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**Conférence Européenne
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Directors of Roads**

DiREC

Digital Road for evolving Connected & Automated Driving

Level of Service Definitions

Deliverable D3

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TRL — THE FUTURE OF TRANSPORT

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Digital Road for Evolving Connected and Automated Driving

Deliverable 3 – Level of Service Definitions

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Final Version

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Introduction

The Level of Service (LoS) is a widely employed metric that quantifies the performance and quality of a provided service, utilizing a predetermined scale. In the transportation domain, road capacity (i.e., maximum throughput in a given road section) is the most widely used performance indicator, where the LoS is applied. In road capacity studies, the LoS definition is dependent upon the specific context and facility under examination, such as urban areas or motorways. In urban settings, the criteria typically employed for determining LoS include average travel speed, average travel time, frequency of stops, and delays. Conversely, on motorways, LoS is determined by factors such as vehicle density, traffic speed, and frequency of lane changes (HCM, 2016). Upon specifying the context, the chosen criteria are applied, and threshold requirements are established to categorize the performance and quality under the appropriate LoS. The LoS scale can range from binary levels (e.g., acceptable or unacceptable) to more nuanced scales. For instance, the HCM (2016) employs a six-point scale (A = very good; B = good; C = acceptable; D = bad; E = very bad; F = system breakdown).

For C-ITS services (i.e., information provision), however, the aim is to provide information that are, among other things, accurate and timely to the road users, connected and autonomous vehicles, so they can react accordingly to events on the road network. The CAV-ready framework (CRF) developed in WP3 aims to illustrate the progress of National Road Authorities (NRAs) towards becoming a digital authority, meaning that the NRAs should provide **traffic related information** (data provision) to its users (connected and autonomous vehicles) that are precise, accurate, and timely. As such, we have defined three distinct LoS categories:

1. Basic: Minimum acceptable performance/quality

2. Enhanced: Not optimal but sufficient performance/quality

3. Advanced: Ideal or best performance/quality

Additionally, we have considered a fourth level for information provision services that are already available. In this case, the LoS metric may be utilized by NRAs to assess the performance and quality of existing services, though we will not be evaluating their performance within the scope of our study.

Criteria, Requirements, and Assessment methods

Transportation facilities may be classified based on road environment types, such as urban, rural, and motorway environments. These contexts may also be applied to our study, as the different environments may impose unique demands due to the traffic they accommodate. Our goal, however, is to develop a generic LoS tool that can be applied to any road environment, to any use case or technology. Therefore, we aim to create an LoS metric that is applicable across all road environments and is technology-agnostic. A list of potential criteria and requirements based on (Lubrich, Geissler, Öörni, & Ryström, 2022), without specific context may include:

- CRF Enablers Criteria:

  1. Geographical coverage (% of network/road classes coverage)

  2. Location accuracy (confidence position accuracy)

  3. Availability (average availability of all connected data senders)

  4. Refreshment rate (time interval for updating status reports)

  5. Latency (total time for messages from a and b | timestamp at C-ITS receiver)

6. Error rate (% of erroneous messages)

7. Report coverage (% of connected C-ITS senders out of all senders)

Other possible candidates are: penetration rate, packet delivery ratio, effective communication range.

- Requirements:

According to (Lubrich, Geissler, Öörni, & Ryström, 2022), the most important quality values are the minimum ones, as the basic requirements to realize an information provision service. If the quality is below this basic level, the benefits would be negligible.

1. Geographical coverage (e.g., only bridges and tunnels, only busy junctions)

2. Location accuracy (off-set < 50 m)

3. Availability (90 %)

4. Refreshment rate (< 60 seconds)

5. Latency (< 150 ms)

6. Reliability (error rate: <5% of erroneous messages)

7. Report coverage (95 % of connected C-ITS senders out of all senders)

LoS Definition

The LoS is a quality and performance evaluation metric based on a set of enablers with predefined requirements. The definition should be generic, applicable to all cases, and technology-agnostic. It is crucial to connect LoS definitions to the CRF (Excel file). Examples of LoS for various levels (basic, enhanced, and advanced) are provided in Table 1.

Table 1: Requirements for C-ITS services. Source: (Lubrich, Geissler, Öörni, & Ryström, 2022).

Criterion	Definition	Basic	Enhanced	Advanced
Availability	Average availability for all operating connected data senders, including the communication chain up to the data receiver.	95% (347 days/year)	99% (361 days/year)	99,5% (363 days/year)
Latency	Total time for communicating messages between A and B	95% of all messages <10 minutes	95% of all Messages <7 minutes	95% of all Messages <2 minutes
Refreshment	Time interval for refreshing / updating the status reports coming from a data sender.	<5 minutes	<3 minutes	<1 minutes
Location	Confidence for the horizontal position	95% of all messages	95% of all messages	95% of all messages

Accuracy	accuracy of the reported location with respect to the actual location.	within tolerance circle <10 m	within Tolerance circle <1 m	within Tolerance circle <10 cm
Error rate	Percentage of messages with erroneous information, as reported by a data sender, with respect to the reality.	<15%	<10%	<1%

List of Possible Enablers

Enablers based on the CRF are grouped into five categories: Physical, Digital, Operation, Connectivity, and Standards. For each enabler, three levels (basic, enhanced, and advanced) should be defined to apply the LoS approach.

Physical

Coverage (tunnels, bridges, busy junctions or segments, full network coverage)

Separate CAV carriageway

Cameras

Lane separation

Additional refuge areas

Shoulder width

Road/bridge strengthening

Legacy (power supply)

Traffic Management Center (TMC)

Digital
HD mapping (static, dynamic)

Digital platform

Operation
Enhanced sign maintenance

Enhanced road marking maintenance

Enhanced emergency response

Equipped vehicles (trailer, patrols) – Mobile RSU

Connectivity
Sat communication (GNSS)

Cellular (LTE, C-V2X)

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Local (RSUs) – ITS G5(same for mobile stations)

Redundancy

Failure mechanism

Legacy (fiber optic)

Standards

ETSI - ITS

ETSI – TS 103 301

DENM message (EN 302 637-3)

SPATEM and MAPEM messages for SI-SPTI