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### **Fostering European Cross-Border Traffic Integration: Insights into the X4ITS project**

**Michel Baustert\***, Maximilian Panczyk, Damaris Anna Gruber, Alina Pinkelnig, Alexander Frötscher

1. AustriaTech – Gesellschaft des Bundes für technologiepolitische Maßnahmen GmbH

Raimundgasse 1/6, 1020 Vienna, Austria

[Michel.Baustert@austriatech.at](mailto:Michel.Baustert@austriatech.at)

[Max.Panczyk@austriatech.at](mailto:Max.Panczyk@austriatech.at)

[Damaris.Gruber@austriatech.at](mailto:Damaris.Gruber@austriatech.at)

[Alina.Pinkelnig@austriatech.at](mailto:Alina.Pinkelnig@austriatech.at)

[Alexander.Froetscher@austriatech.at](mailto:Alexander.Froetscher@austriatech.at)

#### **Abstract**

Cross for ITS (X4ITS) strengthens the corridors of the Trans-European Transport Network (TEN-T) in Central and Eastern Europe based on open standard components and modules. The project partners are working together on harmonised and synchronised cross-border Intelligent Transport Systems (ITS) and data exchange for a better connectivity in Europe. Throughout the X4ITS Project, six European Member States Austria, Croatia, Czechia, Hungary, Romania and Slovenia (AT, CZ, HR, HU, RO, SI) combine their efforts in accordance with the EU ITS Directive [1] and its supplementing Delegated Regulations [2, 3, 4, 5]. This has enabled a unified approach to overcome the challenges posed by fragmented national strategies and varying implementation speeds across the European ITS landscape. The implementation of the project is carried out on a multimodal level including means of public transport (buses and trams), as well as private vehicles. In addition, through cross-network integration including motorways, railways and secondary road networks, a holistic enhancement of transportation systems is ensured. The integration of diverse technologies, including ITS services and Cooperative Intelligent Transport Systems (C-ITS) applications, aims to establish a cohesive network supporting smoother cross-border mobility and improved transport efficiency. X4ITS represents a collaborative step towards achieving a unified and efficient European transport infrastructure, bridging regional differences to facilitate better mobility and connectivity across Central and Eastern Europe.

#### **Keywords:**

Cross-corridor cooperation, ITS, C-ITS, Traffic Management Plans, Data exchange, DATEX II, NAPs

## **Introduction**

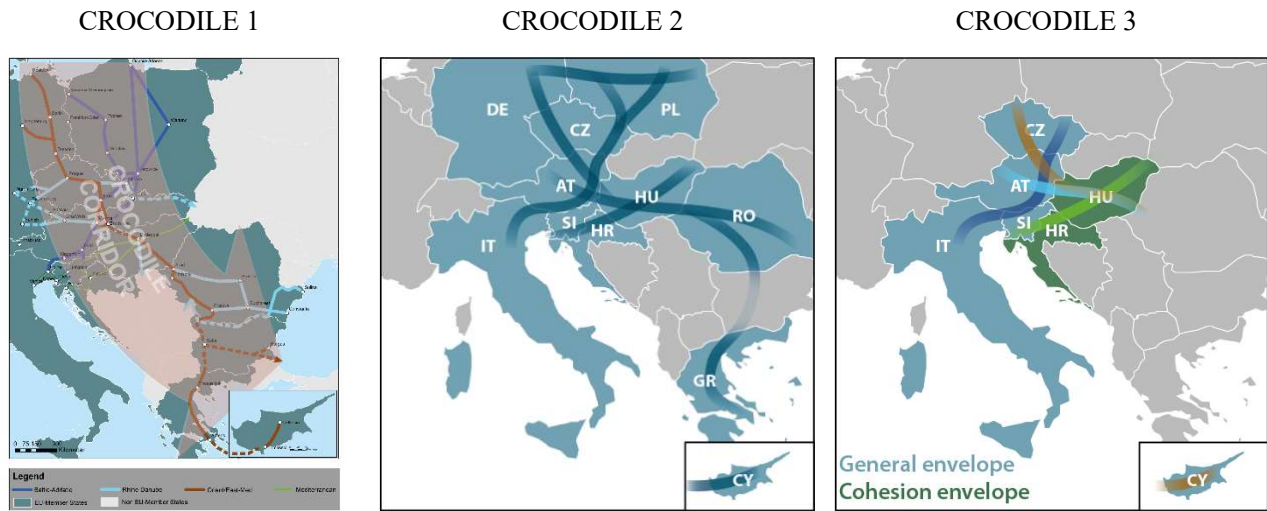
The European ITS landscape is characterised by different national approaches to the implementation of the ITS Directive and their implementation of ITS services and C-ITS applications. X4ITS stands for “Central European Cross Border Cooperation for ITS” and introduces significant developments in cross-border traffic management and ITS by building on the achievements of the previous CROCODILE projects. Through advances of the exchange between the different project partners, cross-border mobility will be improved by increasing cross-border data quality and exchange. The very new approach in X4ITS is to connect the TEN-T network with the secondary road network as well as with urban nodes. In addition, it is the first time, that the focus of a cross-corridor project not only lies on road transport but as well on multi-modal mobility solutions. In addition to the long-lasting success story of cross-border development and usage of ITS, for efficient mobility C-ITS services and use cases will be implemented in X4ITS. The work carried out by the involved six European Member States is building on the European-wide harmonised technical specifications of the C-Roads platform as well as on recommendations by the NAPCORE initiative. For the ITS implementations the Member States are using the data exchange standard DATEX II and exchange information based on common DATEX II nodes and data exchange profiles. Moreover, for the implementation of cross-border Traffic Management Plans distributed sensor networks are being used and data is transmitted via different channels across countries in order to obtain information for traffic information services.

This paper aims on outlining the history of X4ITS, being based on the CROCODILE projects and the added value of X4ITS for the European (C-)ITS landscape. Further it will be demonstrated how the EU ITS Directive is implemented by focusing on the project’s strategic relevance, technical implementations and C-ITS deployments in cities as crucial steps to advance road safety and use cases that promote public transport prioritisation.

## **Building on the Success of CROCODILE**

In 2013, the CROCODILE project marked a pivotal step toward large-scale cooperation, funded by the TEN-T programme, fostering coordination and harmonised information exchange among Member States (AT, CY, CZ, DE, GR, HU, IT, PL, RO, SI). Supported by the EU's Connecting Europe Facility (CEF), two successive projects have further addressed evolving transport challenges (CROCODILE 2 & 3).

Since its inception, the CROCODILE corridor project has focused on facilitating high-quality, reliable data exchange among road operators, private stakeholders, and administrations, aligning with Europe’s vision of seamless mobility.



**Figure 1: The CROCODILE 1, 2 & 3 Member States and the TEN-T Core Network Corridors**

In the second phase of CROCODILE [6, 7, 8], the project had a strong focus on the implementation of DATEX II in its Member States (AT, CY, CZ, DE, GR, HU, IT, PL, RO, SI). The first actual use of DATEX II in CROCODILE 2 was one of a kind in Europe and was acknowledged to be an important basis for ongoing and future cooperation with neighbouring countries. Additionally, a common agreement on how to implement DATEX II has been published during this phase of CROCODILE.

The third phase (2018 – 2022) focused on cross-border data exchange, harmonisation of Traffic Management Plans (TMPs), implementation of standards, and enhanced end-user applications [9, 10] in the Member States (AT, CY, CZ, IT, SI, HR, HU).

The need for further development of common initiatives and to include real-time events and information that could reach drivers, commuters or tourists equally was still present after the three CROCODILE phases. The most pressing issues were ongoing coordination and harmonisation on both a technical and organisational level in accordance with European legislation. This way, operators and service providers can draw from improved access to data and offer the best possible services to end users. Other issues included the harmonised implementation of the ITS Directive and its supplementing Delegated Regulations. While basic principles are set out as mandatory provisions, the technical and organisational details often remain unclear and subject to Member-State-specific approaches. To ensure a common European and corridor-based strategy, it was essential to further foster the alignment of the previously mentioned topics such as National Access Points (NAPs), DATEX II profiles as well as traffic information and management on a cross-border level. This led to the establishment of X4ITS, co-funded by the EU’s CEF funding programme.

**X4ITS – Central European cross-border cooperation for ITS**

During its runtime (2023 - 2027) X4ITS continues the work accomplished in the CROCODILE projects by maintaining achievements and opening new important fields of action. The six European Member States AT, CZ, HR, HU, RO, SI are working together to improve cross-border traffic through implementing harmonised

ITS applications on the high-level road network as well as C-ITS use cases based on C-Roads specifications [11] in urban areas linked to the high-level transport network. This is based on the TEN-T policy which facilitates the development of a connected transportation network across Europe and in accordance with the EU ITS Directive.

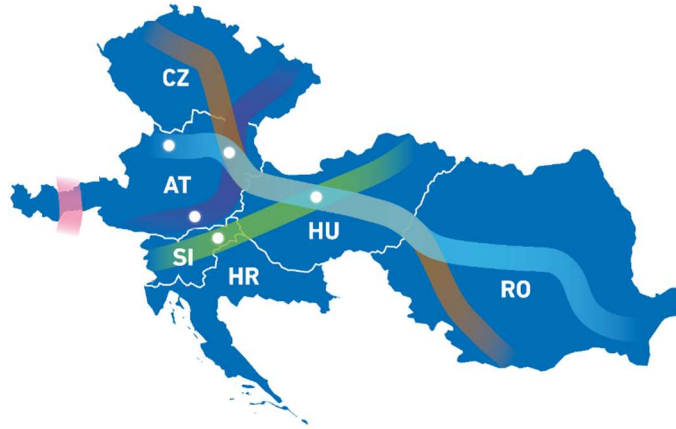


Figure 2 - The X4ITS Member States and the TEN-T Core Network Corridors

Implementations focus on better possibilities for data collection, processing and access. This encompasses the installation of technical equipment, the upgrading of processes and drawing connections to the NAPs, especially when it comes to the connections to the secondary road network as well as to multimodal and urban nodes. In East-Central Europe in particular, with several smaller countries with a significant volume of cross-border traffic, information exchange is a must. Therefore, X4ITS Member States and partners are committed to make data available along the whole corridor which should ultimately lead to high-quality end-user information services. In addition, cross-corridor cooperation, with other corridor projects, will also be further enhanced by a joint process to elaborate a common and harmonised method for impact assessment. This common process on evaluation will go beyond the outcomes of the previous CROCODILE phases. It will highlight the environmental and safety related impact of X4ITS and its contribution to the key priorities within the Sustainable and Smart Mobility Strategy, the decarbonisation and digitalisation of the EU transport sector, as well as in regard to achieving Vision Zero and accident reduction.

### Strategic Relevance

Compared to the previous CROCODILE projects, X4ITS has an increased focus on links to the secondary road network as well as to multimodal and urban nodes, as Europe's urban areas are home to over two-thirds of the EU's population and urban policies have major cross-border significance. This fits the overall scope of X4ITS as a corridor-based approach, which will and must also focus on the entrance and exit points of the relevant corridor transport infrastructure. As an additional perspective, the corridor focus has been extended beyond mere high-level transport infrastructure and encompasses links to urban areas, secondary road network and multimodal nodes.

### Technical Implementations

To receive precise mobility data, hardware solutions such as CCTV cameras and traffic counters are simple yet effective tools for gaining valuable insights into current traffic conditions. Thus, technical implementations in X4ITS include the replacement of outdated traffic counters. Additionally, new traffic counters, CCTV cameras, and weather stations are planned or already implemented in several partner countries. Croatia plans to upgrade data collection equipment and access by replacing a part of existing light-changing signs into Variable Message Signs (VMS). Additionally, Croatia will set up a project design regarding ITS equipment installation on border crossings with non-EU Member States. In Budapest, Hungary, new monitoring and traffic management equipment will be installed.



Figure 3: CCTV Camera and C-ITS Roadside Unit (left), Variable Message Sign (right)

Furthermore, Traffic Control Centers (TCCs) are being upgraded in Croatia and Hungary. The technical specifications for the Hungarian TCC upgrade and the complex infrastructure data warehouse have been finalised, and the procurement procedure has been initiated. A second Hungarian TCC upgrade is planned, along with the upgrade of the Croatian TCC. In addition to the technical implementations mentioned, the following sections give a brief overview of the implementation of DATEX II nodes, the coordination of TMPs and further the development of NAPs to enhance accessibility and ensure seamless interoperability within transportation networks.

#### *DATEX II Deployment / Nodes*

X4ITS continues the implementation of DATEX II nodes to enhance data availability and exchange. The DATEX II nodes play a critical role in the successful deployment of traffic management systems by providing standardised mechanisms for data exchange. At least five DATEX II nodes are upgraded during the project. Implementing infrastructure (e.g. DATEX II nodes) and processes (e.g. common profiling, minimum quality parameters, data exchange) in accordance with the Delegated Regulations are supplementing the ITS Directive to form the basis for service deployments. In addition, the upgrading of existing nodes to the latest version of the DATEX II exchange protocol will be evaluated and implemented. Harmonisation of DATEX II nodes is needed since Member States are still on differing levels regarding DATEX II maturity. X4ITS aims to dedicatedly support and speed up this process.

Coordination issues include the format of identifiers, expressing the validity of an event in time, describing location, providing a free text description of a situation, splitting information for static and dynamic publication, and details such as agreement to use DATEX II of a particular version and using XML and URI types. The middleware developed in CROCODILE is a very important basis and is currently being further developed in X4ITS. It is the starting point for large-scale profile harmonisation.

#### *Traffic Management Plans*

Besides the planned implementation of DATEX II nodes, cross-border TMPs will be expanded. TMPs are guidelines for operationalisation in the processes of corridor traffic management to support activation of planned procedures according to particular TMP scenarios in effect. The goal is to provide automation of the procedures in the process of enforcement of TMP scenarios, so that the traffic operators can focus on the control of measures taken. Furthermore, Croatia, Slovenia, Romania, Czechia and Hungary are working together on the maintenance of existing and the creation of new TMPs. At least four cross-border TMPs will be improved and at least three new cross-border TMPs will be implemented. Romania started exchanging TMPs and information with Hungary and with Bulgaria. The exchange with Serbia is currently being tested but is not yet established. TMPs at cross-border level constitute an important foundation along the corridor, where the need for increased safety and improved traffic flow is considered critical.

#### *National Access Points*

To ensure access to data, X4ITS Member States and partners will work together jointly with NAPCORE to continue to set up harmonised NAPs. Data access is being improved and harmonised at corridor level (and beyond) by implementing recommendations from the NAPCORE project towards further harmonisation of the NAPs, as well as by adapting the NAPs for the new Delegated Regulation (EU) 2022/670 [4]. In Austria, for example, a first description of the new NAP architecture is being finalised, including NAPCORE recommendations and key characteristics to be well prepared for the future. This includes the deployment of an Application Programming Interface (API) aligned with the mobilityDCAT-AP standard (metadata catalogue), aimed at enhancing data accessibility and interoperability.

#### *Service improvements and implementations*

The project also emphasises service improvements and software implementations. In Hungary, the technical specification TN-ITS data service will undergo a strategic expansion, reflecting the growing demand for precise and standardised transport data. In Czechia, efforts are focused on broadening the scope of traffic data collection to encompass the secondary road network, extending the application of floating car data (FCD) for generating comprehensive travel time information across the entire country. At least six end-user services will be upgraded with the aim of improving data processing and enhancing user experience. In Slovenia, server capabilities and disk arrays will be extended to handle an increased capacity of data. Furthermore, Slovenia, Austria and Hungary are committed to upgrading their national traffic mobile applications to offer improved services and a better experience for end-users. The Czech partners will focus on updating their web portal, while in Austria,

ASFINAG will enhance its traffic information smartphone app. Romania (NCRIA) will develop new safety-related and real-time traffic information services, which will be made available through a smartphone app and a dedicated website.

### **C-ITS Technologies in Urban Areas Implementations**

The X4ITS project implements C-ITS use cases in several cities [12] based on open standards and C-Roads specifications (<https://releases.c-roads.eu/>). Since 2019 C-ITS equipped vehicles are on the market in Europe and the vehicle basic system profile is publicly released at C2C CC (<https://www.car-2-car.org/documents/basic-system-profile>). Also, cities and regions have realized that certain C-ITS use cases are enhancing their traffic management capabilities and supporting overall road safety targets. In these cities C-ITS use cases are used mainly for priority for Public Transport services and in some cases also for blue light vehicles (e.g. like Ambulances or Fire Brigades). The overarching aim of the cities is to select main public transport lines, complex intersections, or even “city corridors”. On these lines the public transport vehicles are equipped with C-ITS on-board units and can “request a green phase” when approaching the intersection. For this request a standard C-ITS message (e.g. CAM – Corporate Awareness Message) is used or a combination of standard messages (Signal Request (Status) Extended Message – SREM/SSEM). The intersection controller reacts to this request and adapts the green phase in the requested driving direction and simultaneously informs all C-ITS vehicles in the vicinity with an updated SPAT message about the changed phase. This communication between vehicles and traffic lights is secured with a European Digital Infrastructure, a public PKI – Public Key Infrastructure, which uses an EU-wide trust domain for all C-ITS services. Further details and documentation are online available (<https://cpoc.jrc.ec.europa.eu/ECTL.html>). The C-Roads platform strongly engages in the deployment of urban C-ITS and knowledge is shared between the C-Roads platform and X4ITS regularly. The following sections provide information on planned implementations of the Austrian cities of Vienna, Klagenfurt, and Linz, as well as the cities of Ljubljana and Budapest.

#### *Vienna*

In Vienna, Roadside Units (RSUs) from six different suppliers in up to eight intersections are implemented in order to achieve synergies with the existing C-ITS equipment. Furthermore, hardware capable of detecting vulnerable road users will be implemented and at least two On Board Units (OBUs) in public transport buses are going to be installed and three OBUs are implemented in trams to ensure public transport priority.

#### *Klagenfurt*

During the X4ITS project, Klagenfurt has plans to upgrade 25 traffic lights with C-ITS technology to improve bus traffic acceleration. With 98 buses equipped with OBUs until 2026 the acceleration of public transport is exclusively ensured via C-ITS. Artificial Intelligence is used to monitor traffic, and digital displays warn road users without C-ITS of potential hazards. Klagenfurt is participating in the EU’s ‘100 Climate-Neutral and Smart Cities’ mission which is strongly related to the active participation in X4ITS.

### *Linz*

In Linz, up to eight RSUs will be implemented, and up to six public transport buses and road vehicles will be equipped with OBUs. Next to that, approximately 25 junctions and road sections will be equipped with C-ITS use cases. A special focus lies on the deployment of RSUs in the city centre. Installations will be finished until June 2025.

### *Ljubljana*

Besides the installation of at least 100 RSUs at the two main road entrances, roadside data collection equipment at 120 intersections, on specific urban road sections connected to the TEN-T corridor are deployed in Ljubljana. Each intersection receives an average of four cameras, four ground traffic detectors, and four pairs of buttons to activate traffic lights. The digital road system is upgraded with deployment of TN-ITS. Further deployments include an emergency vehicle approaching system as well as Green Light Optimal Speed Advisory (GLOSA) system on the main entrances to Ljubljana. The urban traffic control system will be connected to the Dynamic Simulation Traffic Model of Slovenia and urban traffic data will be published through the NAP. Finally, two urban traffic data collection systems are installed at the main entrances to the city.

### *Budapest*

In Budapest, Day 1 and Day 1.5 services will be introduced on the main routes in the north-west and south-west regions of Budapest, linked to the existing sites on the M0 expressway and the C-ITS service on the M1/M7 motorway. New RSUs and C-ITS services will be implemented along the Budapest Ring Road (M0) and the urban-interurban interfaces of Budapest. In addition, a dynamic database will be integrated within the C-ITS traffic management system, alongside a TCC upgrade. Budapest, like Klagenfurt, participates in the EU's 100 Climate-Neutral and Smart Cities" mission, which aims to achieve climate neutrality by 2030.

## **Achievements so far**

This section highlights advances in the cross-corridor cooperation with other European corridor initiatives that have been established during events such as the NAPCORE Mobility Data Days. In addition, the first technical workshop has taken place, fostering a transfer of knowledge among X4ITS partners.

### *Cross-corridor cooperation and dissemination*

The cross-corridor cooperation takes place through regular meetings held four times a year between the corridor projects MATIS, MERIDIAN, X4ITS, the C-Roads platform, and NAPCORE. All these initiatives have agreed on a common workshop list. They are organising events together and have compiled a comprehensive list of all ITS implementations from past and present projects or initiatives which is updated regularly. The objective of this cooperation is the comprehensive deployment of C-ITS services based on C-Roads specifications and harmonised updates of National Access Points based on NAPCORE recommendations. The cooperative efforts have already shown results: joint workshops at the NAPCORE Mobility Data Days in 2023 and 2024. In these

workshops implementations and collaborative efforts have been highlighted, discussed and been broad to public. In 2024, X4ITS signed two Joint Declarations of Collaboration with other corridor initiatives (MATIS, MERIDIAN). This strategic framework, designed to promote innovation, connectivity, and cohesion within the European ITS ecosystem, outlines a series of objectives. These include the establishment of a unified vision for a connected European ITS Corridor. Furthermore, experts in (C)-ITS are encouraged to disseminate their knowledge, methodologies and outcomes from pilot implementations to the other corridor projects. The aim of this collaboration and dissemination is to accelerate the introduction of best practices and innovative solutions. Through the Joint Declarations and the cross-corridor collaboration, the methods for monitoring and evaluation shall be improved and refined through continuous exchange. This will ensure alignment with broader transportation and environmental goals.

### *Technical Workshops*

Technical workshops are an important tool in the X4ITS workflow. This ensures a knowledge and experience transfer between all corridor partners, participants, and external stakeholders and the usage of best practises from other pilots. This approach has started in the earlier CROCODILE projects and has been found to be highly effective. The first X4ITS technical workshop took place in close cooperation with the C-Roads platform in May 2024, covering the topics of C-ITS and urban use cases. Urban C-ITS use cases were presented from the cities of Kassel, Graz, Vienna, Győr and Zalaegerszeg. The key findings of the first workshop include avoiding an excessive focus on use cases at the outset, securing a strong political commitment from the city, and sharing experiences and knowledge with other stakeholders. A second technical workshop is planned in Spring 2025 in Croatia with a strong focus on the role of National Access Points. A third technical workshop will be held in autumn 2025 in Slovenia with a focus on Traffic Management Plans.

### **Conclusion**

In conclusion, the overall goal of X4ITS is to enhance cross-border cooperation and deploy (C-)ITS services effectively. This will be achieved through several key initiatives. These include technical implementations, such as CCTV cameras, traffic counters and weather stations. In addition, new DATEX II nodes are implemented, and existing ones are further developed. Traffic Control Centres (TCCs) are upgraded to enhance the quality and accessibility of data for end-users and service providers and expanding and improving cross-border Traffic Management Plans (TMPs). Additionally, the project aims to automate the enforcement procedures for TMP scenarios, allowing traffic operators to focus on controlling the measures implemented. The establishment of National Access Points (NAPs), in line with NAPCORE recommendations, is also a significant component. Expected key challenges include efficient cross-border integration of services such as the TMPs and the achievement of attaining the same levels of NAP functionality for all partners. The key impacts will be more harmonised cross-border data exchange of ITS for better connectivity along the TEN-T corridor. This will be achieved by the project's urban deployments, to ensure comprehensive coverage. These topics are actively discussed and demonstrated through technical workshops, specific working groups, targeted working meetings, and cooperation meetings with other initiatives and corridor projects.

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