GDProject Proposal Summary Sheet

Project Number	**P_YYYY_NO**
Project name	*Combining reference-line based ASAM OpenDRIVE and CityGML for an interoperable, comprehensive road space modelling*
Domain	Wählen Sie ein Element aus.
Impacted standard(s)	
Project type	Wählen Sie ein Element aus.
Start date	DD.MM.YYYY
End date	DD.MM.YYYY
TSC Submission:	DD.MM.YYYY
Proposer(s)	*Should this project be approved, and no other volunteers be identified up to the kickoff workshop to take on the role of project leadership, the Proposer(s) take on the Project Lead role by default.*
ASAM Office Responsible (OR)	
Initiating Companies	*(at least 3 companies are required for a valid proposal submission)*
ASAM funds	
Backwards Compatibility	*If applicable, indicate to which prior version this release is backward compatible.*

For more information on the ASAM project process and the proposal phase in particular, please refer to the ASAM Project Guide.

Table of Contents

1 Executive Summary

For testing and validation of advanced driver assistant systems and automated driving simulation is used. The complex systems under test do not only need precise and detailed modeling of the road but also a growing amount of information about the environment, too.
Currently ASAM OpenDRIVE is fulfilling the task for the road description quite well, thus it became de-facto standard in automotive domain. The newest version 1.8 was published in November 2023. Nevertheless, disadvantages and issues arose, including the following:

- Simulation settings and road settings became more and more complex and therefore the handling of the data does not scale.
- More real-world data was introduced. The modeling approach of ASAM OpenDRIVE is stretched to its limits.
- The databases were linked with various other databases for sensor simulation.

The standard CityGML issued by the international Geospatial Consortium (OGC) is the most commonly used format for storing, modelling and exchanging semantic 3d environments. Highly accurate geo-referenced, geometric and topological information as well as semantic capabilities are key strengths of CityGML. Different thematic modules are available to cover diverse use cases, including simulations and analyses. The newest version 3.0 of CityGML was published in September 2021 and contains revised and extended concepts for modelling the street space. Compared to ASAM OpenDRIVE, CityGML follows a completely different geometric modelling approach based on discrete areas using explicit coordinates. As general exchange standard for 3d city models CityGML does not cover all requirements for a specific application, which results in some drawbacks regarding the automotive domain:

- City management applications often require a fragmented view of the traffic area, which does not match a simulation view.
- Semantic concepts differ with respect to their approach on segmenting the street space in individual objects as well as modelling the road (e.g. linear referencing, parametric geometries).

Only including ASAM OpenDRIVE into CityGML does not solve the ASAM OpenDRIVE issues.

CityGML contains a built-in mechanism for extending the data model of the standard with concepts not originally within its scope called Application Domain Extensions (ADE). This could help in order to bridge the gap between the two standards.

The proposal for this concept project is to re-think the road modeling approach incorporating requirements of automotive domain.

- Use CityGML strength to model a semantic 3d environment
- Define a compact standard based on ASAM OpenDRIVE 1.x to model road logics
- Define a linkage concept to meet requirements of the whole simulation domain and improve interoperability between GIS and automotive domain

- Re-use the linkage concept to connect to additional relevant road information

The concept project will bring together the expertise of both, automotive and city modeling domain to propose an easy and modular solution that is easy to use and extendable by further relevant stakeholders (e.g. traffic or energy management).

2 Overview / Goals

2.1 Motivation

ASAM OpenDRIVE was initially created to describe a road network's logic for synthetic roads. Over time more and more features were added driven by growing use cases and the need for a detailed description of the road space. In addition, semantics and shapes of further features linked to a road network were added, which led to an increase in complexity of the standard. Also, the way ASAM OpenDRIVE is designed limits the level of detail of a road space description including its environment to a certain extent. Nevertheless, the design principle allows smooth simulation of the movement of all traffic participants including the system under test.
With new applications like sensor simulations arising, modelling of surface and material information becomes more and more important. Instead of further bloating the existing ASAM OpenDRIVE standard, we propose to slim it down to its original purpose and outsource additional needs.
To find a new home for 3d environment definition OGC's CityGML standard is a promising candidate, which allows a semantically well-defined description. CityGML is used all over the world for 3D city modelling and can easily be converted to visualization formats like GLTF. Also, using an accepted format can open new data pools, simplify data generation and handling by improving interoperability.
By defining a standardized linkage concept new challenges requiring a detailed road network description can be addressed by making use of the strength of existing concepts.

2.2 Relations to Other Standards, Projects, or Organizations

2.2.1 Standard and Standardization activities

2.2.1.1 Current ASAM OpenDRIVE

Upcoming applications in the automotive domain aim at enabling realistic representations of real-world data on a larger scale. Regarding this, the following issues with the current ASAM OpenDRIVE emerge:

- Modeling is based on reference lines with relative lane definitions. These are usually virtual constructs, based on clear rules. However, roads in complex urban scenarios are often not built according to these road construction guidelines.
- Due to the modeling approach, auxiliary constructions are often necessary, which leads to even more complexity, ambiguities or gaps. It is therefore very difficult to update or patch parts of a complex road model.
- The hierarchical XML specification can lead to multiple definitions of the same elements, such as road marks. The strict hierarchy leads to costly and time-consuming update procedures of subordinate elements in one ASAM OpenDRIVE file.
- Real-world data cannot be transformed into ASAM OpenDRIVE syntax directly. This is due to ASAM OpenDRIVE being a virtual construct. This means, its modeling procedures are not common among other domains, such as road operators or public authorities.

- Scalability and data exchange are very limited, due to a large XML structure that does not have abbreviations, such as namespaces. It is therefore necessary to facilitate huge databases of urban or long motorway settings.

2.2.1.2 Current CityGML

CityGML is the most commonly used data model and exchange format for semantic 3D city models [Kolbe et al. 2021]. Version 3.0 of the international OGC standard CityGML was published in 2021 and introduced revised and extended concepts for modelling transportation infrastructure [Kutzner et al. 2020]. This contains geometric, semantic, topological, temporal and visual concepts for virtually representing cities. The modular structure of the standard provides individual concepts for representing buildings, city furniture, vegetation or transportation objects. The transportation module contains standardized concepts for representing road infrastructure. Objects are hierarchically structured and semantically decomposed. Large road networks, for example, are segmented into individual roads, which are further split into sections and intersections, which again can consist of individual traffic areas representing driving lanes, sidewalks, bicycle paths, etc. This information is contained within dedicated function or usage attributes. Further classes for modelling road markings, holes in a road's surface (such as manholes or roadway damage) as well as clearance spaces are available. Each object contains a unique identifier (gml:id attribute).
All geometries are generally georeferenced using explicit real-world coordinates. Road objects can be represented using linear (graph-based), areal (surface-based) or volumetric geometries in three levels of granularity, ranging from generalized representations of an entire road down to lane-level representations. Topological concepts for representing predecessor and successor relations (e.g. to represent traffic logic) as well as information on traffic directions are available.
Additionally, further thematic modules provide concepts for representing city furniture objects (e.g. traffic signs or traffic lights), vegetation (e.g. trees), buildings, bridges or tunnels. Thus, CityGML provides consistent and integrated concepts for modelling entire city and streetspace environment models. CityGML concepts can be extended by introducing generic classes and attributes or by defining a formal extension to the data model with an Application Domain Extension (ADE).
While CityGML is not a visualization format, common visualization formats such as OBJ, 3D Tiles, glTF, COLLADA or KML can be derived from CityGML using existing tools or ETL processes.

2.2.1.3 Other formats and activities

The project also aims to investigate that the approach aligns well with further standards of ASAM standards. This includes road network and environment descriptions aspects for standards OpenSCENARIO XML and OpenSCENARIO DSL. Furthermore, the OpenMATERIAL project standardizes material properties required for physical sensor simulations.

In addition to formats primarily used during the development phase, there are also lane-level road representations used during the operational phase and should also be considered in this project. This includes the format of the Lanelet2 project and the Open Lane Model from the Navigation Data Standard (NDS). The ISO also develops and provides standards for representing maps, such as the "Geographic Data Files" (ISO 20524-1:2020) and the "Dynamic data and map database specification" (ISO/AWI TS 22726).

2.2.1.4 Already proposed innovation for road modeling

In the ASAM OpenDRIVE concept project the WP05 Area Concept already worked on these issues. To do this, the way of modeling a road network is changed in order to bridge the gap between current simulation use cases and the upcoming challenges of introducing more real-world settings into the simulation as well as data with a higher level of detail. The key motivations are:

- Model roads as they are, without creating gaps.
- Simplify the modeling of complex urban situations.
- Make the usage of existing real-world data easier by integrating data of public authorities faster.
- Use shared geometries to ensure the integrity of topological data and avoid unintended gaps.
- Do not use artificial modeling constructs or helping constructions, such as reference lines, junction containers or hard-coded lane structures, in order to model real-world data.
- Avoid using relative coordinate referencing at any time that is referencing along imaginary reference lines. Instead use absolute coordinates wherever possible.
- Simplify the linkage to other databases in order to easily provide supplementary information.
- Store separate content in layers for flexible access and extension. Layers may be arbitrarily user-defined.
- Improve the maintainability of a database by making it easier to update individual parts or elements.
- Avoid large XML files and enable spatial indexes and queries by using geographic information system (GIS) technology to quickly access and process large databases.
- Improve scalability, since the current ASAM OpenDRIVE is not scalable at all.

A detailed lineup of differences between the proposed Area Concept and ASAM OpenDRIVE 1.x is provided in documentation of the ASAM OpenDRIVE concept project work package WP05 description in Section 1.3.1.

The area concept facilitates stand-alone polygons for the description of the usable area, for example for transport modes or traffic participant types. All polygons belonging to one traffic mode are grouped into a layer. This results in having different independent layers for different traffic modes, which simplifies the modeling of complex urban scenarios. The elements can be combined in a variety of ways:

- Polygons (areas) within the same layer are linked to each other implicitly using shared geometries, which superimpose topology constraints. These topology constraints ensure data integrity and are easy to handle on a database level. The necessary tool support is already available in the GIS domain and partly standardized.
- Explicit linking of elements within one layer or between layers can be achieved on a flat attribute level. Such an approach offers great flexibility and easy extensibility.
- Additional "logical linking layers", for example using reference lines, lane center lines or movement paths, can be included into the layer tree at any time.

The current ASAM OpenDRIVE works well for automated test case generation with a limited scope. The Area Concept enables the extensive use of real-world representations, which is very restricted in ASAM OpenDRIVE. Test case creation of smaller settings is also possible with appropriate tool support due to the different modeling approach.

Therefore, the Area Concept could replace the current ASAM OpenDRIVE. Once the complexity of test cases increases and test cases incorporate more real-world data, the Area Concept will play out its advantages. Due to the completely different nature of road element modeling, at the current design state the Area Concept will most certainly not be directly compatible with the current ASAM OpenDRIVE implementation. This results in a new standard definition. Discussions in the WP05 working group of the ASAM OpenDRIVE concept project led to the common understanding that "there won't be any compatibility to ASAM OpenDRIVE 1.x" and that "the tooling has to be re-invented". Still, a common interpretation of datasets is intended to enable the transfer of ASAM OpenDRIVE 1.x datasets to the Area Concept model without loss of information. This is achieved, for example, by re-using function reference implementations from ASAM OpenDRIVE 1.x and supplying a base converter to translate ASAM OpenDRIVE 1.x datasets into the Area Concept data model.

Thinking about the idea further leads to the conclusion to do the 3d environment modeling in a GIS-like method to follow civil engineering as well as keep the essence of ASAM OpenDRIVE for simulation purpose. The linkage of different layers enables the possibility to add more data if available without the need to reflect all these features in one data format. A reduced ASAM OpenDRIVE and a utilized CityGML connected via a linkage mechanism sounds promising.

2.2.2 Backward Compatibility to earlier releases

No backwards compatibility with ASAM OpenDRIVE 1.x is planned, but a migration guide from ASAM OpenDRIVE 1.x to the proposed approach is to be developed. Moreover, the project intends to investigate the linkage possibilites to OpenSCENARIO XML and DSL.

2.3 Use-Cases

The concept proposal shall cover at least the domains of automotive development, test and verification as well as city modeling. Generally speaking, all their use cases could be stated here. They are the intrinsic driver of comprehensive environment modeling, but more stakeholders can benefit from an overall digital twin. Also, within the two major domains the use cases can vary. Therefore, the following use cases should give an idea of the versatility of the proposed concept but is not limited to the mentioned

Table 1 Generation of High-Definition Road Networks

ID	
Description	Traffic simulation, vehicle dynamics simulation, sensor simulation as well as virtual development, test and validation require synthetic as well as geo-referenced, high-definition maps of road networks. Such kinds of maps are either created based on scenario definitions or by map data provider (e.g., surveying companies) or derived from areal images and ordered by public authorities, car manufacturers, simulation tool vendors, urban planners etc. The road networks should be interchangeable among stakeholders.
Actors	• Surveying companies and map makers • Public authorities • Vehicle manufacturers and their suppliers • Simulation tool vendors • Urban planners

Table 2 Traffic Simulation

ID	
Description	Macroscopic simulation of traffic on road networks. Traffic simulation may incorporate large numbers of various traffic participants, e.g. pedestrians, cyclists, road and rail vehicles etc. Traffic simulation is used to simulate surrounding traffic of a system under test, traffic volume in specific areas, accident probabilities, traffic management strategies, impacts of changes in the road network etc. Traffic simulation requires a logical description of corresponding road networks for varying kinds of traffic participants.
Actors	• Public authorities • Mobility (as a Service) operators • Road operators • Vehicle manufacturers and their suppliers • Simulation tool vendors • Urban planners

Table 3 Sensor Simulation

ID	
Description	Simulation of sensors as a device, module or subsystem of a vehicle or infrastructure is indispensable for the selection of individual sensors as wells as for the compilation of sensor sets and the development of sensors and sensor-based functionalities in the automotive and traffic management context. Sensor simulation provides the foundation for development and test of driving assistance functions, for automated and autonomous driving functions as well as for intelligent traffic management. The environment and its physical appearance have a strong influence on sensor’s behavior.
Actors	• Vehicle manufacturers and their suppliers • Simulation tool vendors • Road operators • Urban planners

Table 4 Virtual Development, Test and Validation

ID	
Description	Development, testing, validation and verification of automated and autonomous driving functions are increasingly carried out virtually. Also the final approval will base heavily on virtual testing and verification. The reproduction of countless, realistic journeys over millions of kilometers requires complex road networks and an extensive amount of scenarios as input files. Major requirements on corresponding file formats is standardization and exchangeability.

Actors	• Vehicle manufacturers and their suppliers • Simulation tool vendors • Public Authorities • Testing organizations

Table 5 City Planning

ID	
Description	The overall planning of urban areas have to include various aspects such as change of mobility, livability (regarding supply and emission reduction), ecological as well as economical impact, solar potential calculation, heat distribution, air and emission flow simulation, citizen needs, etc. A lot of these aspects are influencing each other. Therefore, a detailed modeling of Environment, supply infrastructure including traffic networks is crucial especially if different simulation tools are used. Using the same data source ensures that everybody is simulation on the same basis.
Actors	• Simulation tool vendors • Public Authorities

Table 6 City Management and Operation

ID	
Description	The management of urban areas covers not only the road operation but also energy management, green-space management, etc. Road operations should manager its infrastructure assets in a way that e.g. traffic simulation can use this knowledge base to calculate impacts of changed traffic flows, constructions sides temporary measures. For that a detailed modeling of the road and roadside infrastructure as well as environment is necessary.
Actors	• Simulation tool vendors • Public Authorities • Mobility (as a Service) operators • Road operators

3 Technical Content

The project aims to establish a data model that provides a comprehensive, standardized, and easily understandable description of drivable area street space. This involves clearly separating logic and visualization. ASAM OpenDRIVE's role is reduced to defining the minimal viable drivable area, while other essential information for visualization or other applications is outsourced and linked in a standardized manner.

3.1 Description of Road Space Using ASAM OpenDRIVE and CityGML

The modelling of road space is segmented into different components, leveraging established concepts and formats to enhance acceptance and leverage different modelling approaches and domains.

3.1.1 Components Modelled in ASAM OpenDRIVE

ASAM OpenDRIVE was initially designed to depict road network logics. The reference line-based model is well established and shall be maintained. The future proposed ASAM OpenDRIVE should include:

- Course of the road
- Road lane definitions
- Lane linkages
- Temporary lane definitions (e.g., for construction sites)

All other details such as road markings or object shapes are excluded from ASAM OpenDRIVE to maintain a streamlined base definition.

3.1.2 Components Modelled in CityGML

CityGML provides a detailed, three-dimensional representation of the urban environment, offering semantic and geometric data for:

- General terrain
- Road cross-sections (including lane elevations)
- Real-world objects (e.g., vegetation, street furniture, buildings) with material data
- Road layouts not covered by lane definitions (e.g., central islands, restricted areas)
- Road markings
- Traffic signs and signals

Compared to current possibilities of ASAM OpenDRIVE, this enables the modelling of an aerial, non-redundant 3D street space. CityGML's current capabilities can be validated to collect missing features and initiate further extensions.Two requirements towards CityGML representation, that can already be stated are:

- Extend modeling of entities with material description for sensor simulation
- Enable access to entities for animation and state control

3.2 Standardizing Linkage

Additional information beyond the road network's logic will not be directly defined in ASAM OpenDRIVE but rather linked externally. Therefore, a well-defined linking mechanism must be established.

3.2.1 Linkage Between ASAM OpenDRIVE and CityGML

Standardizing the integration between ASAM OpenDRIVE and CityGML ensures seamless interoperability. Key considerations include:

- Defining a Concept to Reference Features: Establishing a robust referencing system for accurate data representation across formats.
- Bi-directional or One-directional Interface: Determining the interface directionality to optimize data flow between CityGML and ASAM OpenDRIVE.
- Utilizing CityGML Global Identifiers: Leveraging CityGML's existing global identifier system to establish references in ASAM OpenDRIVE for efficient data integration.
- Linking via Identifier in ASAM OpenDRIVE: Incorporating CityGML global identifiers into ASAM OpenDRIVE to establish direct references, ensuring alignment between logical road network representations and spatial features.

Several questions remain regarding the interface specifics:

- Content of ASAM OpenDRIVE (ODR): Defining the exact scope of ASAM OpenDRIVE content, influencing interface design.
- Objects Requiring Direct Reference: Identifying critical objects necessitating explicit references between ASAM OpenDRIVE and CityGML.
- Implicitly Linked Objects: Determining objects that can be linked implicitly based on attributes and spatial relationships, streamlining the referencing system.

3.2.2 Linkage Between ASAM OpenDRIVE and Auxiliary Data Layers

In addition to CityGML, ASAM OpenDRIVE interfaces with auxiliary data layers, including road regulation data, fleet drive paths, and environmental impacts on road usage. Standardizing these linkages through an API facilitates comprehensive data integration.

3.3 Summary of key features

Key features of the planned standardized components are:

- Slim ASAM OpenDRIVE: Focuses solely on road network logics for enhanced efficiency.
- Non-redundant 3D Street Space Model in CityGML: Provides accurate urban environment representations.
- Improved Interoperability: Facilitates adoption across domains like simulation and urban planning.

The proposed changes aim to enhance the current standard by:

- Simplifying Street Space Modelling: Introducing new approaches to make the process more intuitive and versatile.
- Outsourcing of Non-essential Concepts: Streamlining ASAM OpenDRIVE by removing elements it was not originally intended to handle.
- Bridging the Gap Between Research and Real-world Data: Ensuring the standard can accommodate high-level research data as well as practical, end-user applications.
- Enhanced Interoperability and Extendibility: Creating defined interfaces to avoid misuse of non-standard data tags.

3.4 Methods of standardization

The standardization process begins with a proposal for a specification, which includes:

- Top-level Requirements: Establishing the essential criteria for developing the standard.
- Data Model: Defining the structure and relationships between different data components.

For better understanding and practical testing of proposed concepts some example datasets may be created.

3.5 Assumptions

The standardization effort is based on several assumptions:

- CityGML's Comprehensive Modelling: CityGML can effectively represent environments at various levels of detail.
- Extension Mechanism: CityGML’s extension mechanism is robust and well-established.
- Impact of Reduced Scope in ASAM OpenDRIVE: Simplifying ASAM OpenDRIVE will lead to breaking changes but result in a more precise and lightweight road space description.

4 Deliverables

Provide a list of deliverables, which are handed over to ASAM at the end of the project. Deliverables must be material items, e.g., documents, code, or executables. They are delivered in an electronic format, e.g., as files.

Please note that the sources for generating or compiling the deliverables, including tool-related files that are needed for the generation or compilation process, must be delivered to ASAM, too. Those sources and files need not to be listed in this chapter.

At the end of the project, the project group will hand over the following deliverables to ASAM:

Table 1 Deliverables

Item No.	Description
1	Proposal for ASAM OpenDRIVE 2.0 standard for road logic definition including linkage concept with CityGML
2	Migration Guide ASAM OpenDRIVE 1.x to ASAM OpenDRIVE 2.0 with CityGML environment representation
3	Example dataset including lined ODR and CityGML
4	
5	
6	
7	

4.1 Review Process

The process for deliverable review documented in the project guide is applicable to all projects (see here).

The ASAM OR will provide further details on quality criteria and tools used prior to the initiation of a review in a project.

Table 2 Selection of Review Type

Please indicate whether the project is aiming to perform an ASAM member review or a full public review. This is not required for maintenance projects.	Wählen Sie ein Element aus.

5 References

Provide a list of documents and their authors that are referenced in earlier chapters. Use the sequential number in squared brackets for referencing them in earlier chapters.

See guidance on References in the ASAM Editorial Guide

[1] Kolbe, T.H., Kutzner, T., Smyth, C.S., Nagel, C., Roensdorf, C., Heazel, C.: OGC City Geography Markup Language (CityGML) Part 1: Conceptual Model Standard. Open Geospatial Consortium (2021) https://docs.ogc.org/is/20-010/20-010.html

[2] Kutzner, T., Chaturvedi, K., Kolbe, T.H. CityGML 3.0: New Functions Open Up New Applications. PFG – Journal of Photogrammetry, Remote Sensing and Geoinformation Science, 19, (2020) http://dx.doi.org/10.1007/s41064-020-00095-z City

[3] CityGML Open Data examples: https://github.com/OloOcki/awesome-citygml