlanoRodoviarioNacional.aspx>

<sup>43</sup><https://www.imt-ip.pt/sites/IMTT/Portugues/Legislacao/Paginas/Legislacao.aspx>



Figure 4-3: NorScut also provide tourist information pertaining to the A24<sup>44</sup>

A significant aspect of NorScut operations is also toll collection, which serves as a primary revenue source. By operating toll roads, NorScut collects fees from users, which are then utilized to fund ongoing maintenance and operational costs, as well as to provide returns on investment. The company employs advanced toll collection systems, including electronic toll collection, to streamline the process and enhance efficiency for users.

#### 4.2.4 Tier 4: Citizens & Society

The final tier in the value chain of this case encompasses all road users and citizens who benefit from better planned, better maintained, and safer roads. Well-connected cities, ports, and regions within Portugal can significantly boost a country’s economy by reducing non-tariff barriers to trade. An advanced road network facilitates the swift and efficient transport of people, capital, and goods, thereby stimulating business and economic activities. Economic beneficiaries of improved roads include freight companies, transport companies, and corporations that move large volumes of goods and capital between locations. They can lower operating costs due to shorter travel times and more efficient fuel use. Moreover, high-quality road infrastructure supports the development and success of modern supply chain management, impacting a vast range of stakeholders, from large commercial companies to individual citizens. Improved roads can also enhance various social factors, including reducing traffic congestion, decreasing road accidents and fatalities, increasing access to education and healthcare, and lowering CO<sub>2</sub> emissions.

<sup>44</sup>[http://www.norscut.com/subcanais\\_n1.asp?id\\_subcanal\\_n1=230&id\\_canal=139](http://www.norscut.com/subcanais_n1.asp?id_subcanal_n1=230&id_canal=139)

#### 4.2.5 Other Beneficiaries

Although not directly involved in the value chain, there are other beneficiaries in this case. Firstly, the [Autoridade Nacional de Segurança Rodoviária - ANSR](#) (National Road Safety Authority) benefit from enhanced safety due to the reduced likelihood of road infrastructure being affected/damaged as a result of several types of threats (discussed further in the next chapter). ANSR is a governmental organization dedicated to improving road safety and reducing traffic-related accidents and fatalities. ANSR plays a critical role in formulating and implementing road safety policies and strategies. Its mission encompasses a wide range of activities aimed at enhancing the safety of road users, including drivers, passengers, pedestrians, and cyclists. Furthermore, ANSR oversees the coordination and support of emergency response services related to road accidents. This includes ensuring that emergency responders are adequately trained and equipped to handle traffic incidents efficiently. By improving the response to road accidents, ANSR helps to minimise the impact of these incidents on victims and reduce the overall severity of injuries.

Secondly, the [Instituto da Conservação da Natureza e das Florestas – ICNF](#) (Institute for Nature Conservation and Forests) benefit indirectly from the maintenance of roadside vegetation. ICNF is a key governmental body in Portugal dedicated to the conservation, management, and sustainable use of the country's natural resources and forested areas. One of the primary responsibilities of the ICNF in relation to Natura 2000 is the identification and protection of sites that qualify for protection under the network. As already stated, the A24 motorway passes through areas that belong to the Natura 2000 network. The companies involved in this report are not accountable for the network's monitoring, but by undertaking diligent, up-to-date, and preventive roadside vegetation management, they indirectly contribute to the environmental maintenance and protection of Natura 2000.

## 5 Assessing the Benefits

Now that we understand the effects of the Sentinel-enabled motorway monitoring service on the later stages of the value chain, we can identify the various benefits it generates. What financial value can we attribute to the availability of this service? What environmental or regulatory benefits can we identify? Are there social or scientific impacts we can track? These are the questions we address in this chapter. In this context, it is useful to revisit our value chain diagram and add the final two layers to it.

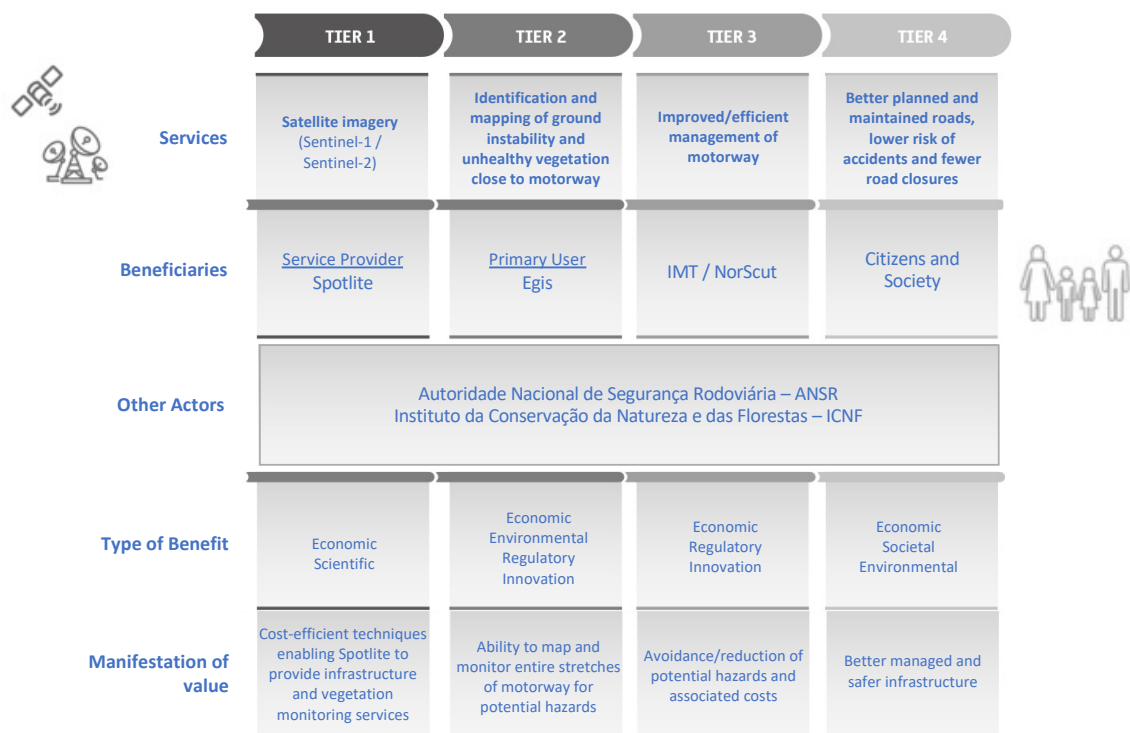


Figure 5-1: Benefits along the value chain

### 5.1 Overview

In this section we look at the benefits which were and continue to be generated using Sentinel-enabled service. We will examine the impacts comprehensively, considering more than just economic factors, although these are typically the benefits of most interest to readers. In our prior research, we have discovered that non-monetary benefits often play a significant role in creating substantial value.

Before we dive into the discussion for each of the tiers it is instructive to make a high-level observation:

- **Attribution of value to Sentinel data**

In most cases analysed under the *Sentinel Benefits Study* the question of attribution arises, i.e., what part (or percentage for the economic value) of the produced benefit can be attributed to the use of Sentinel data? In this case, Egis estimates that by using the Sentinel-enabled service they can

optimise operations by between 10% and 20%. We will therefore use these figures as our value attribution where applicable.

## 5.2 Benefits along the Value Chain

### 5.2.1 Tier 1: Service Provider – Spotlite

Spotlite’s reliance on a completely free primary data source allows them to consistently reduce substantial operational costs. If Spotlite had to pay continuously for such large volumes of data, it would likely necessitate a dramatic overhaul of their business model, ultimately resulting in reduced profits. The ability to use Sentinel data, due to its free and open nature, has been instrumental in helping Spotlite maintain a sustainable business model. This freedom from certain financial constraints is helpful for smaller companies like Spotlite when it comes to getting “off the ground”, entering the market and innovating.

In order to estimate the economic benefit at this tier, the Spotlite team has provided an estimate of cost savings associated with using Sentinel data in lieu of commercial data. Spotlite estimate that they save between **€60,000 per year in commercial data costs**. The estimation is based on a counterfactual scenario where if Spotlite were to use Cosmo Skymed Strimap with 3 metre resolution, they would have to spend around €60,000 a year to monitor the 160 km of motorway in question. This cost would entail 4 x €15,000, with each each of the four acquisitions corresponding to a 40 km x 40 km image.

Apart from the economic aspects, it is crucial to highlight Spotlite’s significant contribution to the scientific understanding of how road infrastructure and surrounding areas can be managed. This contribution stems from their inventive utilisation of Sentinel data to create algorithms and methods for the detection of ground movement close to motorways in conjunction with the estimation of health and height of trees which could present a problem should they fall. Two scientific papers<sup>45,46</sup> were published which relate directly to this case. These papers explain the innovative techniques and algorithms developed and applied in this case. For a full list of relevant scientific publications see **Annex 1**. For more information on related innovative developments that Spotlite is currently pursuing and aims to enhance in the future, please refer to section **3.3.1 – Future Evolution of the Service**.

### 5.2.2 Tier 2: Primary User – Egis

As the primary user of Spotlite’s service, Egis has benefited in several ways. Firstly, without the use of Spotlite’s Sentinel-enabled service, it would have been extremely challenging for them to gain a comprehensive understanding of the extent of ground subsidence across the motorway network.

---

<sup>45</sup><http://ocs.editorial.upv.es/index.php/JISDM/JISDM2022/paper/viewFile/13839/7619>

<sup>46</sup>[https://10crp.crp.pt/wp-content/uploads/2022/07/paper\\_132.pdf](https://10crp.crp.pt/wp-content/uploads/2022/07/paper_132.pdf)

In this case, Egis' goal was to maximise the operational efficiency of the A24 motorway, monitoring for potential risks such as ground movement or rockfall in order to assure the continued safety of the structure and prevent road closures or accidents. Furthermore, they also needed to detect instances where the safety of the motorway had been compromised by the condition of roadside trees, either by falling trees or fires. It is relevant to note that the elevated risk of wildfires in Portugal due to high temperatures and dry weather was a key factor in Egis' decision to partner with Spotlite.

Consequently, Egis benefited in many ways from Spotlite's service. First, let's look into the economic benefits:

**a) Ground motion**

- Although the provided tools don't directly imply the saving of the upcoming costs, they are intended to help prioritise the assets to be inspected and alert to situations that may require specific attention/increased monitoring.
- In order to monitor walls, slopes, topographic and inclinometric conditions, all structures are subject to maintenance checks of every two years (with half of the structures undergoing checks on an annual basis). Egis have estimated that this requires approximately 120 person days per year at a rate of €600 per day.
- Therefore, estimated monitoring yearly costs:  **$(120 \times 600) = \text{€}72,000/\text{year}$**
- Egis have estimated that the annual efficiency gains from using satellite data to optimise operations and better pinpoint areas of interest are between 10% and 20%.
- Therefore, the lower estimate of the yearly economic benefits:  **$0.1 \times \text{€}72,000 = \text{€}7,200/\text{year}$**
- The upper estimate of the yearly economic benefits:  **$0.2 \times \text{€}72,000 = \text{€}14,400/\text{year}$**

**b) Vegetation monitoring**

- Additionally, Egis have estimated the savings in efficiency gains when it comes to inspecting roadside vegetation to be **€10,000/year**.

We therefore arrive at the following lower and upper estimates:

- Lower estimate: *(Lower estimate for Ground Motion + Vegetation Monitoring estimate)* = **€17,200/year**
- Upper estimate: *(Upper estimate for Ground Motion + Vegetation Monitoring estimate)* = **€24,400/year**

There are also environmental benefits in this tier. By adopting the remote sensing solution, Egis can reduce emissions from vehicles used for in-person maintenance checks. As discussed, the Spotlite service allows for the pinpointing of areas of interest, meaning vehicles can be used in a more fuel-efficient manner to reach them, thereby lowering the company's overall carbon footprint. Additionally, it helps identify isolated intervention areas, reducing CO<sub>2</sub> emissions from vegetation-cutting activities. In the medium and long term, this leads to greater carbon compensation by minimizing interventions in green spaces.

Egis is also better able to abide by safety standards and regulations when it comes to the operation and preservation of the A24. As discussed, the improved monitoring system can aid in the application of various aforementioned national and EU level laws, regulations and directives including the **Directive on the Resilience of Critical Entities**<sup>47</sup> and various parts of the **EU Directive 2019/1936 on Road Infrastructure Safety Management**<sup>48</sup> (further details on the better compliance of the latter are given in section 5.2.3).

Since motorways belong to the transportation sector, they most prominently need to comply with the 2008 [European Critical Infrastructures Directive \(ECI\)](#), and its follow-up 2023 [Directive on Resilience of Critical Entities](#). These two directives fall under the [European Programme for Critical Infrastructure Protection \(EPCIP\)](#), aimed at both European and national infrastructure.

As the company responsible for the maintenance of the A24, Egis would have to carry out (at least every 4 years) the Critical Entity Risk Assessment, which consists of taking into account the relevant natural and human risks that could lead to incidents, including cross-sectoral or cross-border risks, accidents, natural disasters, etc. Most of these processes can be improved with the support of satellite data.

Finally, Egis also contributes to the innovation landscape via their adoption of new, cutting-edge services. There can often be an unwillingness for companies to change of traditional working practices (i.e., on-site checks) as they may involve an element of the “unknown” or sometimes even have associated costs. Egis’ willingness to do so is a testament to their commitment to innovation.

### 5.2.3 Tier 3: IMT & NorScut

The economic benefits in this tier primarily revolve around the avoidance of costs resulting from infrastructure damage and loss of revenue from toll collection as a result of road closures. An in-depth study has been conducted which can provide insight into potential economic penalties associated with such interruptions.

The ROADAPT<sup>49</sup> project (*roads for today adapted for tomorrow*) provided a set of guidelines for the preparation of adaptation strategies by road network administrations. The guidelines covered the basic steps from climate change projections to vulnerability and socio-economic assessments. As part of the project, a modelling exercise was undertaken and a **detailed report was published**<sup>50</sup> which modelled the potential impacts and likelihood of natural disasters specifically on the A24 itself, which we will use as a basis of our calculations. NorScut themselves took part in the study. The approach was based around 3 workshops:

- **Workshop 1:** This involved the selection of the relevant climate threats, determination of the relative importance of the A24 motorway sections, discussion and ranking of the possible

---

<sup>47</sup>[https://home-affairs.ec.europa.eu/policies/internal-security/counter-terrorism-and-radicalisation/protection/critical-infrastructure-resilience\\_en](https://home-affairs.ec.europa.eu/policies/internal-security/counter-terrorism-and-radicalisation/protection/critical-infrastructure-resilience_en)

<sup>48</sup><https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L1936>

<sup>49</sup><https://climate-adapt.eea.europa.eu/en/metadata/guidances/roadapt-guidelines-for-adaptation-of-road-infrastructure-to-climate-change>

<sup>50</sup><https://www.scribd.com/document/410115118/ROADAPT-Case-Study-A24-Portugal-Quicksan-Report>

consequences of climate threats, scoring of the climate threats regarding their potential impact on each consequence criterion.

- **Workshop 2:** Building upon Workshop 1, this involved scoring of the probabilities of the threats, evaluation and prioritisation of the climate risks, and the selection of the risks that can be mapped.
- **Workshop 3:** Finally, this involved a discussion on risk acceptability (i.e., which risks require action), determination of a climate change adaptation action plan, and the prioritisation of the actions.

### **Avoided repair costs due to reduced likelihood of hazards occurring**

As part of the study, a panel of 9 experts modelled the impacts and probabilities of various types of natural and climate-related threats to produce various risk scenarios. The types of threats modelled included flooding, heat waves, fog, drought etc. Given that the Spotlite service primarily revolves around the monitoring of ground instability and roadside vegetation monitoring, three of the threats modelled pertain most directly to this report, namely, “**external slides, ground subsidence or collapse affecting the road**”, “**slides of the roadbed**” and “**susceptibility to wildfires that threaten the transportation infrastructure directly**”.

#### a) **Threat - External slides, ground subsidence or collapse affecting the road**

- The study deemed that this threat, should it happen at any point along the entirety of the A24, it would likely incur “**direct costs for management of the incident and repair**” of greater than **€500,000** (the highest cost category in the study). To remain conservative, we will take €500,000 as our cost variable.
- They also concluded that the probability of this threat happening would be “**no more than once every 5 years**” (the second most frequent probability category in the study). Given that we have no further information on potential frequencies, we will take this as an event that is likely to occur once every 5 years.
- We will therefore average this risk out to a probabilistic cost of **€100,000/year**.
- Through Egis’s maintenance routines, we can claim that the likelihood of such a threat happening is reduced, but we cannot claim that the risk is totally eradicated. To estimate the reduction in risk is difficult and depends on several unknowns, however, one study<sup>51</sup> on the effectiveness of road maintenance measures **demonstrated a decrease of between 32% and 75% in hazards identified via a combination of general prevention principles and safety measures** (i.e., traditional, in-situ maintenance checks). We will therefore assume a 50% reduction in the likelihood of this threat occurring as a result of traditional maintenance routines/activities, leaving us with a probabilistic cost of **€50,000/year**.
- Moreover, we cannot claim that 100% of this probabilistic cost can be avoided thanks to the use of Sentinel data as the traditional in-person maintenance checks would be carried out as usual, irrespective of the use of Sentinel data. However, as already

---

<sup>51</sup>[https://www.researchgate.net/publication/337288537\\_Safety\\_management\\_in\\_the\\_maintenance\\_works\\_on\\_motor\\_ways\\_through\\_DELPHI\\_methodology\\_and\\_Pareto's\\_concepts](https://www.researchgate.net/publication/337288537_Safety_management_in_the_maintenance_works_on_motor_ways_through_DELPHI_methodology_and_Pareto's_concepts)

discussed under the Tier 2 benefits (section 5.2.2), Egis estimates that thanks to the use of Sentinel data, they can optimise maintenance routines (and their associated costs) by between 10% and 20%. Although not an exact proxy, we will assume the same attribution when it comes to avoided threats thanks to enhanced Sentinel-based monitoring.

- We can therefore estimate that between **€5,000/year** and **€10,000/year** of repair costs are avoided thanks to the use of Sentinel data.

b) **Threat – Slides of the roadbed**

- Again, the study deemed that this threat would likely incur **“direct costs for management of the incident and repair” of greater than €500,000.**
- The study again also concluded that the probability of this threat happening would be **“no more than once every 5 years”.**
- This also gives an average probabilistic cost of **€100,000/year.**
- Again, we will claim that 50% of this probabilistic cost can be avoided thanks to maintenance activities/routines, leaving us with a probabilistic cost of **€50,000/year.**
- Just as above, we will attribute between 10% and 20% of this avoided cost to the use of Sentinel data, providing us with an estimate of between **€5,000/year** and **€10,000/year** of avoided repair costs due to the use of Sentinel data.

c) **Threat – Susceptibility to wildfires that threaten the transportation infrastructure directly**

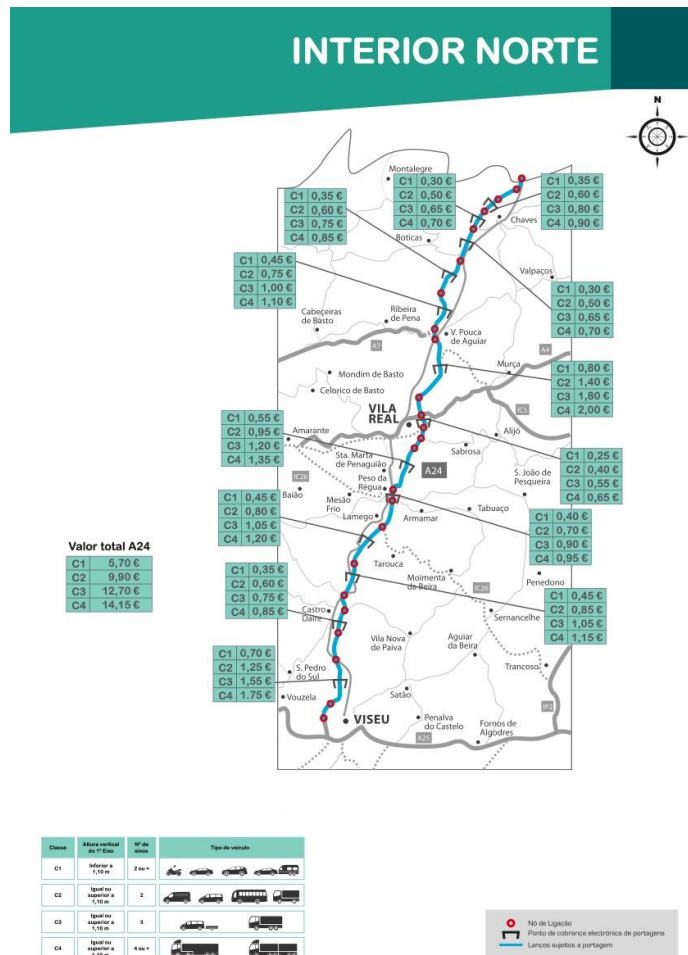
- The study deemed that this threat would likely incur **“direct costs for management of the incident and repair” of between €100,000 and €500,000.** We will therefore take an average cost of **€300,000** for this threat.
- The study concluded that the probability of this threat happening would be more common than the other threats and deemed it as likely to happen **“several times per year”.** We will therefore make a conservative assumption of this occurring twice per year along the entire stretch of the A24.
- This gives a probabilistic cost of **€600,000/year.**
- Again, we will claim that 50% of this probabilistic cost can be avoided thanks to maintenance activities/routines, leaving us with a probabilistic cost of **€300,000/year.**
- Just as above, we will attribute between 10% and 20% of this avoided cost to the use of Sentinel data, providing us with an estimate of between **€30,000/year** and **€60,000/year** of avoided repair costs due to the use of Sentinel data.

We can therefore claim **a total economic benefit here of between €40,000/year and €80,000/year.**

The study also initially investigated the threat of trees falling on the road. However, after preliminary analysis, discounted this threat as not particularly relevant and excluded it from the analysis. We will therefore not quantify any avoided costs relating to tree falls.

**Loss of revenue from toll collection**

The A24 has 13 electronic tolls, each of which has a different price depending on vehicle type. According to data from IMT, roughly 1.7 million vehicles used the A24 in 2023<sup>52</sup>, however, not all of these will have paid a toll as the tolls are located only on certain sections of the road, see image below. The IMT data provides vehicle usage for given segments on the A24, therefore, using the map shown below we have estimated that roughly 970,000 road users paid a toll in 2023. We also do not have granular data on “light vehicle” versus “heavy vehicle” road usage on the A24, but according to one source, the ratio is typically 92% “light vehicles” to 8% “heavy vehicles” in Portugal<sup>53</sup>. Again, relating to the map below, for the purposes of this calculation, we will consider categories C1 and C2 as being suitable for “light vehicle” pricing and categories C3 and C4 as being suitable for “heavy vehicle” pricing. Applying these assumptions, we arrive at an estimated toll revenue of **€613,000/year** along the A24.



**Figure 5-2: Tolls and pricing along the A24<sup>54</sup>**

<sup>52</sup><https://www.imt-ip.pt/sites/IMTT/Portugues/InfraestruturasRodoviaras/RedeRodoviaria/Paginas/Relatorios.aspx>

<sup>53</sup><https://www.asecap.com/component/content/article/9-en/52-portugal>

<sup>54</sup>[https://www.portugaltolls.com/sites/default/files/2024-01/IN\\_01janeiro2024.pdf](https://www.portugaltolls.com/sites/default/files/2024-01/IN_01janeiro2024.pdf)

We then must look at the duration for which the A24 would lose toll revenue as a result of potential hazards:

- a) **Threat - External slides, ground subsidence or collapse affecting the road**
  - Returning to the ROADAPT report<sup>55</sup>, it was concluded that the threat of “**external slides, ground subsidence or collapse affecting the road**” would on average render the entire A24 unavailable for 6 hours (this threat would likely render smaller sections of the A24 unavailable for much longer, however we don’t have information on that).
  - Again, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a probabilistic outage time of 3 hours.
  
- b) **Threat – Slides of the roadbed**
  - Again, the ROADAPT report concluded that the threat of “**slides of the roadbed**” would render the entire A24 unavailable for 6 hours.
  - Again, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a probabilistic outage time of 3 hours.
  
- c) **Threat – Susceptibility to wildfires that threaten the transportation infrastructure directly**
  - The ROADAPT report concluded that the threat of “**susceptibility to wildfires that threaten the transportation infrastructure directly**” would render the entire A24 unavailable for between “**6-24 hours**”. We will take an average figure of 15 hours of unavailability in this case.
  - Once more, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a probabilistic outage time of 7.5 hours.

All in all, we arrive at quite a low figure for potential avoidance of toll revenue loss (around €1000/year), even before attributing 10% and 20% of this benefit to Sentinel data. We will therefore not include this figure in the overall calculation of benefits.

Within this tier we can also claim regulatory benefits. Thanks to the Spotlite system, IMT and NorScut are ultimately better able to abide by safety standards and regulations when it comes to the operation and preservation of critical national infrastructure such as motorways. In particular, the improved monitoring system can aid in the application of various parts of the **EU Directive 2019/1936 on Road Infrastructure Safety Management**<sup>56</sup>. In particular, with regard to Articles 5 and 6, concerning network-wide road safety assessment and periodic road safety inspections, IMT

---

<sup>55</sup><https://www.scribd.com/document/410115118/ROADAPT-Case-Study-A24-Portugal-Quickscan-Report>

<sup>56</sup><https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32019L1936>

and NorScut are able to carry out more efficient (in terms of expenditure and personnel) visual inspections and incident analyses.

#### 5.2.4 Tier 4: Citizens & Society

The utilisation of the Sentinel-enabled Spotlight service can reduce the duration of road closures due to ground instability or even prevent them entirely. Road closures negatively affect citizens by obstructing travel routes and necessitating alternative detours, which prolongs travel time and disrupts daily routines and activities. Additionally, there is a societal cost associated with road closures due to the lack of “return on investment” from the funds spent on building the roads. While it is challenging to quantify the societal cost of road closures in monetary terms, some conservative assumptions can be made to estimate this impact:

- The development of A24 was financed in 2000 for **€726 million** under the assumption of an amortization period of 30 years<sup>57</sup>. We do not know the exact breakdown of all financial contributions; therefore, we will take this figure entirely as a public investment.
- Correcting for inflation since the year 2000, the €726 million investment equates to **€1.222 billion in 2024**.
- Averaging this €1.222 billion investment over 30 years **equates to an €40.7 million/year public investment**.

a) **Threat - External slides, ground subsidence or collapse affecting the road**

- Returning to the ROADAPT report<sup>58</sup>, it was concluded that the threat of “**external slides, ground subsidence or collapse affecting the road**” would on average render the entire A24 unavailable for 6 hours (this threat would likely render smaller sections of the A24 unavailable for much longer, however we don’t have information on that).
- This 6-hour unavailability equates to a lack of return on investment or “loss of benefit” cost of €28,000/year.
- However, we must remember that this event is only likely to happen once every 5 years, meaning averaged out over 5 years, we see a lack of return on investment of €5,600/year.
- As before, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a lack of return on investment of €2,800/year.

b) **Threat – Slides of the roadbed**

- Again, the ROADAPT report concluded that the threat of “**slides of the roadbed**” would render the entire A24 unavailable for 6 hours.
- This 6-hour unavailability equates to a lack of return on investment or “loss of benefit” cost of €28,000/year.

<sup>57</sup>[http://www.norscut.com/subcanais\\_n1.asp?id\\_canal=132&id\\_subcanal\\_n1=220](http://www.norscut.com/subcanais_n1.asp?id_canal=132&id_subcanal_n1=220)

<sup>58</sup><https://www.scribd.com/document/410115118/ROADAPT-Case-Study-A24-Portugal-Quicksan-Report>

- Again, we must average this out over 5 years, resulting in a lack of return on investment of €5,600/year.
- Again, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a lack of return on investment of €2,800/year.

c) **Threat – Susceptibility to wildfires that threaten the transportation infrastructure directly**

- The ROADAPT report concluded that the threat of “**susceptibility to wildfires that threaten the transportation infrastructure directly**” would render the entire A24 unavailable for between “**6-24 hours**”. We will take an average figure of 15 hours of unavailability in this case.
- This 15-hour unavailability equates to a lack of return on investment or “loss of benefit” cost of €70,000/year.
- In Tier 3 we estimated that this is likely to happen twice per year, resulting in a lack of return on investment of €140,000/year.
- Again, we will claim that 50% of this outage can be avoided thanks to traditional maintenance activities/routines, leaving us with a lack of return on investment of €70,000/year.

Overall, adding all the lack of return-on-investment figures as a result of threats occurring, we arrive at a value of **€75,600/year**. Similar to what is seen in Tier 3, we will attribute between 10% and 20% of this avoided cost to the use of Sentinel data. This results in a value estimation of **€7,560/year** and **€15,120/year**.

Although we see modest figures in this tier, these kinds of benefits, which are backed up by solid threat and risk modelling, show how value is manifested using Sentinel data. It should also be remembered that this benefit is experienced year on year, which adds up to much more substantial figures over an asset’s lifetime.

There are societal benefits in this tier that stem from a well-maintained road infrastructure, such as increased public safety due to the avoidance of potentially dangerous hazards which could increase the risk of traffic accidents and loss of lives. The better maintenance of roads also helps in public wellbeing as it provides efficient transport routes for users, saving them time and money. Several studies have demonstrated the massive economic benefits roads bring to society. For example, in a “Partners for Roads”<sup>59</sup> initiative, the Dutch Directorate for Traffic and Infrastructure assessed the impact of roads on regional economies in The Netherlands. The study found that areas with high job densities (over 200 jobs per square kilometre) were consistently located near major road arteries. This is because industries prefer easy access to suppliers, customers, and employees. Additionally, a study in Spain<sup>60</sup> analysed the economic benefits of constructing the A92 motorway in the south. Over 30 years, the benefits totalled €39.9 billion, primarily due to road users saving

---

<sup>59</sup>Partners for Roads – Roads and Regional Development, Presentation delivered at the European Road Congress (Lisbon, Nov. 2004) by Mr. Michel Goppel, M.Sc and Mr. Benno Bultink, Directorate for Traffic and Infrastructure, The Netherlands

<sup>60</sup>[https://www.aecarretera.com/cdc/ERF\\_Los%20beneficios%20socioeconomicos%20de%20las%20carreteras%20en%20Europa.pdf](https://www.aecarretera.com/cdc/ERF_Los%20beneficios%20socioeconomicos%20de%20las%20carreteras%20en%20Europa.pdf)

time by making shorter journeys, reducing congestion, and lowering traffic accident rates. Given that this case is specifically looking at the benefits of proactive maintenance relating to ground subsidence around roads, we will not count numbers such as these in this case, but they remain an important testament to the value of these critical infrastructures.

Environmental benefits are also experienced in this tier both thanks to the avoidance of road and traffic interruptions and the complementary monitoring of natural resources close to the road. Firstly, by helping in the pre-emptive targeting of areas of concern when it comes to infrastructure stability, traffic jams and gridlocks can be reduced, thereby reducing unnecessary emissions from build ups in road users. Secondly, by monitoring the health of tree vegetation along the roadside, the efforts of the value chain in this case can help pinpoint potential issues with roadside vegetation. As already stated, the A24 crosses an area integrated into the Natura 2000 Network. Although Natura 2000 monitoring is not a responsibility of the entities in this value chain, the better management of vegetation along the motorway means fewer negative implications for the biodiversity and ecologically protected areas adjacent to it.

### 5.2.5 Other Beneficiaries

The other beneficiaries benefit indirectly from the actions of the stakeholders in the value chain. The **Autoridade Nacional de Segurança Rodoviária – ANSR** benefit from enhanced safety due to the reduced likelihood of road infrastructure being affected or damaged as a result of the types of threats discussed. The **Instituto da Conservação da Natureza e das Florestas – ICNF** benefit from the stakeholders involved in the value chain undertaking diligent, up-to-date, and preventive roadside vegetation management, which contributes to the environmental protection of Natura 2000 sites along the A24.

## 5.3 Summary of Benefits

In this section, we draw together the different benefits to the stakeholders identified along the value chain, grouping them by six dimensions of value-chain analysis. A summary of the degree of the benefits as applicable to this case, taking into account previously studied cases, is shown below. The assessment is subjective; the basis for it is given in Annex A2.

Economic	Environmental	Societal	Regulatory	Innovation & Entrepreneurship	Scientific & Technological
★ ★ ★	★	★ ★ ★	★	★ ★ ★	★ ★

**Table 5-1: Benefits Assessment by Category**

### 5.3.1 Economic

Although this case focussed only on one motorway in northern Portugal, as is common with SeBS cases, we try to estimate the potential value of such a service, should it be applied and extrapolated to a country-wide scale. The A24 is 157 km long, while the total Portuguese motorway network is

3,065 km long<sup>61</sup>, meaning the A24 accounts for about 5% of the total network. Applying the benefits manifested in this case to the country scale would yield between **€2.5 million/year** and **€3.6 million/year**. Of course, the caveat here is that these figures assume the same levels of potential risks and associated costs for the whole network as there are with the A24 specifically, meaning they stand as an estimate, but a testament to the potential value.

The economic benefits for the A24 and the extrapolated potential benefits for the entire country are shown in the table below.

Tier	Benefits identified	Annual economic value stemming from the use of Sentinel-enabled services <u>along the A24</u> (€/year)		Annual economic value stemming from the use of Sentinel-enabled services for <u>the entire country</u> (€/year)	
		Lower	Upper	Lower	Upper
<b>Tier 1 (Spotlite)</b>	Savings linked to the use of Sentinel data	<b>€60,000</b>		<b>€1.2 million</b>	
<b>Tier 2 (Egis)</b>	Reduction in need for in-person maintenance checks	<b>€7,200</b>	<b>€14,400</b>	<b>€144,000</b>	<b>€288,000</b>
	Efficiencies in in-person vegetation management	<b>€10,000</b>		<b>€200,000</b>	
<b>Tier 3 (IMT/ NorScut)</b>	Avoidance of reparation costs	<b>€40,000</b>	<b>€80,000</b>	<b>€800,000</b>	<b>€1.6 million</b>
<b>Tier 4 (Citizens/ Society)</b>	Avoidance of road closures	<b>€7,560</b>	<b>€15,120</b>	<b>€151,200</b>	<b>€302,400</b>
<b>TOTALS</b>		<b>€125,000</b>	<b>€180,000</b>	<b>€2.5 million</b>	<b>€3.6 million</b>

**Table 5-2: Summary of economic benefits**

As discussed in previous sections, there are undoubtedly many economic benefits manifested in each tier of the value chain that have not been quantified within this report due to the many unknowns or unavailability of robust data. Therefore, it should be noted that the figures in the table are what could be objectively quantified within this report and are considered quite conservative in terms of the actual total economic value Sentinels are bringing in this case.

	<ul style="list-style-type: none"> <li>• Cost savings linked to the use of Sentinel data (tier 1)</li> <li>• Savings in on-site inspection costs (tier 2)</li> <li>• Avoidance of reparation costs land (tier 3)</li> <li>• Improved availability of road infrastructure (tier 4)</li> </ul>
--	--

<sup>61</sup><https://www.statista.com/statistics/449702/portugal-timeline-of-total-motorway-length/#:~:text=The%20total%20length%20of%20motorways%20Portugal%20amounted%20to%203%2C065%20kilometers%20in%202021>

### 5.3.2 Environmental


Through the efforts of the stakeholders in tiers 2 and 4, significant environmental benefits are realised.

#### Reduced emissions from on-site inspections

By utilising the Spotlite service, Egis is able to pinpoint more accurately parts of the motorway which may need further inspection with on-site visits. This allows for more efficient use of inspection vehicles and cuts out need for more widespread visits across larger stretches of the road. This means less fuel usage and lower associated emissions.

#### Monitoring of roadside vegetation


Through the enhanced monitoring of roadside vegetation, particularly trees, issues with the health of surrounding vegetation can be easily detected. As discussed, several Natura 2000 sites cross the A24's path. Although Natura 2000 monitoring is a competency of the actors in this value chain, better vegetation management along the motorway reduces negative impacts on nearby biodiversity and protected areas.



- Reduction in emissions from vehicles used for in-person maintenance checks (tier 2)
- Monitoring of roadside vegetation health (tier 4)
- Reduction in traffic emissions (tier 4)

### 5.3.3 Regulatory

Egis, IMT and NorScut are all ultimately better able to abide by safety standards and regulations when it comes to the operation and preservation of the A24. As discussed, the improved monitoring system can aid in the application of various parts of the EU Directive 2019/1936 on Road Infrastructure Safety Management.



- Better ability to abide by infrastructure maintenance and safety regulations (tiers 2 and 3)

### 5.3.4 Entrepreneurship & Innovation

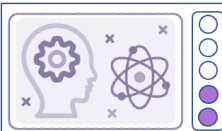
Through their collaboration, Spotlite and Egis have enhanced the entrepreneurship and innovation landscape by deploying and adopting an innovative motorway management solution. We also see how this innovative solution is being applied by Egis elsewhere (see Widening the Perspective) to great effect. The adoption of new technologies by firms like Egis often takes a “leap of faith” as changing of traditional working practices can be difficult and often expensive. Egis’ willingness to do so is a testament to their commitment to innovation. Furthermore, as in most cases practices cannot be changed without the support of the public road authority (and the concessionaire), IMT and NorScut are also involved in promoting entrepreneurship and innovation practices.



- Change of traditional working practices to innovative services (tiers 2 and 3)

### 5.3.5 Science and Technology

Spotlite’s have made several contributions to the scientific understanding of how road infrastructure and surrounding areas can be managed. This contribution stems from their inventive utilisation of Sentinel data to create algorithms and methods for the detection of ground movement close to motorways in conjunction with the estimation of health and height of trees which could present a problem should they fall. As already mentioned, two scientific papers were published which relate directly to this case. For a full list of relevant scientific publications see **Annex 1**.



- Contribution to the development of new remote sensing techniques relating to road infrastructure and vegetation monitoring (tier 1)

### 5.3.6 Societal

Due to the fact that this case primarily revolves around an important piece of public infrastructure, there are many benefits to citizens and society. Firstly, the avoidance of potential infrastructural issues helps ensure public safety when using the road and reduces the likelihood of road accidents. This also has a secondary benefit to society in the fact that it reduces the likelihood of road closures, meaning the availability of such a vital piece of infrastructure remains intact, allowing citizens and commerce alike to utilise and benefit from this public good. The reduction of emissions (accounted for in other tiers) is also a societal benefit given the major focus on air quality all over Europe.



- Avoidance of road safety / traffic related accidents (tier 4)
- Increased availability of critical infrastructure (tier 4)

## 5.4 Synoptic overview

Having looked at the different types of benefits and before proceeding to the conclusions extracted in this study it is instructive to provide a synoptic overview in the table below.

Tier	Benefits identified	Type	Value where economic – <u>A24</u> (annual)	Value where economic – <u>Entire country</u> (annual)
Tier 1 (Spotlite)	Cost savings linked to the use of Sentinel data	Economic	€60,000	€1.2 million
	Development of new remote sensing-based ground motion and	Science and Technology		

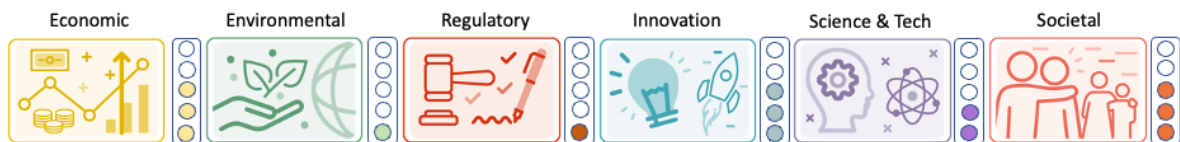
	vegetation monitoring techniques			
<b>Tier 2 (Egis)</b>	<b>Reduction in need</b> for in-person maintenance checks	Economic	€7,200 - €14,400	€144,000 - €288,000
	<b>Efficiencies in in-person</b> vegetation management	Economic	€10,000	€200,000
	<b>Reduction in emissions</b> from in-person maintenance checks	Environmental		
	<b>Ability to better comply</b> with safety standards and regulatory requirements	Regulatory		
	<b>Changing of traditional working practices</b> for innovative monitoring techniques	Entrepreneurship & Innovation		
<b>Tier 3 (IMT &amp; NorScut)</b>	<b>Avoidance of maintenance/repairation</b> costs	Economic	€40,000 - €80,000	€800,000 - €1.6 million
	<b>Ability to better comply</b> with safety standards and regulatory requirements	Regulatory		
	<b>Changing of traditional working practices</b> for innovative monitoring techniques	Entrepreneurship & Innovation		
<b>Tier 4 (Citizens and Society)</b>	<b>Avoidance of road closures</b>	Economic	€7,560 - €15,120	€151,200 - €302,400
	<b>Avoidance of traffic-related accidents</b>	Societal		
	<b>Increased availability</b> of critical infrastructure	Societal		
	Monitoring of roadside vegetation health	Environmental		
	Reduction in traffic emissions	Environmental		
<b>TOTALS</b>			<b>€ 125k – 180k</b>	<b>€2.5 - €3.6 million</b>

**Table 5-3: Summary of benefits for each tier**

## 6 Key Findings and Final Thoughts

### 6.1 Key findings

This case highlights the increasing adoption of InSAR in ground and infrastructure monitoring using Sentinel-1 data, but interestingly also exemplifies the parallel use of Sentinel-2 data in vegetation monitoring to make a robust motorway monitoring product. The service studied in this case shows how Sentinel data, when applied effectively, can become a key source of intelligence which contributes to the maintenance of prominent and vital infrastructure in a country. **In that regard, the standout benefits in this case relate to the societal dimension.** The avoidance of potentially fatal infrastructure failures as well as the continued availability of such an important motorway in northern Portugal means that citizens remain safe, and commerce remains flowing.



**Figure 6-1: Delivering value across the full range of dimensions**

Although the economic benefits in this case remain rather modest for the A24 alone, it is the innovative application of Sentinel data that tells the real story of this case. Moreover, as already stated, the availability of the A24 undoubtedly brings very large economic benefits to the region of northern Portugal. However, when extrapolated to the country scale, we see the size of benefits become quite impressive.

### 6.2 The Impact of Sentinel Data

In most cases analysed under the *Sentinel Benefits Study* the question of attribution arises, i.e., what part (or percentage for the economic value) of the produced benefit can be attributed to the use of Sentinel data? In this case, Egis estimates that by using the Sentinel-enabled service they can optimise operations by between 10% and 20%. We have therefore used these figures as our value attribution where applicable. The efficiencies gained in terms of more targeted ground movement monitoring and the ability to “see” issues further ahead of time over such a large area are solely thanks to remote sensing. Had Sentinel data not been used, much more comprehensive in-person checks would be required. In-person inspections can realistically only sample a small number of areas, thereby not providing the high-quality analysis performed. Commercial data could be bought but given the free and open nature of Sentinel data, Spotlite could perform the analysis for Egis at a competitive price.

### 6.3 Widening the Perspective

The main focus of this case has been the use of radar data to detect ground/infrastructure movement and optical data to detect vegetation health in Portugal. These applications are by no means specific to this country. Instead, it has a much wider perspective. This can be studied along three dimensions: (i) geographic extension, (ii) increased market penetration and (iii) improved technological maturity. Below we discuss these dimensions in the context of this case

#### - **Geographic Extension**

The type of monitoring services showcased in this report easily lend themselves to diverse geographic coverage. Despite the administrative and bureaucratic hurdles in providing services globally, the technical barriers to entry remain relatively low when it comes to applying the techniques seen in this case elsewhere. In fact, Spotlite have collaborated with Egis to monitor the development and operation of infrastructure projects in Greece and Turkey<sup>62</sup> in a very similar manner to the types of services seen in this case. The global coverage of Sentinel data therefore quite easily lends itself to geographic extension in this context.

As already stated, applying the benefits manifested in this case to the country scale would yield between **€2.5 million/year** and **€3.6 million/year**. However, these figures assume the same levels of potential risks and associated costs for the whole network as there are with the A24 specifically, meaning they stand as a coarse estimate, but a testament to the potential value.

#### - **Increased Market Penetration**

As already mentioned, the geographic expansion of such services is relatively straightforward, allowing Spotlite to easily extend their services to other regions. To truly increase "market penetration," a company like Spotlite would need to diversify its service portfolio to include other applications. When discussing market penetration in this context, it is more relevant to focus on the application of these services for different types of infrastructures and the expansion of new types of monitoring capabilities. Spotlite, in collaboration with Egis have shown how this can be done through an ESA-funded demonstration project<sup>62</sup>. Within this project, it was shown how the Sentinel-based services developed can be applied to other infrastructure types, including railway lines. Moreover, in the case of the pilot application in Turkey, a first integration of 3D digital twins for asset management was also developed, as well as an experimental application of the solution to assess the impacts on the infrastructure of the February 2023 earthquake that impacted Turkey and Syria.

#### - **Improved Technological Maturity**

Improvements are clearly possible for this type of service, such as smarter and more accurate detection services and the further integration of Sentinel data into the likes of digital twins. As already shown, Spotlite are continually working on such services.

## 6.4 Final Thoughts

This case exemplifies how Sentinel data have proven to be invaluable in monitoring road infrastructure. Sentinels provide a cost-effective and efficient means to survey large areas, offering detailed insights into the status of road networks while simultaneously reducing the need for extensive on-site inspections. As shown clearly in this case, Sentinel data also facilitates the timely identification of potential hazards caused by the likes of landslides, enabling swift response and maintenance efforts. This proactive approach not only enhances the safety and reliability of road

---

<sup>62</sup><https://business.esa.int/projects/spotlite>



infrastructure but also helps in optimising maintenance budgets and extending the lifespan of road assets. Additionally, this case shows how different types of data i.e., optical data from Sentinel-2, can be used in conjunction with radar (Sentinel-1) to provide holistic infrastructure monitoring services.

## Annex 1: References and Sources

The list below covers only the main sources used extensively throughout the study. The reader can find more references in the form of footnotes or hyperlinks throughout the report.

1. [KPI Report on Infrastructure, Baseline project](#), July 2020-October 2022.
2. [National Road Safety Profile – Portugal](#), European Road Safety Observatory, 2023.
3. Zêzere J. L., [Geohazards in Portugal: A State of the Art](#), Finisterra 58, 2023.
4. Ermitão T., Páscoa P., Trigo I., Alonso C. & Gouveia C. [Mapping the Most Susceptible Regions to Fire in Portugal](#). Fire, 2023.
5. Carvalho, A. & Costa, A., [New Ground motions relations for Portugal Mainland using a stochastic finite fault modelling](#), 2010.
6. Cano-Díaz C., Zeiss R., et al., [Mapping socio-environmental pressures to assess Portuguese soil vulnerability](#), 2023.
7. Belo A.D.F., Fernandes M.P., Matono P., Canha P. & Pinto-Cruz C., [Best Practice Guide to Manage Vegetation and Promote Biodiversity in Linear Infrastructures](#), Project LIFE LINES, 2022.
8. [Report on Road and Automotive](#), Copernicus User Needs and Requirements, 2023.
9. Dall K., [A satellite-based drought impact assessment in Eastern Cape, South Africa: Earth Observation capabilities to support the implementation of the Sendai Framework](#), 2017.
10. Lefeuvre F. & Tanzi T., [Radio Science Contribution to Emergency Disaster](#). Radio Science Bulletin, 2014.
11. Roque D., Correia M., Cabral R., Davies S., Cordeiro T., Fonseca A. & Barreto P., [InSAR displacement time series post-processing to back-analyze a slope failure](#), 5<sup>th</sup> Joint International Symposium on Deformation Monitoring (JISDM), 2022.
12. Barreto P., Silva L., Cabral R., Correia M., Davies S. & Cordeiro T., [MONITORIZAÇÃO DE OBRAS GEOTÉCNICAS COM TÉCNICAS BASEADAS EM SATÉLITES](#), 10<sup>th</sup> CONGRESSO RODOFERROVIÁRIO PORTUGUÊS, 2022.

## Annex 2: General Approach and Methodology

This case has been analysed as a part of the Sentinel Benefits Study (SeBS), which looks at the value being created by the use of Sentinel data. It follows a methodology<sup>63</sup>, established during a previous study, looking at a value chain for the use of a single EO service.

For each case, a value chain is established with a service provider and a primary user. The value-chain is validated with these two key players. Through a combination of desk and field research, we develop our understanding of all the actors in the value chain, the role that they play and how they may benefit through the use of the satellite-derived products.

The value-chain is divided into a number of tiers where the supplier is Tier 1, and the primary user is Tier 2. The last Tier is always “Citizens and Society”. The number may vary according to the complexity of the value-chain. The benefits are then analysed against each of these tiers.

Once written, the draft report is then shared with all the persons with whom we have spoken, and their comments are incorporated, or a further discussion is held to establish a common understanding. Note that we are not asking these experts to endorse our findings but to indicate any gross errors or sensitivities which may have been introduced. At the end of this process, the report is made public.

As work has proceeded and more cases analysed, some modifications have been made to the methodology described in reference 63. The first of these has been to expand from the two dimensions used earlier, namely economic and environmental benefits, to add those connected to societal, regulatory, innovation and entrepreneurship and scientific and technological. These six dimensions are described in the table A2-1 below.

Dimension	Definition
<b>ECONOMIC</b>	Impacts related to the production of goods or services, or impacts on monetary flow or volume, such as revenue, profit, capital and (indirectly, through turnover generation) employment.
<b>ENVIRONMENTAL</b>	Impacts related to the state and health of the environment, particularly as regards the ecosystem services on which human societies depend.
<b>SOCIETAL</b>	Impacts related to societal aspects such as increased trust in authorities, better public health or secured geostrategic position.
<b>REGULATORY</b>	Impacts linked to the development, enactment or enforcement of regulations, directives and other legal instruments by policymakers.
<b>INNOVATION-ENTREPRENEURSHIP</b>	Impacts linked to the development of new enterprise and/or the introduction of technological innovation into the market.
<b>SCIENCE-TECHNOLOGY</b>	Impacts linked to academic, scientific or technological research and development, the advancement of the state of knowledge in a particular domain.

**Table A2-1: Definitions for the benefit dimensions**

<sup>63</sup>SeBS Methodology; June 2017.

For each of these, a ranking has been introduced to give an immediate, visual impression of the scale of the benefits under each dimension. To aid in the quantification of these, a guide has been introduced which is shown in Table A2-2.

Rank	Benefit status	Criteria
0	<b>Null</b>	The case presents no perceivable benefits in this dimension, and no potential for such benefits to emerge is anticipated.
1	<b>Latent</b>	The value chain described in the case may, in general, present potential benefits in this dimension, but none have been identified or described in this particular instance.
2	<b>Manifest:</b>	<b>Low</b>
3	At least one benefit in this dimension has been identified through the value chain within the case. Its significance in the context of the case overall is judged to be:	<b>Moderate</b>
4		<b>High</b>
5		<b>Exceptional</b>

**Table A2-2: The ranking of the benefits.**

In order to introduce further basis for comparison, a systematic approach has been developed for the analysis of the benefits. A series of indicators have been defined for each of the benefit dimensions against which each case can be considered.

The indicators used in the case are listed in chapter 5, and a full list of all indicators considered is provided in Table A2-3.

Dimension	Indicator	What it can mean.
Economic	Avoided costs (AV)	Alternative means to gather data
	Increased Revenues (IR)	Increased production/sales
	Reduced Inputs (RI)	Less time spent or material saved
	Improved Efficiency (IE)	Better use of resources
Environmental	Reduced pollution (RP)	Reduced amounts of pollutants in key resources e.g. water, air
	Reduced impact on natural resources (RR)	Reduced environmental impact e.g erosion, habitats/biodiversity.
Societal	Improved public health (IPH)	Less toxicological risk
	Common Understanding (CU)	Better control and communication of remedial efforts i.e through common maps.
	Increased trust and better transparency (ITT)	Improved preparedness / response
	Strategic Value (SV)	Common societal value to a country or region.
Regulatory	Improved policy / regulation design/drafting	Better information (scale, accuracy) leading to better regulation
	Improved efficiency in policy/regulation monitoring	Better information available to monitor adherence to regulations.
Innovation & Entrepreneurship	Innovative products	Sentinel data leads to creation of new products / services
	New Business models	New ways to generate income.
	New markets	Global nature of sentinel data enables international business development
	New businesses	Creation of new companies; start-ups
Science & technology	Academic output	
	Research exploitation	Applied science to operational services
	Research contribution	New product enabling scientific research

**Table A2-3: Complete list of indicators considered within SeBS analyses**

## Annex 3: About the Authors



*Júlia Caufapé, BscEcon (Economics) – Universitat Pompeu Fabra*

Júlia is a consultant at the Brussels-based consultancy Evenflow, who work in collaboration with EARSC on the Sentinel Benefits Study (SeBS). Júlia graduated in Economics from Pompeu Fabra University (UPF) in 2023 and moved to Brussels to pursue her career as a consultant in the space sector. As part of the Erasmus exchange programme and before completing her bachelor's degree, she completed her Economics training at the Erasmus Universiteit Rotterdam (EUR). Júlia has been involved in SeBS cases for a year, among many other Horizon Europe projects, which provide her with critical research, analysis, and articulation tools to conduct these studies.

Email: [julia@evenflow.eu](mailto:julia@evenflow.eu)



*Dáire Boyle, BEng (Electrical Engineering), MSc Business & Economics*

Dáire is a consultant with the Brussels-based consultancy Evenflow, who work in collaboration with EARSC on the Sentinel Benefits Study (SeBS). Dáire worked as an engineer for a large upstream oil & gas company in Aberdeen, Scotland for 4 years before moving to Belgium to complete a Master's in International Business Economics & Management. Dáire has extensive economic analysis, market research and R&D exploitation experience developed through his 5 years as consultant and his academic career.

Email: [daire@evenflow.eu](mailto:daire@evenflow.eu)