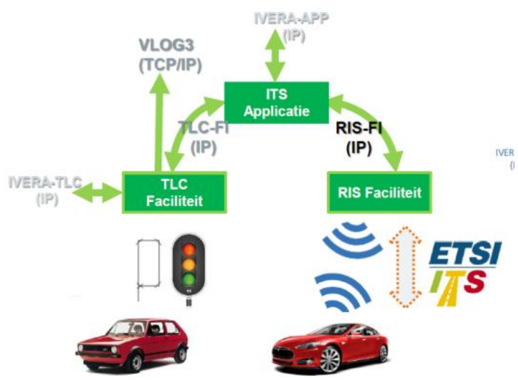
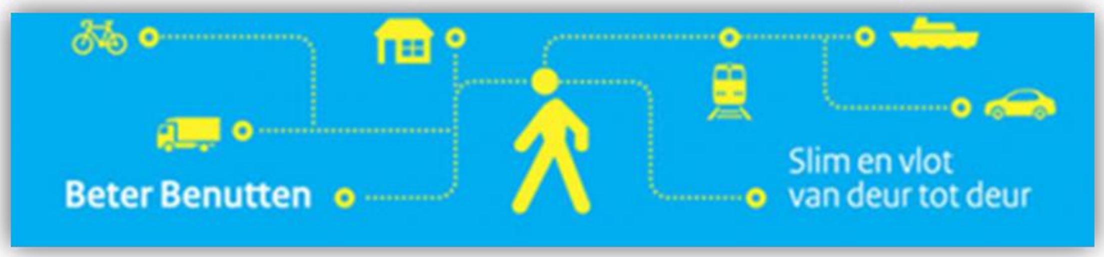
# Intelligente Verkeers Regel Installatie (iVRI) – Fase 1

# Deliverable E: Use Case beschrijvingen

Uitwerking geprioriteerde use cases (gecombineerd profiel voor connected, coöperatief, uni- en bi directioneel) met stakeholders uit de hele keten. Regie op overleg met landelijke tafels wordt gevoerd door BBV.

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Versie: 7

## Voorwoord

In juni 2015 is opdracht verstrekt door het Ministerie van Infrastructuur en Milieu via het Beter Benutten Vervolg (BBV) programma aan vier VRA leveranciers om te komen tot een gezamenlijke definitie van VRA standaarden ten behoeve van connected en coöperatieve functionaliteit.

Dit document vormt Deliverable E van de afgesproken leverdelen in de opdrachtverstrekking, omschreven als:

Uitwerking geprioriteerde use cases (gecombineerd profiel voor connected, coöperatief, uni- en bi directioneel) met stakeholders uit de hele keten. Regie op overleg met landelijke tafels wordt gevoerd door BBV.

Dit document is tot stand gekomen door samenwerking van de vier leveranciers in de werkgroep bestaande uit:

Herman van der Vliet

Peter Luns

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**This rest of this deliverable has been written in English to facilitate international exchange.**
**Elk hoofdstuk eindigt met een Nederlandse samenvatting.**

# INPUT CONTRIBUTION
## PROPOSED ITS USE CASES

| | |
|---|---|
| Company Name:* | Beter Benutten Vervolg (BBV) |
| Project Name:* | VRI Tafel |
| Source:* | Workgroup 2 |
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| Date:* | 5 December 2015 |
| Contact:* | Herman van der Vliet |
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| Agenda Item:* | Use-case |
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| Version: | v7 (final) |
| Document(s) Impacted* | IRS / IDD WG3 |
| Intended purpose of document:* | ☒ Decision<br>☐ Discussion<br>☐ Information<br>☐ Other <specify> |
| Decision requested or recommendation:* | Proposed implementation of use cases |

## IPR STATEMENT

# Table of Contents

## List of Figures



## Acronyms and abbreviations

| Acronym & Abbr. | Description |
|---|---|
| TTG | Time To Green |
| TTR | Time To Red |
| I-TLC | Intelligent Traffic Light Controller |
| BBV | Beter Benutten Vervolg |
| SPAT | Signal Phase and Timing |
| MAP | Data structure containing topology information of a road section |
| C-ITS | Cooperative Intelligent Transportation System |
| RSU | Road Side Unit |
| RTM | Road Traffic Manager |
| IE | Installation Engineer |
| TE | Traffic Engineer |
| RIS | Road Side ITS |
| TDC | Traffic Data Center |
| TCS | Traffic Control System |
| VIS | Vehicle ITS |
| RU | Road User |
| IVI | In Vehicle Information |
| HGV | Heavy Goods Vehicle |
| PT | Public transport |
| TMS | Traffic Management System |

## Document history

| Document / Revision | Revised section / paragraph | Short description of the change | Revised by | Date (yyyy-mm-dd) |
|---|---|---|---|---|
| V1 | Entire document | General introduction and merge of individual use case descriptions | Herman van der Vliet | 2015-12-05 |
| V2 | Chapter 2,3 | Added Use case 8 details (TTG/TTR) | Peter Luns | 2015-12-05 |
| V3 | Chapter 6,7 | Added use cases U04A and U05A | Jeroen Douma | 2015-12-07 |
| V3 | Chapter 5 | Added use case Green Wave | Jaap Zee | 2015-12-07 |
| V4 | Chapter 4 | Added use case gap measurement | Herman van der Vliet | 2015-12-08 |
| V5 | Entire document | Layout | Jaap Zee | 2015-12-08 |

| | | | | |
|---|---|---|---|---|
| V6 | Entire document | Updated with review comments | Peter Luns | 2016-01-19 |
| V7 | Entire document | Updated with review comments | Jaap, Jeroen, Herman | 2016-01-21 |

# 1 Introduction

## 1.1 Smart mobility

Cooperative systems show a promising future for road users as well as road authorities. In general the functionality enables information sharing between relevant actors in the system based on which all sub-systems can optimize their functioning. As a result safety, throughput and livability are improved.

Both on European level (ETSI) and national level (DITCM) a clear focus is set towards a cooperative future in traffic systems by means of ITS applications.

The automotive industry is moving forward in standardization with a long term objective of autonomous vehicles. Along this road the vehicles will become important sensors for traffic systems.

This document is written from the context of TLC's which play an important role in the infrastructure especially with regards to traffic safety. The TLC is both interfacing with vehicles as well as management systems and allows for local optimizations with respect to throughput, environment and comfort.

## 1.2 Cooperative and connected systems

Cooperative systems can be described as intelligent systems sharing their intended activities and planning. By sharing, other systems can adapt to the behavior; needless to state that this works vice versa.

Connected systems can be described as top-down instructive sub-systems. Information is gathered from all sub-systems and conclusions and directives are communicated in return based on which the sub-systems can adapt their behavior.

## 1.3 Context and scope

The BeterBenuttenVervolg (BBV) program focuses on introducing connected and cooperative services. In relation to the intelligent Traffic Light Controller (iTLC) this translate to standardization of (communication) interfaces and creation of an architecture allowing for such services. All definitions are aligned with European standardization.

Functionally the services are described as use cases. This document focuses on the most valuable use cases from an iTLC perspective.

## 1.4 Prioritized use cases

Within the scope of the TLC over thirty use case have been defined in three categories: Informing, Prioritization and Optimization. The ranking is based on expert opinions from both road authorities and TLC suppliers estimating the usability, feasibility and expected effect. This results in the following use cases which are furtherly explored and described in this document.

Informing

- U08-a: Time to green for speed advice, start/stop etc.
- U08-b: Time to red for speed advise, start/stop etc.

Optimization

- U07-b: Gap measurement
- U07-i/U10-f: Cooperative Green Wave

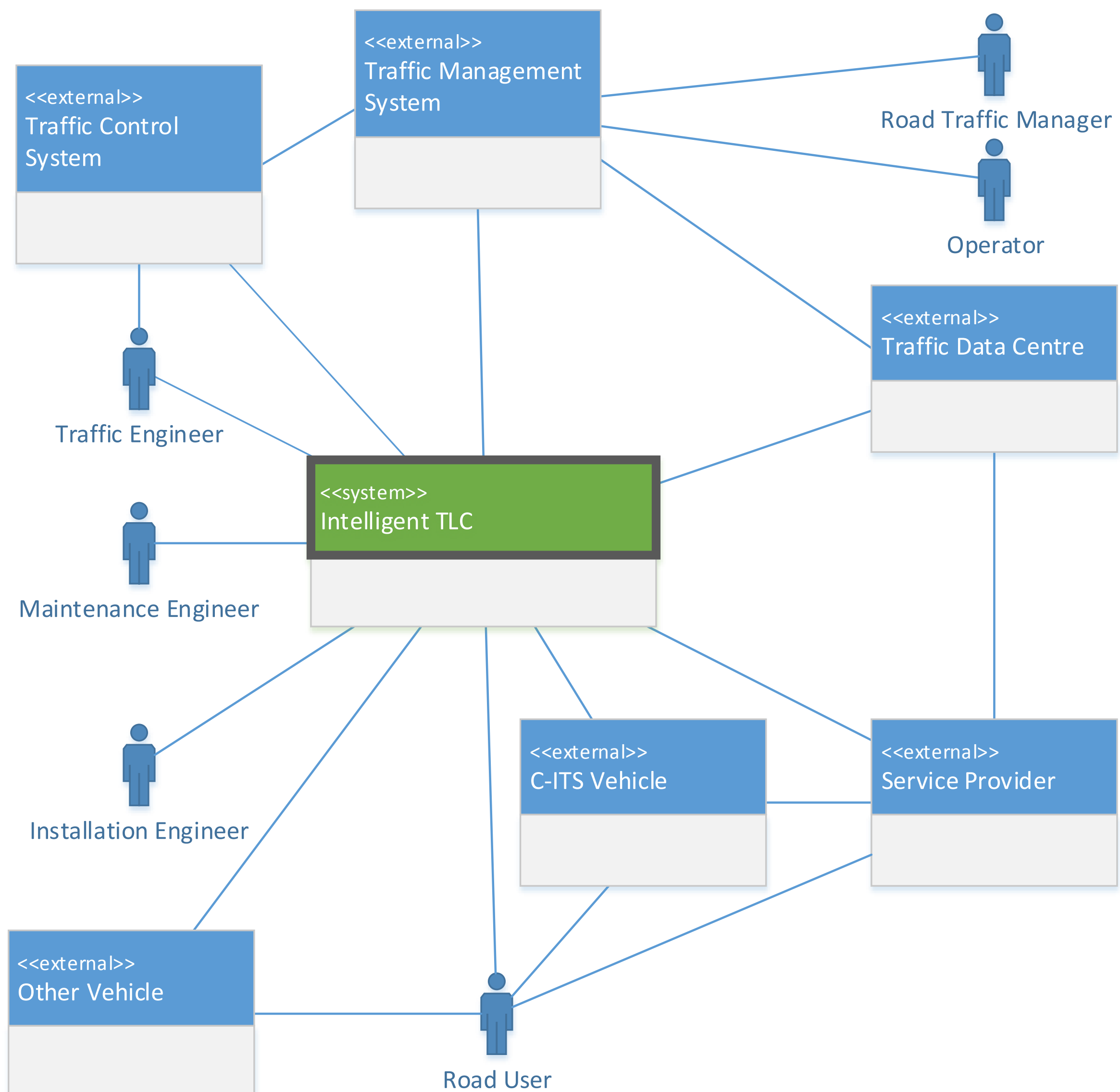
Document: U08-A, U08-B, U07-B, U07-I, U04-A, U05-A

Prioritization

- U04-a: Cooperative Magic Green
- U05-a: Specific groups (e.g. Public Transport)

Note that the total set of use cases are listed and described in document deliverable D.

## 1.5 Actors



| External entity | | |
|---|---|---|
| Traffic Engineer (TE) | | |
| | Description | Responsible for implementing, defining, designing and functional maintenance of traffic algorithm for the Traffic Control System and/or Intelligent TLC. |
| Maintenance Engineer (ME) | | |
| | Description | Responsible for operational maintenance of the Intelligent TLC using diagnostic facilities. |
| Installation Engineer (IE) | | |
| | Description | Responsible for deployment of hardware, software and infrastructure of the Intelligent TLC. |
| Road Traffic Manager (RTM) | | |
| | Description | Responsible for determining and setting of traffic management policies. |
| Operator | | |
| | Description | Executes policies for the traffic system by using the Traffic Management System. |
| Traffic Control System (TCS) | | |
| | Description | External system implementing a traffic control algorithm actively influencing the Intelligent TLC to control traffic. Realising set traffic control policies. (Operational Management) |
| Traffic Management System (TMS) | | |
| | Description | External system responsible for monitoring, evaluation and management of the functional and technical state of the Intelligent TLC and Traffic Control System. Used to set high-level policies. Translates policies to required behaviour of the underlying systems. (Strategic Management) |
| Traffic Data Centre (TDC) | | |
| | Description | Responsible for collecting, aggregating, distributing and managing (e.g. deleting) of traffic data. |
| Service Provider (SP) | | |
| | Description | Responsible for providing services to one or more customers. Customers can include both other systems and end-users. |
| C-ITS Vehicle (VIS) | | |
| | Description | A vehicle equipped with ETSI cooperative functionality using ITS G5 or cellular technology. Complies with the definition of a Vehicle ITS Station (V-ITS-S). |
| Other Vehicle | | |
| | Description | Other vehicle, not being a C-ITS Vehicle. |
| Road user (RU) | | |
| | Description | A person participating in the traffic (e.g. driver, pedestrian, cyclist). |

## 1.6 Communication infrastructure

In order to connect all relevant actors a robust communication infrastructure is required. Many techniques are available nowadays. Although somewhat out of scope of this document it needs to be pointed out that security becomes a much more important topic when connecting many systems (including vehicles) in one infrastructure.

Connections through central systems and road side systems logically are IP based (preferably wired) allowing for sub-networks to be connected by routing technologies.

Connections with road users are logically wireless with low latency. A distinction can be made in connection oriented (cellulair, point-to-point) and connectionless (ad hoc, broadcast) communications. The latter typically is used in cooperative systems, for example Wifi-p based.

## 1.7 Relation to other initiatives

There are multiple initiatives with respect to connected and cooperative systems. The intention of this document is to describe the connected and cooperative view from the TLC perspective and hence be complementary to other initiatives.

A short (incomplete) list of related initiatives:

- DITCM
- Spookfiles
- ITS Corridor
- Compass4D
- PPA (Praktijkproef Amsterdam)

## 1.8 Nederlandse samenvatting

Coöperatieve systemen (c.q. ITS applicaties) beloven een toekomst voor zowel de weggebruiker als de wegbeheerder door het delen van informatie waardoor snellere en betere beslissingen genomen kunnen worden.

Standaardisatie vindt plaats op Europees (ETSI) en nationaal (DITCM) niveau in de vorm van ITS applicaties. De rol van de VRI in de infrastructuur is hierbij van groot belang voor veiligheid, doorstroming, milieu en comfort. Het BBV programma richt zich op de introductie van ITS diensten. Dit document beschrijft de meest waardevolle use-cases vanuit VRI oogpunt.

De automotive industrie beweegt zich richting autonome coöperatieve voertuigen waarvoor standaardisatie eveneens noodzakelijk is.

De communicatie infrastructuur omvat logischerwijs zowel connectie georiënteerde technieken (IP based) alsook adhoc technieken (broadcasting).

# 2 Use case U08-A “Time to Green”

## 2.1 Introduction Use-Case

### 2.1.1 Use case ID

U08-a: Time to green

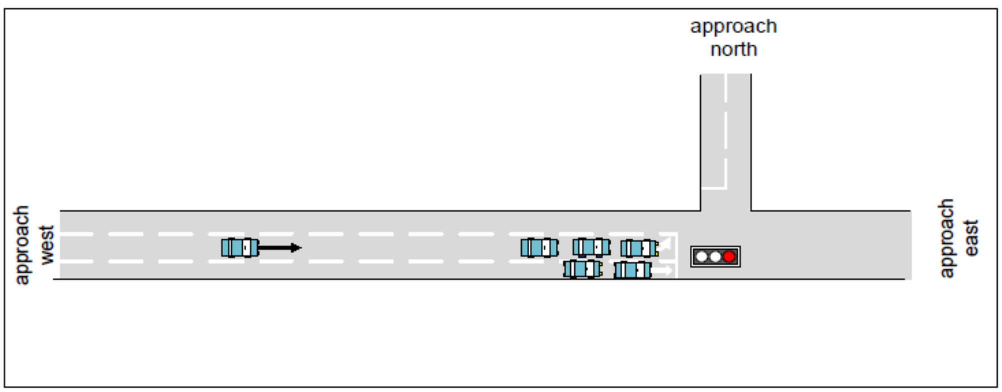
### 2.1.2 Background

The use-case has been defined within the scope of the BBV project to support approaching vehicles of any type (e.g. car, bus, bicycle …) in a smoother transition, reduce unnecessary stops and to increase the intersection safety. The use-case has been selected due to the ranking provided in Deliverable D.

### 2.1.3 Objective

The envisioned result is that the Road User will have a smoother travelling experience when crossing intersections. The use case currently focusses on vehicles that could benefit from the TTG function.

- The time delay introduced by modern vehicles with a start/stop engine system is eliminated (increased traffic flow and reduced environmental impact).
- Approaching vehicles can adapt their speed causing the vehicle to reach the intersection when the light has turned to green, thus minimizing the amount of physical stops (increased traffic flow, safety, and reduced environmental impact).




Time to green can be viewed from different perspectives.

A. From the perspective of driving towards a traffic light and the traffic light is NOT green

B. From the perspective of waiting for a traffic light to turn to green

### 2.1.4 Source:

ISO TS-19091 (v 5.14); MS4, MS6 and MS7

ISO TS-19091 – Annex D; §1.2.1, §1.2.2

Compass 4D D2.1; C4D.EEIS 3.3

Compass 4D D2.3.2; §2.2.3, D2.3.3; §2.2.3

SAE J2735 Appendix H

DITCM Architecture; §3.1.1.11, §3.1.1.13, §3.3.10, §3.3.11

Eco-AT SWP2.1 Overview On Use Cases v02.00; §2.4

Eco-AT SWP2.1 Intersection Safety v02.00; §4 Use case 1, Use case 2

VRI Tafel

ASN.1 definitions ETSI, dd 04-11-2015

## 2.2 Description Use-Case

Perspective A:

Any type of vehicle approaching a traffic light from any direction will be provided with the current traffic light phase schedule by the intelligent TLC. The OnBoard unit in the vehicle can calculate an approach speed, at which the vehicle will reach the intersection during a green phase. This calculated approach speed is presented to the road user who can then avoid an unnecessary stop.

The Traffic Light Controller providing time-to-green information to approaching vehicles enables in-vehicle applications implementing use cases like ‘Green Light Optimal Speed Advise’, ‘Idling stop support’ and ‘Start delay prevention’

Perspective B:

The same information can be used by a stationary road user waiting for the “Green phase” at an intersection. This to prevent unnecessary reaction delays at the transition of the traffic light to green.

### 2.2.1 Current situation

In the current situation distributing TimeToGreen information is limited:

- To a small geographic area in close proximity (visual range) of the intersection.
- Road users can only be informed using visual means at close range.
- Road users further away from the intersection cannot be informed, thus cannot anticipate on the current Signal State phase information at hand.

### 2.2.2 Transition phase

During the transition phase the TTG information dispersion is extended beyond the range of visual means at an intersection. Road users outside the visual range of the intersection can be informed due to the nature of cooperative technology. These road users can adapt the approach speed of the vehicle enabling them to reach the intersection at the start of the Green Phase. Effectively increasing the amount of vehicles capable of utilizing the green phase of a signal group, and reducing the environmental impact of vehicles passing an intersection.

### 2.2.3 Post transition phase

When all vehicles participating in traffic are equipped with cooperative systems the utilization of visual means required to distribute TTG information ceases to exist. Thus creating opportunities to reduce on costs when creating and /or maintaining intersections.

## 2.3 Target System

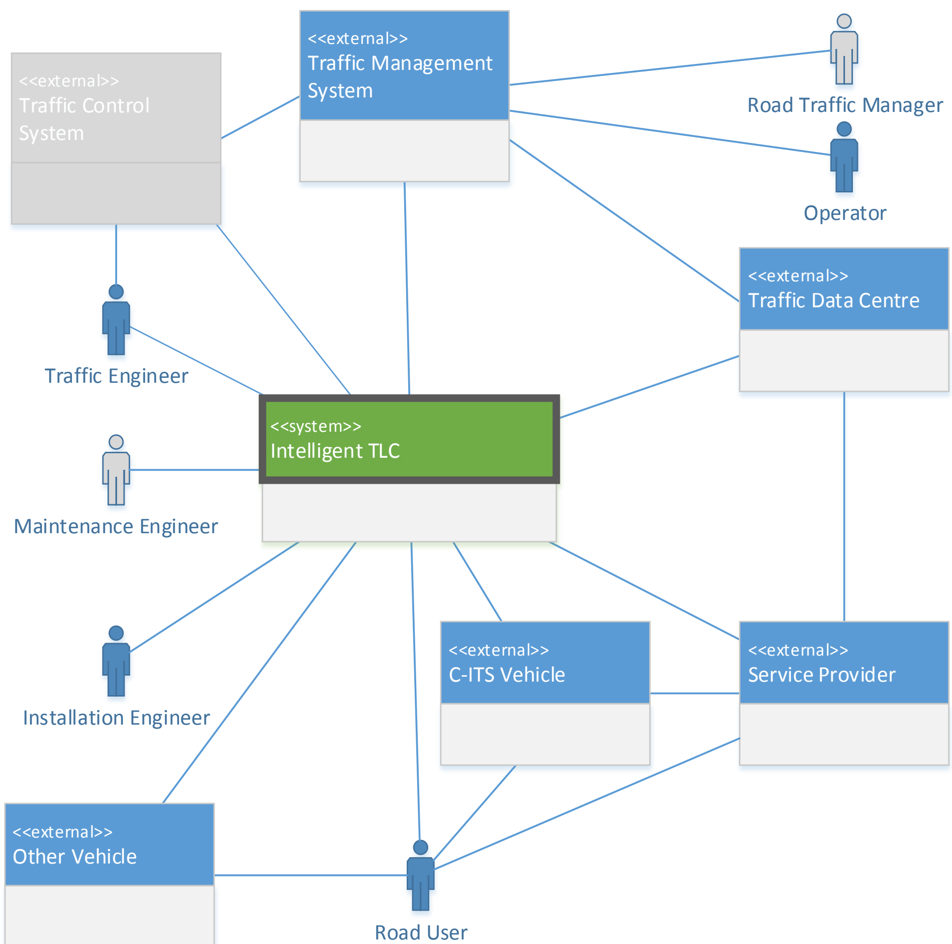
Intelligent TLC

## 2.4 Implementation environment

Selected signalized intersections equipped with an iTLC. The following diagram illustrates the context of the iTLC.

## 2.5 Actors

As can be viewed in the following diagram the actors involved are mentioned in the table below by describing their “Role” (= involvement) in the Time to Green use case.




The actors that do not participate in the use case have been greyed out.

| **External entity** | | |
|---|---|---|
| Traffic Engineer (TE) | | |
| | Role | Defines & maintains TTG-functionality (out of scope, is a pre-condition for the use-case) |
| Installation Engineer (IE) | | |
| | Role | Installs the TTG-functionality in iTLC |
| Operator | | |
| | Role | Activates broadcast of TTG information via TMS. |
| Traffic Management System (TMS) | | |
| | Role | Activates the TTG function on the iTLC upon request from the Operator. |
| Traffic Data Centre (TDC) | | |
| | Role | Receives the current Signal Group State and intersection Topology from the iTLC and offers the information to subscribed service providers. |
| Service Provider (SP) | | |
| | Role | Provide/configures connected service e.g. geographical boundaries |
| C-ITS Vehicle (VIS) | | |
| | Role | Receives the information from the iTLC.<br>Triggers sensors (loop detector below the road surface) that influences the light phase schedule. |
| Other Vehicle | | |
| | Role | Triggers sensors (loop detector below the road surface) that influences the light phase schedule. |
| Road user (RU) | | |
| | Role | Triggers sensors (e.g. pedestrian push button) that influences the light phase schedule |

## 2.6 Pre-conditions

The addition cooperative and/or connected indicates that the pre-condition applies to the cooperative and/or connected domain.

Intelligent TLC:

- is operational and is not in failure state (cooperative, connected).
- has been provided the topology of the intersection (cooperative, connected).
- is capable of providing Signal Phase and Timing information (cooperative, connected).
- is capable of calculating the Signal Phase and Timing (cooperative, connected).
- TTG function has been designed and made available on the iTLC.

C-ITS Vehicle is capable of receiving and processing the information being:

- Intersection Topology (cooperative)
- Signal Phase and Timing (cooperative, connected)
- Speed Advice (connected)

Operator has activated Time to Green functionality (cooperative, connected).

Traffic Engineer has designed, implemented and tested the TTG functionality for an iTLC (cooperative, connected).

Installation Engineer has installed and commissioned an iTLC with TTG functionality (cooperative, connected).

Service Provider provides a TTG service for C-ITS Vehicles (connected).

Road User has access to TTG information in the vehicle he/she is operating (cooperative, connected).

## 2.7 Trigger conditions

Cooperative infrastructure:

- The intelligent TLC is switched to “Control Mode”.

Connected infrastructure:

- The intelligent TLC is switched to “Control Mode”.
- The vehicle sends speed, direction and location information to the Service Provider.

## 2.8 Use-Case Diagram

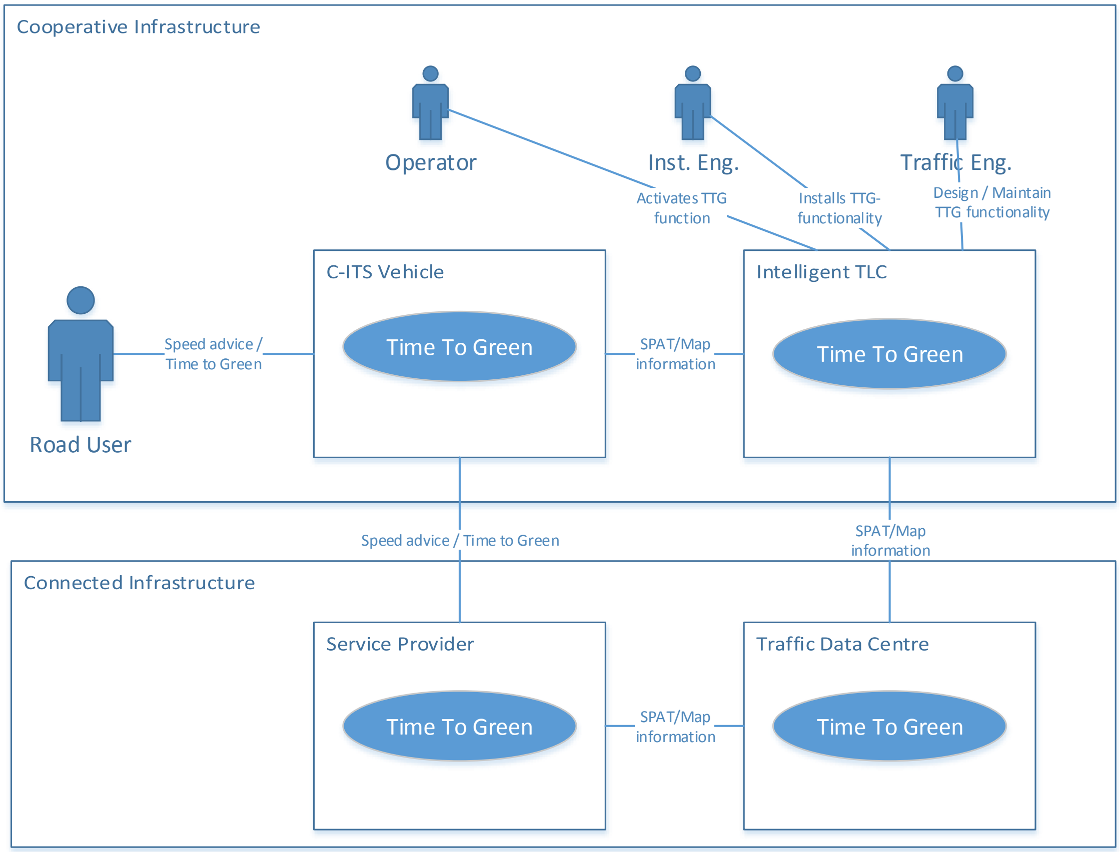



*Figure 2-1Time to Green use case diagram*

In the above diagram the Time to Green function is depicted several times. The actual implementation of the function for each process is different, of course, but all contribute and are a required to enable the complete use case function “Time to Green”.

## 2.9 Normal Flow

Cooperative infrastructure

- A Road User approaches an intersection.
- The intelligent TLC broadcasts Signal Phase and timing/ Topology information.
- The C-ITS vehicle will receive Signal Phase and timing/ Topology information that is broadcasted (every second) by the intelligent TLC.
- The C-ITS Vehicle can, after receiving the Signal Phase and timing/ Topology information, provide the Road User a speed advice and time until the next signal phase transition. With this speed advice the Road User can adjust the speed of the vehicle and reach the intersection at the beginning of the green phase.

- When the C-ITS vehicle is waiting at an intersection the received Signal Phase and timing/ Topology information will be utilized to start the engine of the C-ITS vehicle before the beginning of the green phase.

Connected infrastructure

When a Road User approaches an intersection, the intersection is equipped with “Time to Green” functionality, the vehicle is a C-ITS Vehicle, and the Road User has a Time-to-Green application in the vehicle from a Service Provider. The application can provide speed, destination and location information to the Service Provider. The Service Provider can provide the speed advice to the Road User by using the speed, destination and location of the vehicle. The Service Provider will need to obtain up to date Signal Phase & timing – and Topology-information from the Traffic Data Centre. The Intelligent TLC will provide the Traffic Data Centre with Signal Phase and timing / Topology information of the intersection every second.

Taking into account

- that  the delays involved to obtain up-to-date Signal phase & timing information from the iTLC by the Service Provider (through the TFC)
- and the limited geographic scope of the TTG-function

We can conclude that the TTG use case is not suitable for implementation by means of connected infrastructure when the road user comes within range of 650 meters of the intersection (WiFi-P range). Beyond the cooperative range the information provided by the Service provider can extend the application range of the use case.

## 2.10 Post-conditions

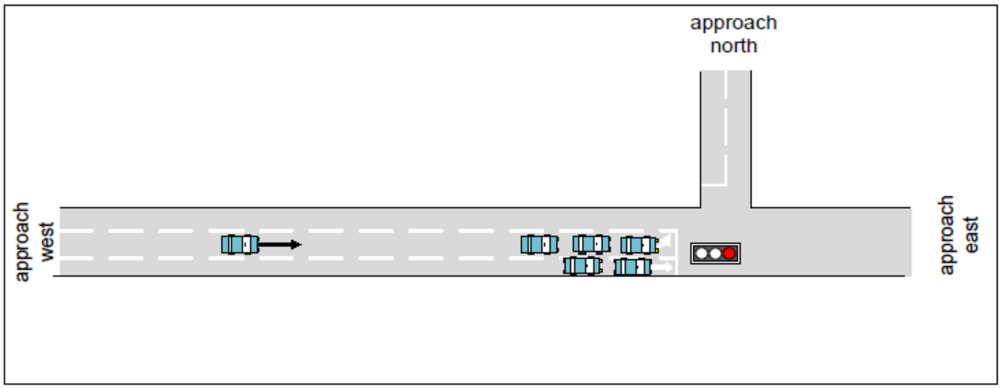
-

## 2.11 Termination conditions

The current green phase of one or more signal groups can be interrupted (aborted) due to various reasons:

- A priority request for emergency vehicles approaching the intersection.
- iTLC conflict causing a possible unsafe situation in the conflict area.
- iTLC detecting a Red light violation.
- iTLC has detected a technical failure resulting in a shutdown or reset of the iTLC.
- Approaching Public transport vehicles
- ….

## 2.12 Use-Case Illustration




## 2.13 Potential requirements

| Req: | TTG-1 |
|---|---|
| Text: | The information contained in the Signal Phase and timing messages must have an event horizon of at least 30 seconds towards the future<br>(additional details can be found in section "Implementation aspects") |

| Req: | TTG-2 |
|---|---|
| Text: | The Signal Phase and Timing (SPAT) information will be broadcasted continuously with a transmission interval of 1 second when the TTG function is active |

| Req: | TTG-3 |
|---|---|
| Text: | The Topology information (MAP) will be broadcasted continuously with a transmission interval of 2 seconds when the TTG function is active. |

| Req: | TTG-4 |
|---|---|
| Text: | The Signal Phase & Timing and MAP information will be broadcasted using:<br>iTLC RIS-Facilities (ETSI G5 Wifi-P ) for any C-ITS-Vehicle<br>iTLC TLC-Facilities (VLOG) for any Service Provider subscriber to the TDC |

## 2.14 Linked use cases (as applicable)

N/A

## 2.15 Implementation aspects

The following diagrams give an overview of the interactions between the actors and systems involved in the Time to Green use case. In the diagrams some actors and / or systems may have been greyed out, indicating that the actor or systems is not participating (no interactions) in the diagram.

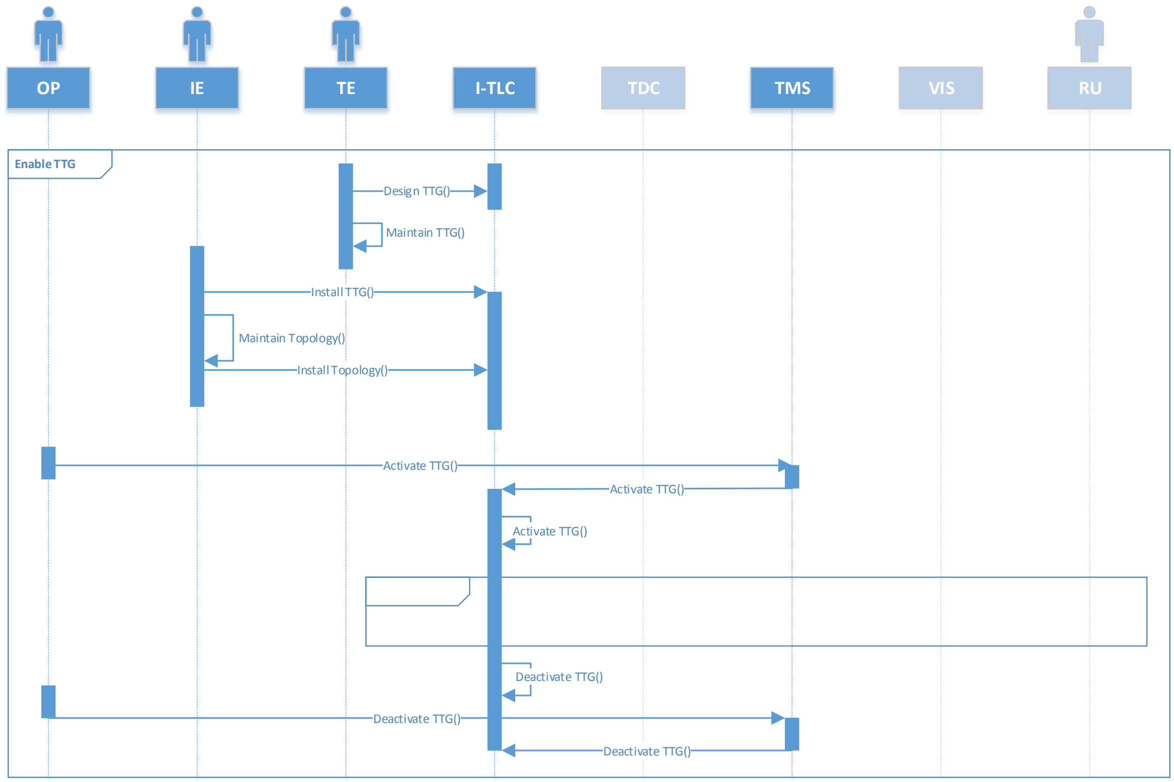



*Figure 2-2: Sequence diagram Enable Time to Green*

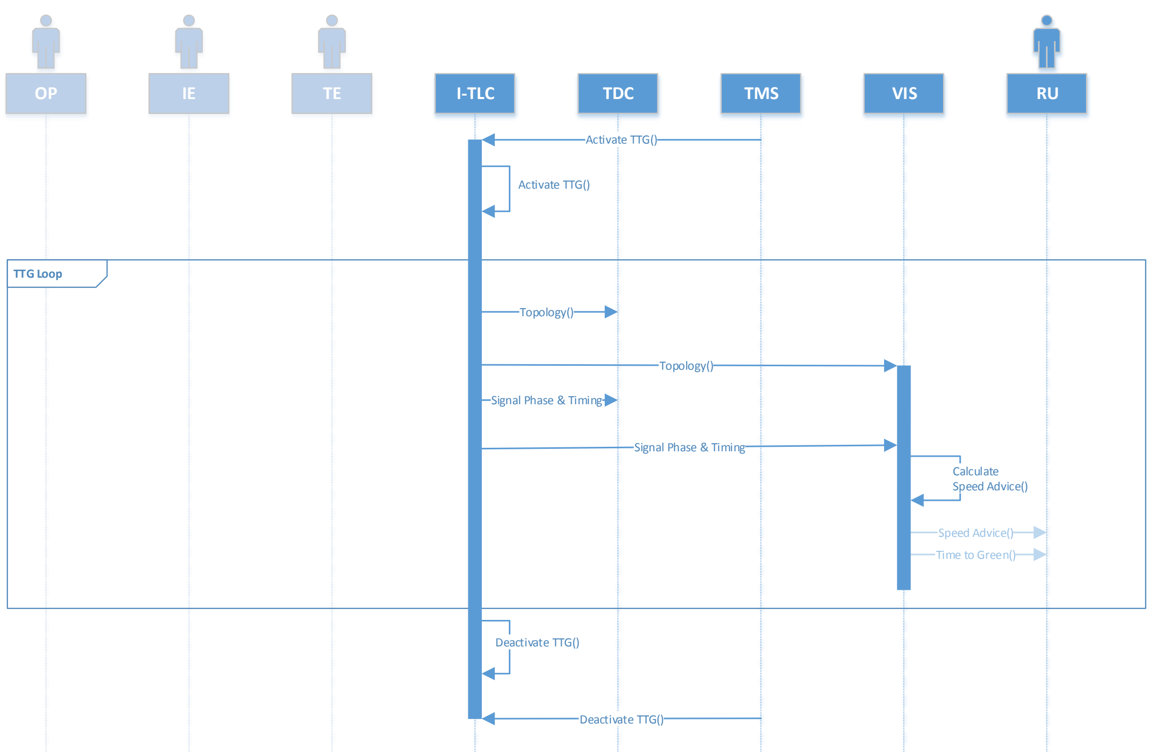



*Figure 2-3 Sequence diagram - Time to Green operational*

Interactions

| Design TTG() | |
|---|---|
| Description: | The Time To Green function will be designed by the Traffic Engineer using input from the Road Traffic Manager concerning broad cast policies.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain TTG() | |
|---|---|
| Description: | The Time To Green function that has been designed and implemented may need to be optimized due to e.g. changing traffic conditions.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain Topology() | |
|---|---|
| Description: | The Topology of the intersection may need to be changed temporary due roadworks.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Install TTG() | |
|---|---|
| Description: | The Time To Green function in the iTLC will be installed in the TLC.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Install Topology() | |
|---|---|
| Description: | The geographical layout of the intersection is made available in the iTLC<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |

| | |
|---|---|
| Frequency: | - |

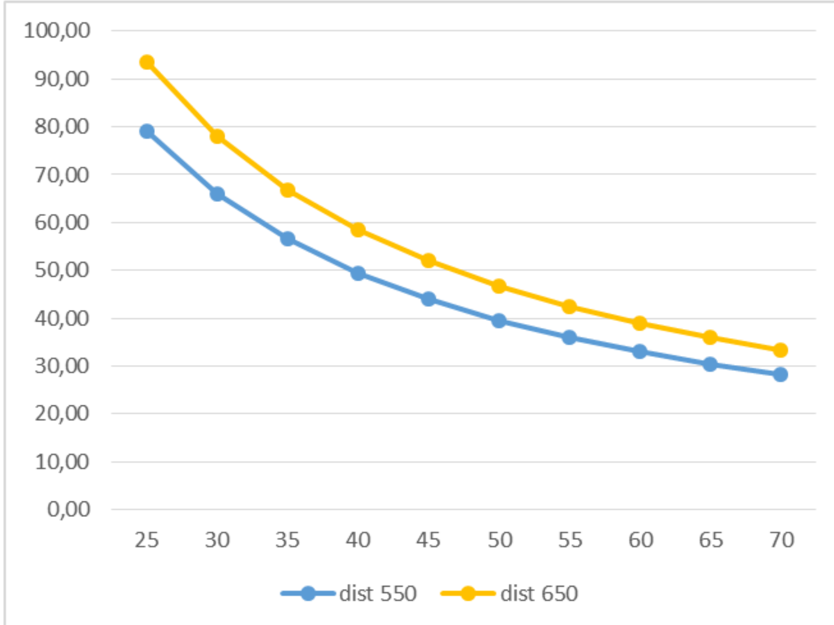
| **Activate TTG()** | |
|---|---|
| Description: | The Time To Green function in the iTLC will be enabled. |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTG ( True ) |
| Frequency: | - |

| **Deactivate TTG()** | |
|---|---|
| Description: | The Time To Green function in the iTLC will be disabled. |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTG ( False ) |
| Frequency: | |

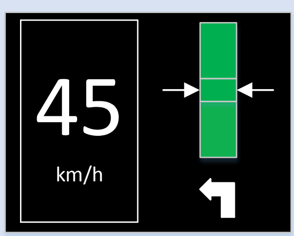
| **Topology()** | |
|---|---|
| Description: | The iTLC will provide the topology of the intersection.<br><br>This function will need to be repeated regularly (e.g. every 2 or 3 seconds) to inform al C-ITS vehicles coming within range of the intersection (UDP).<br><br>The information will also be provided to the Traffic Data Centre (TCP). |
| Interface: | TCP & UDP |
| Message: | mapData-P |
| Frequency: | Every 2 seconds |

| **Signal Phase & Timing()** | |
|---|---|
| Description: | The TLC will provide the current Sign Group State and provide the calculated signal group state with a timeframe up to 30 seconds in the future.<br><br>The information will also be provided to the Traffic Data Centre (TCP). |
| Interface: | TCP & UDP |
| Message: | signalPhaseAndTimingMessage-P |
| Frequency: | Every 1 second. |

| distance (mtr) | 500 | 550 | 600 | 650 |
|---|---|---|---|---|
| speed (km/h) | time (sec) | time (sec) | time (sec) | time (sec) |
| 25 | 72,00 | 79,20 | 86,40 | 93,60 |
| 30 | 60,00 | 66,00 | 72,00 | 78,00 |
| 35 | 51,43 | 56,57 | 61,71 | 66,86 |
| 40 | 45,00 | 49,50 | 54,00 | 58,50 |
| 45 | 40,00 | 44,00 | 48,00 | 52,00 |
| 50 | 36,00 | 39,60 | 43,20 | 46,80 |
| 55 | 32,73 | 36,00 | 39,27 | 42,55 |
| 60 | 30,00 | 33,00 | 36,00 | 39,00 |
| 65 | 27,69 | 30,46 | 33,23 | 36,00 |
| 70 | 25,71 | 28,29 | 30,86 | 33,43 |

<table>
<tr><td></td><td>
</td></tr>
</table>

| Calculate Speed advice() | |
|---|---|
| Description: | Calculate the optimal speed for the vehicle to reach the intersection when the green phase of the signal group has started.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Interface: | - |
| Message: | - |
| Frequency: | - |

<table>
<tr><th colspan="2">Speed advice()</th></tr>
<tr><td>Description:</td><td>Provide the Road User with an optimal speed enabling the road user to adjust the vehicle speed to reach the intersection when the signal group will turn to green.<br><br>
<br>This is a function in the VIS and the implementation is out of scope of this document.<br><br>Currently the implementation of the speed adjustment is left to the Road User. In the (near) future the implementation of the speed adjustment could be done by an automated vehicle driving system.</td></tr>
<tr><td>Interface:</td><td>-</td></tr>
<tr><td>Message:</td><td>-</td></tr>
<tr><td>Frequency:</td><td>-</td></tr>
</table>

| Time to Green() | |
|---|---|
| Description: | Provide the Road user the timeframe for the signal group to turn no green. |

| | |
|---|---|
| | This is a function in the VIS and the implementation is out of scope of this document. |
| Interface: | - |
| Message: | - |
| Frequency: | - |
| | |

## 2.16 Nederlandse samenvatting

De use-case “Tijd tot Groen” is een coöperatieve functie die de verkeersdeelnemers zal ondersteunen bij het nemen van een kruispunt. Het beoogde doel is om de verkeersdeelnemers met een minimum aan oponthoud het kruispunt over te laten steken. Het minimaliseren van het oponthoud uit zich in minder/of geen wachttijd voor het kruispunt, meer voertuigen die per groenfase het kruispunt over kunnen steken en mogelijk aanpassing aan de naderingssnelheid van het kruispunt.

Tevens is de “Tijd tot Groen” een basale onderliggende functionaliteit die noodzakelijk is om een aantal andere Use-Cases mogelijk te maken (bijv. Coöperatieve Groene Golf, Groen verlenging Zwaar vrachtverkeer, …).

We kunnen voor deze functie onderscheid maken in de volgende situaties:

A. Oprijden naar het kruispunt buiten de groenfase.
B. Stilstaan bij het kruispunt, wachtend op de volgende groenfase.

Situatie A:

Elk voertuig dat het kruispunt nadert, ongeacht vanuit welke richting, zal voorzien worden door de iVRI van de actuele “Signaal Groep Status” voor elke rijrichting. De “OnBoard Unit” in het voertuig kan op basis van de aangeleverde SGS, zijn huidige positie en snelheid uitrekenen wat de optimale snelheid is om bij aanvang van de eerstvolgende groenfase bij het kruispunt aan te komen. Dit resulteert in een stabielere verkeerstroom, minder milieubelasting ( uitlaatgassen door optrekken, …) en meer voertuigen per groenfase.

Situatie B:

Als een wachtend voertuig toegang heeft tot de actuele SGS kan het Start/Stop systeem de motor starten vlak voor de groenfase begint en de bestuurder informeren over de aanvang van de groenfase. De bestuurder kan dan eerder optrekken direct bij aan vang van de groenfase, vertragingen als gevolg van menselijke reactietijden behoren dan tot het verleden. Ook hiermee kunnen er meer voertuigen gebruik maken van een groenfase.

# 3 Use case U08-B “Time to Red”

## 3.1 Introduction Use-Case

### 3.1.1 Use case ID

U08-b: Time to Red

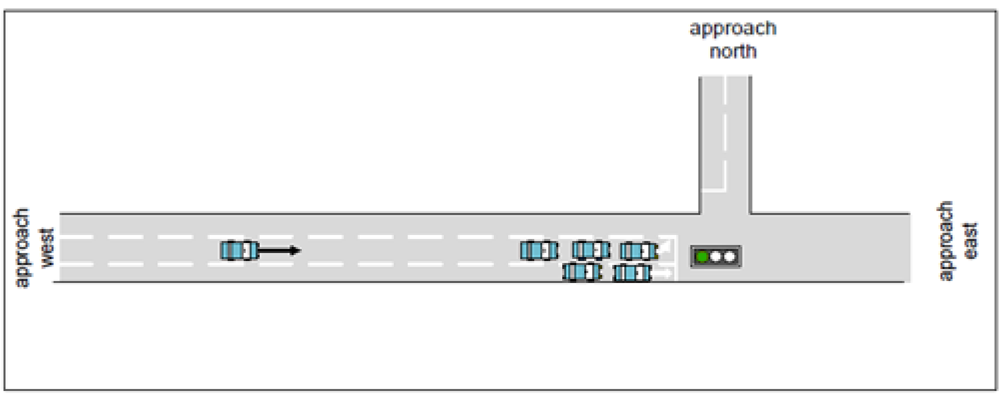
### 3.1.2 Background

The use-case has been defined within the scope of the BBV project to support approaching vehicles of any type (e.g. car, bus, bicycle …) in a smoother transition, reduce unnecessary stops and to increase the intersection safety. The use-case has been selected due to the ranking provided in Deliverable D.

### 3.1.3 Objective

The envisioned result is that the Road User will have a smoother travelling experience when crossing intersections. The use case currently focusses on vehicles that could benefit from the TTR function.

- Approaching vehicles can adapt their speed causing the vehicle to reach the intersection when the light has turned to red, thus minimizing the amount of physical stops (increased traffic flow, safety, and reduced environmental impact).
- Vehicles waiting at the intersection to cross the stop bar during the green phase of a signal group can anticipate, using the TTR information, by either picking up speed or letting go off the throttle and wait for the next green phase.




Time to Red can be viewed from different perspectives.

A. From the perspective of driving towards a traffic light and the traffic light is green.
B. From the perspective of waiting for a signal group to turn to red during the green phase.

Taking into account

- that  the delays involved to obtain up-to-date Signal phase & timing information from the iTLC by the Service Provider (through the TFC)
- and the limited geographic scope of the TTR-function

We can conclude that the TTR use case is not suitable for implementation by means of connected infrastructure when the road user comes within range of 650 meters of the intersection (wifi-P range). Beyond the cooperative range the information provided by the Service provider can extend the application range of the use case.

### 3.1.4 Source:

ISO TS-19091 (v 5.14); MS4, MS5

SAE J2735 Appendix H

DITCM Architecture; §3.1.1.11, §3.1.1.13, §3.3.10

Eco-AT SWP2.1 Overview On Use Cases v02.00; §2.4

Eco-AT SWP2.1 Intersection Safety v02.00; §4 Use case 1, Use case 3

VRI Tafel

ASN.1 definitions ETSI, dd 04-11-2015

## 3.2 Description Use-Case

Perspective A:

Any type of vehicle approaching a traffic light from any direction will be provided with the current traffic light phase schedule by the intelligent TLC. The OnBoard unit in the vehicle can calculate an approach speed, at which the vehicle will reach the intersection during a green phase. This calculated approach speed is presented to the road user who can then avoid an unnecessary stop.

The Traffic Light Controller providing time to red information to approaching vehicles enables in-vehicle applications implementing use cases like ‘Green Light Optimal Speed Advise’.

Perspective B:

The same information can be used by a stationary road user waiting to cross over the conflict area the “Green phase” when somewhere in the back of a platoon. The road user can decide either accelerate to benefit from the current “Green phase” or choose to wait for the next “Green phase”. Thus enabling a smoother approach to the intersection of increasing the amount of vehicles that benefit from the current “Green Phase”.

### 3.2.1 Current situation

In the current situation distributing Time To Red information is limited:

- To a small geographic area at close proximity (visual range) of the intersection.
- Road users can only be informed using visual means at close range.
- Road users further away from the intersection cannot be informed, thus cannot anticipate on the current Signal State phase information at hand.

### 3.2.2 Transition phase

During the transition phase

The TTR information dispersion is extended beyond the range of visual means at an intersection. Road users outside the visual range of the intersection can be informed due to the nature of cooperative technology. These road users can adapt the approach speed of the vehicle enabling them to reach the intersection at the start of the Green Phase. Effectively increasing the amount of vehicles capable of utilising the green phase of a signal group, and reducing the environmental impact of vehicles approaching and crossing an intersection.

### 3.2.3 Post transition phase

When all vehicles participating in traffic are equipped with cooperative systems the utilisation of visual means required to distribute TTR information ceases to be necessary. Thus creating opportunities to reduce on costs when creating and /or maintaining intersections.

## 3.3 Target System

- Intelligent TLC

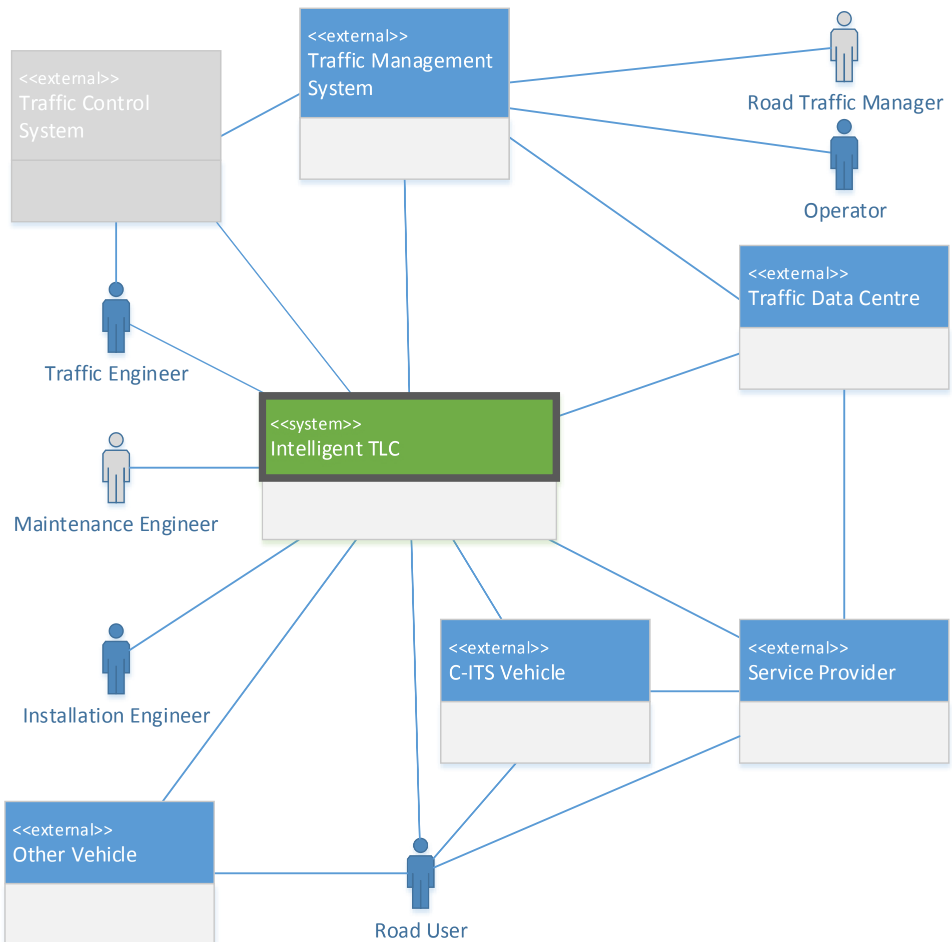
## 3.4 Implementation environment

Selected signalized intersections equipped with an iTLC.

The diagram in the next paragraph illustrates the context of the iTLC.

## 3.5 Actors

As can be viewed in the following diagram the actors involved are mentioned in the table below by describing their “Role” (= involvement) in the Time to Red use case.




The actors that do not participate in the use case have been greyed out.

| **External entity** | | |
|---|---|---|
| Traffic Engineer (TE) | | |
| | Role | Defines & maintains TTR-functionality (out of scope, is a pre-condition for the use-case) |
| Installation Engineer (IE) | | |
| | Role | Installs the TTR-functionality in iTLC |
| Operator | | |
| | Role | Activates broadcast of TTR information via TMS. |
| Traffic Management System (TMS) | | |
| | Role | Activates the TTR function on the iTLC upon request from the Operator. |
| Traffic Data Centre (TDC) | | |
| | Role | Receives the current Signal Group State and intersection Topology from the iTLC and offers the information to subscribed service providers. |
| Service Provider (SP) | | |
| | Role | Provide/configures connected service e.g. geographical boundaries |
| C-ITS Vehicle (VIS) | | |
| | Role | Receives the information from the iTLC.<br>Triggers sensors (loop detector below the road surface) that influences the light phase schedule. |

| Other Vehicle | | |
|---|---|---|
| | Role | Triggers sensors (loop detector below the road surface) that influences the light phase schedule. |
| Road user (RU) | | |
| | Role | Triggers sensors (e.g. pedestrian push button) that influences the light phase schedule |

## 3.6 Pre-conditions

Intelligent TLC:

- is operational and is not in failure state (cooperative, connected).
- has been provided the topology of the intersection (cooperative, connected).
- is capable of providing Signal Phase and Timing information (cooperative, connected).
- is capable of calculating the Signal Phase and Timing (cooperative, connected).
- TTR function has been designed and made available on the iTLC.

C-ITS Vehicle is capable of receiving and processing the information being:

- Intersection Topology (cooperative)
- Signal Phase and Timing (cooperative, connected)
- Speed Advice (connected)

Operator has activated Time to Red functionality (cooperative, connected).

Traffic Engineer has designed, implemented and tested the TTR functionality for an iTLC (cooperative, connected).

Installation Engineer has installed and commissioned an iTLC with TTR functionality (cooperative, connected).

Service Provider provides a TTR service for C-ITS Vehicles (connected).

Road User has access to TTR information in the vehicle he/she is operating (cooperative, connected).

## 3.7 Trigger conditions

Cooperative infrastructure:

- The intelligent TLC is switched to “Mode Regelen”.

Connected infrastructure:

- The intelligent TLC is switched to “Mode Regelen”.
- The vehicle sends speed, direction and location information to the Service Provide
- 

## 3.8 Use-Case Diagram

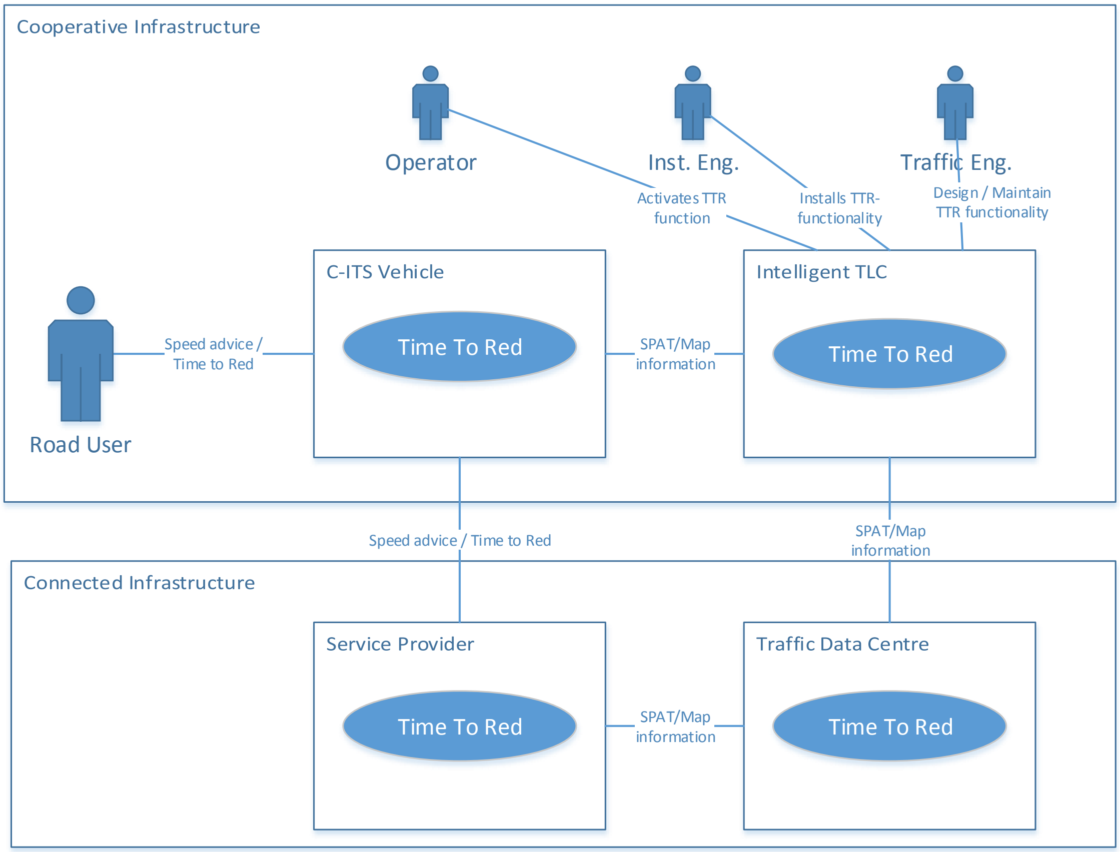



*Figure 3-1 Time to Red use case diagram*

In the above diagram the Time to Red function is depicted several times. The actual implementation of the function for each process is different, of course, but all contribute and are a required to enable the complete use case function “Time to Red”.

## 3.9 Normal Flow

Cooperative infrastructure

- A Road User approaches an intersection.
- The intelligent TLC broadcasts Signal Phase and timing/ Topology information.
- The C-ITS vehicle will receive Signal Phase and timing/ Topology information that is broadcasted (every second) by the intelligent TLC.
- The C-ITS Vehicle can, after receiving the Signal Phase and timing/ Topology information, provide the Road User a speed advice and time until the next signal phase transition. With this speed advice the Road User can adjust the speed of the vehicle and reach the intersection the end of the green phase. Or choose to wait for the next green phase at the intersection.

- When the C-ITS vehicle is waiting at an intersection the received Signal Phase and timing/ Topology information can be utilized by the driver to increase acceleration to benefit from the current green phase before transition to red will occur.

Connected infrastructure

When a Road User approaches an intersection, the intersection is equipped with “Time to Red” functionality, the vehicle is a C-ITS Vehicle, and the Road User has a Time to Red application in the vehicle from a Service Provider. The application can provide speed, destination and location information to the Service Provider. The Service Provider can provide the speed advice to the Road User by using the speed, destination and location of the vehicle. The Service Provider will need to obtain up to date Signal Phase & timing – and Topology-information from the Traffic Data Centre. The Intelligent TLC will provide the Traffic Data Centre with Signal Phase and timing / Topology information of the intersection every second.

Taking into account

- that the delays involved to obtain up-to-date Signal phase & timing information from the iTLC by the Service Provider (through the TFC)
- and the limited geographic scope of the TTR-function

We can conclude that the TTR use case is not suitable for implementation by means of connected infrastructure when the road user comes within range of 650 meters of the intersection (WiFi-P range). Beyond the cooperative range the information provided by the Service provider can extend the application range of the use case.

## 3.10 Post-conditions

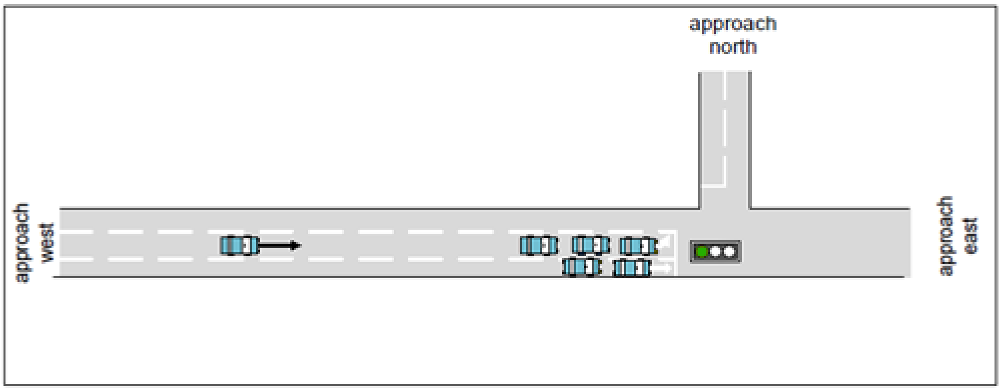
-

## 3.11 Termination conditions

The current green phase of one or more signal groups can be interrupted (aborted) due to various reasons:

- A priority request for emergency vehicles approaching the intersection.
- iTLC conflict causing a possible unsafe situation in the conflict area.
- iTLC detecting a Red light violation.
- iTLC has detected a technical failure resulting in a shutdown or reset of the iTLC.
- ….

## 3.12 Use-Case Illustration




## 3.13 Potential requirements

| Req: | TTR-1 |
|---|---|
| Text: | The information contained in the Signal Phase and timing messages must have an event horizon of at least 30 seconds towards the future |

| Req: | TTR-2 |
|---|---|
| Text: | The Signal Phase and Timing (SPAT) information will be broadcasted continuously with a transmission interval of 1 second when the TTG function is active |

| Req: | TTR-3 |
|---|---|
| Text: | The Topology information (MAP) will be broadcasted continuously with a transmission interval of 2 seconds when the TTG function is active. |

| Req: | TTR-4 |
|---|---|
| Text: | The Signal Phase & Timing and MAP information will be broadcasted using:<br>iTLC RIS-Facilities (ETSI G5 Wifi-P ) for any C-ITS-Vehicle<br>iTLC TLC-Facilities (VLOG) for any Service Provider subscriber to the TDC |

## 3.14 Linked use cases (as applicable)

-

## 3.15 Implementation aspects

The following diagrams give an overview of the interactions between the actors and systems involved in the Time to Red use case. In the diagrams some actors and / or systems may have been greyed out, indicating that the actor or systems is not participating (no interactions) in the diagram.

Document: U08-A, U08-B, U07-B, U07-I, U04-A, U05-A

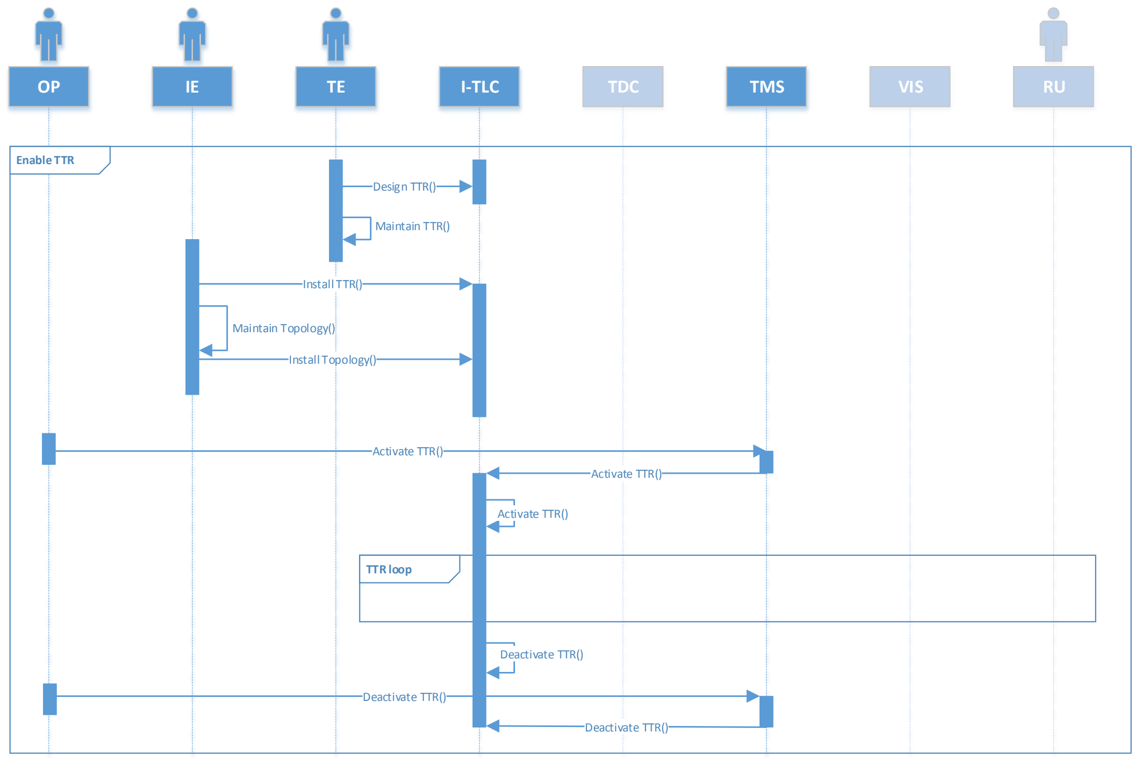



*Figure 3-2 Sequence diagram Enable Time to Red*

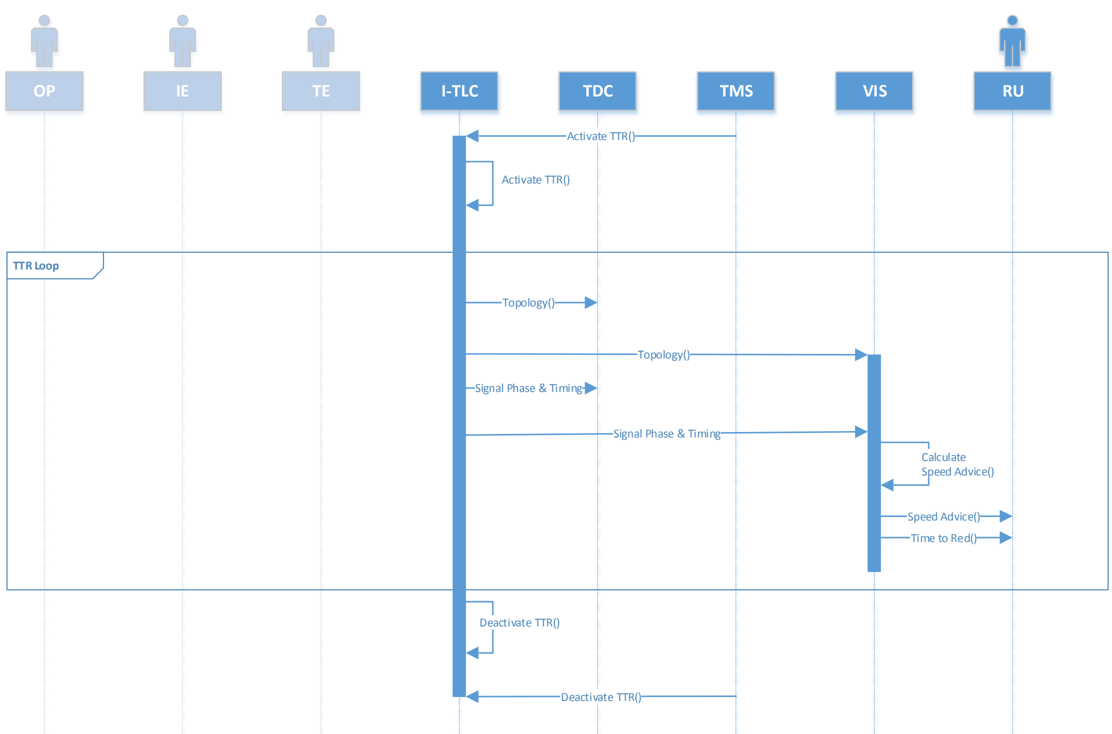



*Figure 3-3Sequence diagram - Time to Red operational*

## Interactions

| Design TTR() | |
|---|---|
| Description: | The Time to Red function will be designed by the Traffic Engineer using input from the Road Traffic Manager concerning broad cast policies.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain TTR() | |
|---|---|
| Description: | The Time to Red function that has been designed and implemented may need to be optimized due to e.g. changing traffic conditions.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain Topology() | |
|---|---|
| Description: | The Topology of the intersection may need to be changed temporary due roadworks.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Install TTR() | |
|---|---|
| Description: | The Time to Red function in the iTLC will be installed in the TLC.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Install Topology() | |
|---|---|
| Description: | The geographical layout of the intersection is made available in the iTLC<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Activate TTR() | |
|---|---|
| Description: | The Time to Red function in the iTLC will be enabled. |

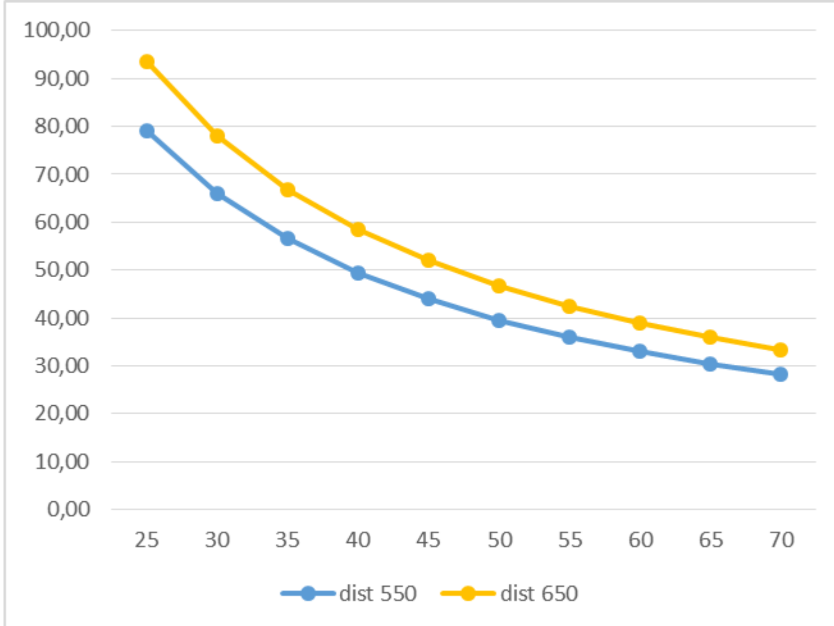
| | |
|---|---|
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTR ( True ) |
| Frequency: | - |

| Deactivate TTR() | |
|---|---|
| Description: | The Time to Red function in the iTLC will be disabled. |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTR ( False ) |
| Frequency: | |

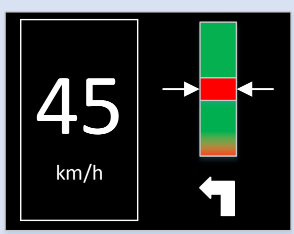
| Topology() | |
|---|---|
| Description: | The iTLC will provide the topology of the intersection.<br><br>This function will need to be repeated every 3 seconds to inform al C-ITS vehicles coming within range of the intersection (UDP).<br><br>The information will also be provided to the Traffic Data Centre (TCP). |
| Interface: | TCP & UDP |
| Message: | mapData-P |
| Frequency: | Every 2 seconds |

| Signal Phase & Timing() | |
|---|---|
| Description: | The TLC will provide the current Sign Group State and provide the calculated signal group state with a timeframe up to 30 seconds in the future.<br><br>The information will also be provided to the Traffic Data Centre (TCP). |
| Interface: | TCP & UDP |
| Message: | signalPhaseAndTimingMessage-P |
| Frequency: | Every 1 second. |

| distance (mtr) | 500 | 550 | 600 | 650 |
|---|---|---|---|---|
| speed (km/h) | time (sec) | time (sec) | time (sec) | time (sec) |
| 25 | 72,00 | 79,20 | 86,40 | 93,60 |
| 30 | 60,00 | 66,00 | 72,00 | 78,00 |
| 35 | 51,43 | 56,57 | 61,71 | 66,86 |
| 40 | 45,00 | 49,50 | 54,00 | 58,50 |
| 45 | 40,00 | 44,00 | 48,00 | 52,00 |
| 50 | 36,00 | 39,60 | 43,20 | 46,80 |
| 55 | 32,73 | 36,00 | 39,27 | 42,55 |
| 60 | 30,00 | 33,00 | 36,00 | 39,00 |
| 65 | 27,69 | 30,46 | 33,23 | 36,00 |
| 70 | 25,71 | 28,29 | 30,86 | 33,43 |




| **Calculate Speed advice()** | |
|---|---|
| Description: | Calculate the optimal speed for the vehicle to reach the intersection when the green phase of the signal group has started.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| **Speed advice()** | |
|---|---|
| Description: | Provide the Road User with an optimal speed enabling the road user to adjust the vehicle speed to reach the intersection when the signal group will turn to green.<br><br> <br><br>This is a function in the VIS and the implementation is out of scope of this document.<br><br>Currently the implementation of the speed adjustment is left to the Road User. In the (near) future the implementation of the speed adjustment could be done by an automated vehicle driving system. |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| **Time to Red()** | |
|---|---|
| Description: | Provide the Road user the timeframe for the signal group to turn no green. |

| | |
|---|---|
| | This is a function in the VIS and the implementation is out of scope of this document. |
| Interface: | - |
| Message: | - |
| Frequency: | - |

## 3.16 Nederlandse samenvatting

De use-case “Tijd tot Rood” is een coöperatieve functie die de verkeersdeelnemers zal ondersteunen bij het nemen van een kruispunt. Het beoogde doel is om de verkeersdeelnemers met een minimum aan oponthoud het kruispunt over te laten steken. Het minimaliseren van het oponthoud uit zich in minder/of geen wachttijd voor het kruispunt, meer voertuigen die per groenfase het kruispunt over kunnen steken en mogelijk aanpassing aan de naderingssnelheid van het kruispunt.

We kunnen voor deze functie onderscheid maken in de volgende situaties:

A. Oprijden naar het kruispunt tijdens de groenfase

B. Wachtend voor het kruispunt tijdens de groenfase.

Situatie A:

Elk voertuig dat het kruispunt nadert, ongeacht vanuit welke richting, zal voorzien worden door de iVRI van de actuele “Signaal Groep Status” voor elke rijrichting. De “OnBoard Unit” in het voertuig kan op basis van de aangeleverde SGS, zijn huidige positie en snelheid uitrekenen wat de optimale snelheid is om gebruikt te kunnen make van de huidige groenfase dan wel bij aanvang van de eerstvolgende groenfase bij het kruispunt aan te komen. Dit resulteert in een stabielere verkeerstroom, minder milieubelasting ( uitlaatgassen door optrekken, …) en meer voertuigen per groenfase.

Situatie B:

De actuele SGS kan gebruikt worden door een voertuig wachtend ergens in het peloton om de kruising over te steken om te bepalen of er gebruik gemaakt kan worden van de huidige of de volgende groenfase voor zijn richting. De kan resulteren in een veel rustiger verkeersbeeld (minder acceleratie om toch nog even groen te pakken)

Met betrekking tot beschikbaar maken van deze functie met behulp van “Connected” of “Coöperatieve” technieken kan het volgende gesteld worden:

Het tijdsaspect waarmee de informatie gedeeld moet worden met de coöperatieve voertuigen is dusdanig kort, binnen en straal van 650 meter van het kruispunt, dat het beschikbaar maken van deze functie buiten bereik valt van de “connected” route.

Op het moment de TTR-informatie over een groter gebied (buiten 650 meter van het kruispunt) beschikbaar gemaakt zal gaan worden vervalt de beperking voor het tijdsaspect en is de “connected” route mogelijk.

# 4 Use case U07-B “Gap measurement”

Gap measurement is used to determine the optimal timing to end the green phase with respect to the vehicles.

## 4.1 Introduction Use-Case

Information about the actual vehicles approaching the TLC is needed to determine the end of the green phase. The more information is available the better timing will be.

### 4.1.1 Use case ID:

U07-b

### 4.1.2 Background:

Currently gap measurement is performed at a fixed distance from the stop line. Some dynamics are supported by means of parameters defining the minimum size of gap to be measured.

This mechanism has a limitation since no information is available about traffic upstream of the measurement point. This leads to situations in which a gap is measured while, from a traffic engineer point of view, it should not lead to ending the green phase. Also the existing mechanism is purely available for vehicles exluding other road users. Using new technologies more information is available about approaching traffic upstream of the measurement point that can be used to decide when to terminate the green phase.

Ultimately, new technology will replace the current gap measurement mechanism leading to less installation and maintenance costs.

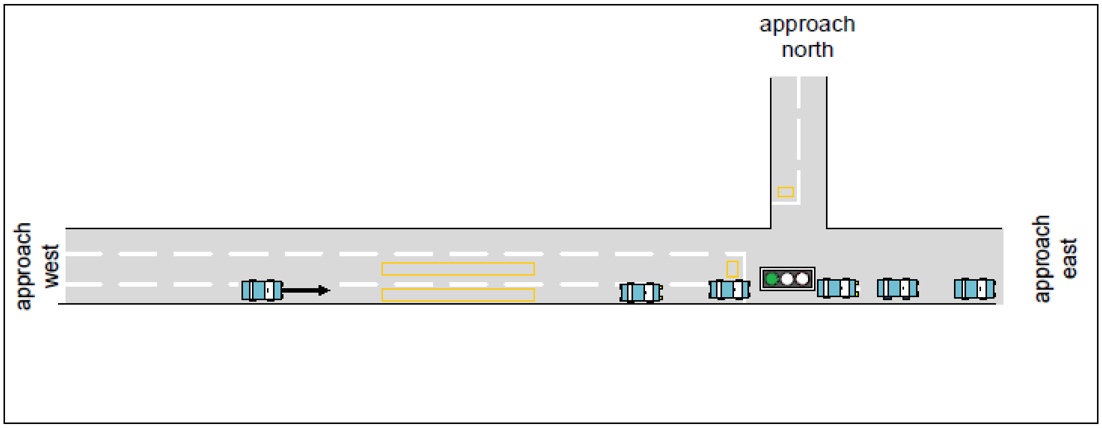
The Dutch traffic control philosophy supports a number of internal signalgroup statuses:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |

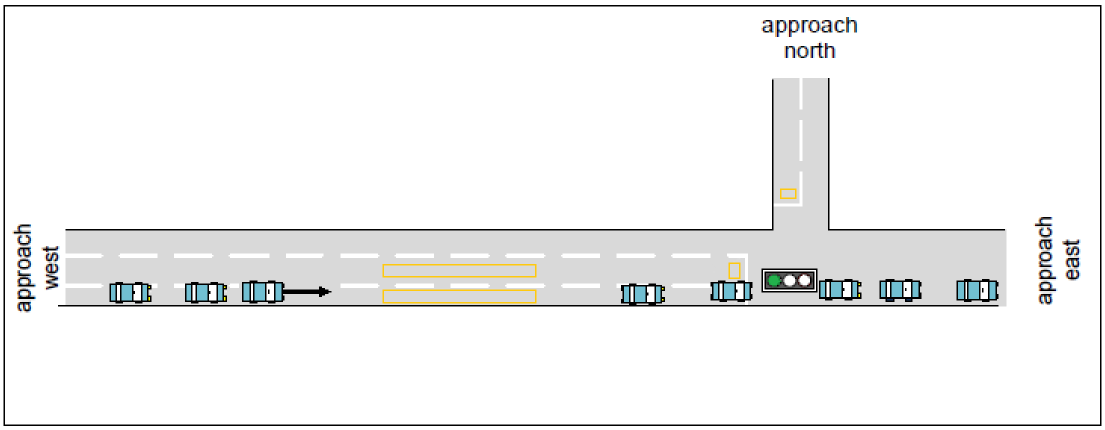
1. Red
2. Red after request
3. Prestart green
4. Fixed green
5. Waiting green
6. Extension green
7. Parallel extension green
8. Amber

The statuses are in principle sequential. All statuses except Red and Waiting green have a configurable maximum duration. The gap measurement determines the ending of extension green. Note that after gap measurement the signalgroup might still show green externally due to parallel extension green.

Note that the traffic control philosophy itself is outside the scope of this document.




About 30 meter downstream, the stop line a long loop is used to measure the gap in the platoon. After a configurable time of unoccupied state the gap is triggering the ending of extension green.




The current gap measurement does not distinct a difference in the situations shown in the pictures above. This will most likely lead to road users being captured by a red light.

### 4.1.3 Objective:

The objective of this use case is to prevent the current gap measurement mechanism to end to green phase untimely. This has a positive effect on throughput. Ultimately, it will replace the current gap measurement mechanism saving installation costs. Note that this use case is also applicable for slow traffic whereas current gap measurement is not.

Since this use case is very specific to the local situation at the intersection it fully depends on V2I communication. The information provided is used to optimize the active traffic control strategy at a very low level.

Therefore, this use case purely leans on cooperative techniques and exclude connected solution. Note that connected solutions, as well as other cooperative solutions, can be used for other criteria influencing the traffic control strategy. Such solutions are outside the scope of this document.

### 4.1.4 Source:

For more information about gap measurement and traffic control philosophy see the CROW publications

- http://www.crow.nl/publicaties/handboek-verkeerslichtenregelingen-2014

## 4.2 Description Use-Case

Cooperative technologies provide vehicle information including a number of characteristics to the iTLC. Based on this information the iTLC can calculate if an approaching vehicle is able to reach the stopline before the green phase will be ended. If so, the green phase can be extended until the vehicle passes the stop line. Note that the green phase extension is limited to a maximum configurable number of seconds. Also, depending on the traffic algorithm, there might be other criteria for ending a green phase (e.g. conflicting traffic).

This use case specifically zooms in on gap measurement. During the transition phase of cooperative technology (i.e. more and more vehicles equipped) this use case provide additional information used to decide if the existing gap measurement should be optimized.

No direct feedback about the gap measurement process is provided. Road users and centres are informed by means of signal group status and timing. There is no use to provide internal traffic control strategy information at that level since that would lead to an overkill of irrelevant information.

After the transition period (i.e. 85% of vehicles are equipped) this use case replaces the current gap measurement mechanism. Also during this period it seems valuable to already replace the current mechanism at side roads.

### 4.2.1 Transition situation using current gap measurement

During the transition period towards cooperative technology, there are limited vehicles equipped. This information can be used to overcome the limitation of the existing gap measurement.

Based on the number of approaching vehicles downstream the detection point and close enough to reach the green in time, the TLC decides to maintain the extension green status.

The TLC must be able to filter information from approaching vehicles based on position and expected time of arrival at the stop line.

### 4.2.2 Transition situation replacing current gap measurement

During the transition period the number of cooperative vehicles is growing. At some point there is enough V2I information available to replace the existing gap measurement mechanism at side roads. These roads typically have less traffic and are less dependent on gap measurement from a traffic control point of view.

The TLC monitors the number of approaching vehicles filtering on position and expected time of arrival at the stop line per signalgroup. Based on this information the extension green state is either maintained or ended. Note that the extension green state will also be ended by a configurable maximum time.

### 4.2.3 End situation

Ultimately the cooperative technology will replace the existing gap measurement mechanism saving installation costs.

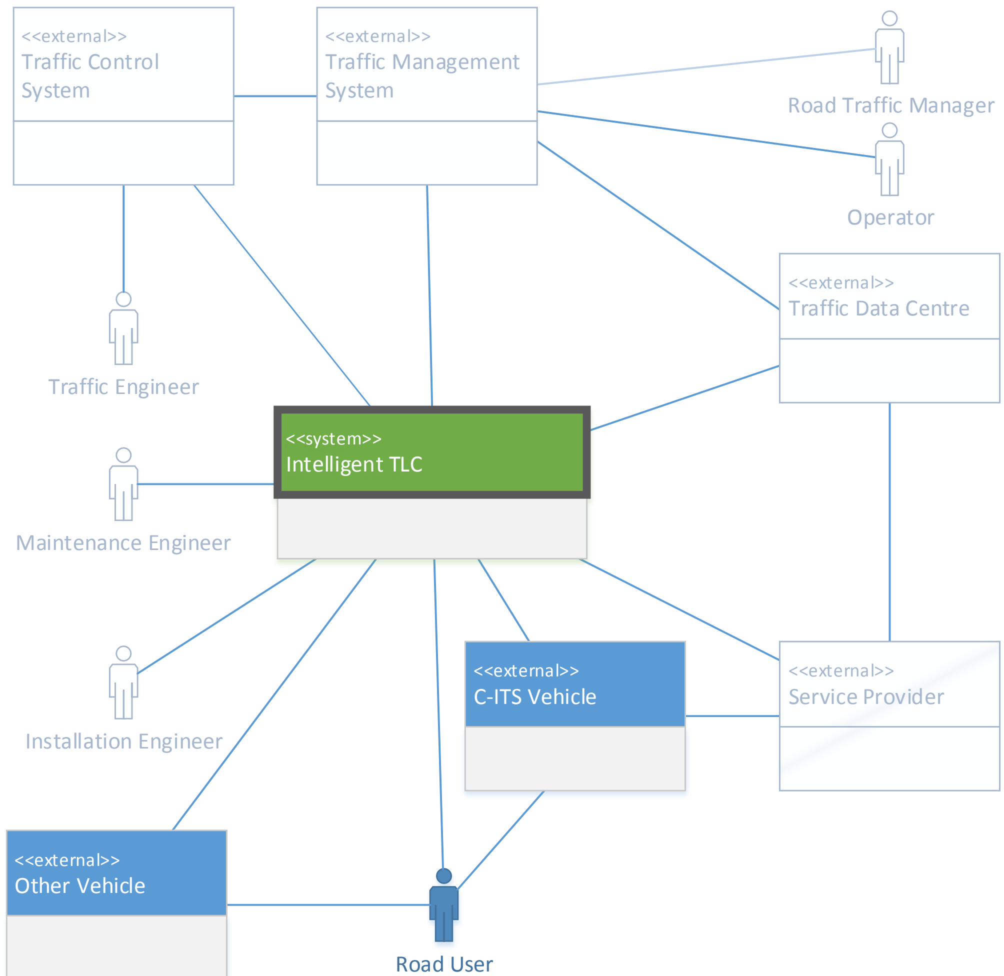
The TLC monitors the approaching road users per signalgroup filtering on position and expected time of arrival at the stop line. Also it determines the first encountered delta in expected time of arrival greater than the configurable gap threshold. Based on this information the TLC decides to either maintain or end the extension green state. Note that this state is also limited by a configurable maximum time.

Note that more detailed arriving pattern algorithms are in the domain of network traffic control applications. As such it influences the decisions made by the TLC in a network of TLC's via different criteria. These mechanisms are outside the scope of this document.

## 4.3 Target System (as applicable)

Intelligent TLC

## 4.4 Actors




| **External entity** | | |
|---|---|---|
| C-ITS Vehicle (VIS) | | |
| | Role | Triggers conventional and cooperative gap measurement |
| Other Vehicle | | |
| | Role | Triggers conventional gap measurement |
| Road user (RU) | | |
| | Role | n.a. |

## 4.5 Pre-conditions (if any)

Intelligent TLC:

- Is running in mode Control
- Has gap measurement configured
- Is capable of retrieving vehicle information; depending on interface already tailored to the filtering needs
- Is able to map vehicle information on signalgroups (topology)

C-ITS Vehicle

- Provides position, direction and speed information on regular basis

## 4.6 Triggers conditions (if any)

The trigger for gap measurement is the start of the signalgroup state Extension green. Input for the measurement by means of loop detector and vehicle data is continuously received.

## 4.7 Normal Flow (as applicable)

During the Extension green state the TLC continuously determines if the criteria for ending the state are met.

### 4.7.1 Transition situation including existing mechanism

Per signalgroup in state Extension green:

- TLC checks if a gap is measured on the configured detection point
- TLC checks if there are approaching vehicles within a configurable travel time downstream the detection point
- TLC decides to maintain or end the Extension green state

### 4.7.2 Transition situation replacing existing mechanism

Per signalgroup in state Extension green:

- TLC checks how many vehicles are approaching within a configurable travel time downstream stop line
- TLC decides to maintain or end the Extension green state

### 4.7.3 End situation

Per signalgroup in state Extension green:

- TLC checks how many vehicles are approaching within a configurable travel time downstream stop line
- TLC decides to maintain or end the Extension green state

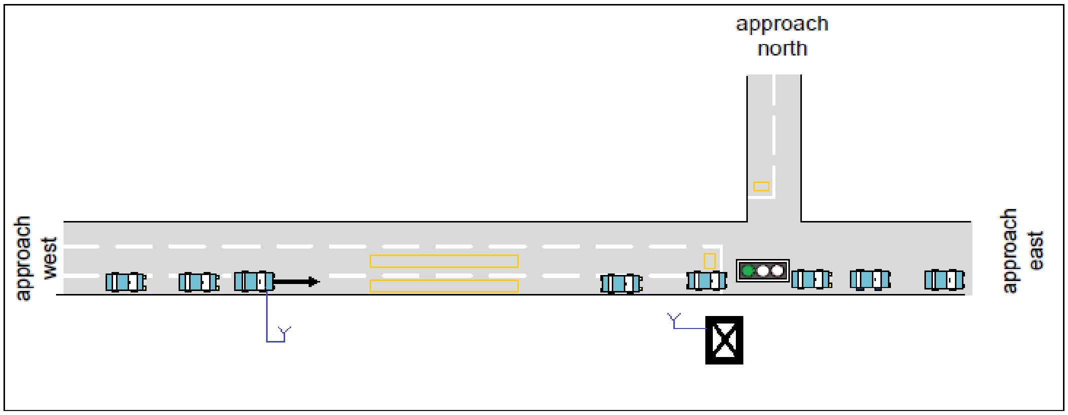
## 4.8 Post-conditions (if any)

n/a

## 4.9 Terminiation conditions (if any)

The traffic control strategy might include criteria besides gap measurement resulting in ending the green phase of a signalgroup. If any of these criteria are met the Extension green state is ended resulting in termination of the gap measurement.

## 4.10 Use-Case Illustration (as applicable)




Approaching vehicle provides information to the iTLC to improve the gap measurement mechanism. Ultimately most vehicles are equipped resulting in a full replacement of the existing loop based mechanism. During the transition period, the replacement can already be implemented on roads less dependent on gap measurement (typically side roads).

## 4.11 Nederlandse samenvatting

Hiaatmeting is bedoeld om optimale timing van einde verlenggroen te bepalen. De huidige meting vindt in principe plaats met de “lange lus” op een vaste afstand van de stopstreep (zie CROW publicaties voor meer informatie). Het mechanisme kent beperkingen:

- Geen informatie van voertuigen voorbij de puntmeting
- Alleen beschikbaar voor gemotoriseerd verkeer

Nieuwe technologieën leveren meer en nauwkeurige informatie waardoor betere (timing) beslissingen genomen kunnen worden.

- Informatie van voertuigen (bijv. snelheid, aantal) voorbij het meetpunt
- Soortgelijke informatie van andere typen weggebruikers

Deze use-case voorkomt onterecht beëindigen van verlenggroen op basis van hiaatmeting. Initieel, bij lage penetratiegraad van coöperatieve voertuigen, kan het huidige mechanisme verbeterd worden. Tijdens de transitiefase naar coöperatieve voertuigen zal het algoritme steeds nauwkeuriger worden. Tevens kan op minder belangrijke richtingen de conventionele hiaatmeeting uit gefaseerd worden. Ultiem vervangt coöperatieve technologie de huidige meetmethode.

De besparing omvat zowel een winst in doorstroming (op basis van betere algoritmes) alsook een besparing in aanleg en onderhoud van lussen.

Voorwaarde voor het welslagen is een VRI met een ITS applicatie die voertuiginformatie kan ontvangen en verwerken. Daarbij wordt de relatie tussen voertuiginformatie en signaalgroepen gelegd.

# 5 Use case U07-I “Cooperative Green Wave”

## 5.1 Introduction Use-Case

The Cooperative Green Wave use-case aims to improve the benefit of the current Green Waves by using C-ITS.

### 5.1.1 Use case ID:

U07-i: Cooperative Green Wave

U10-f: Cooperative Green Wave for Bicycles

### 5.1.2 Background:

In the current situation Green Waves can be implemented on road infrastructure with several sequential controlled intersections. The objective of Green Waves in general is that vehicles travelling along with the Green Wave (with an appropriate speed) will not have to stop at intersections (they get a green light). This leads to:

- less acceleration and breaking
- reduction of noise production
- reduction of CO2, NOx and PM10 emissions
- reduction of fuel consumption
- increased throughput

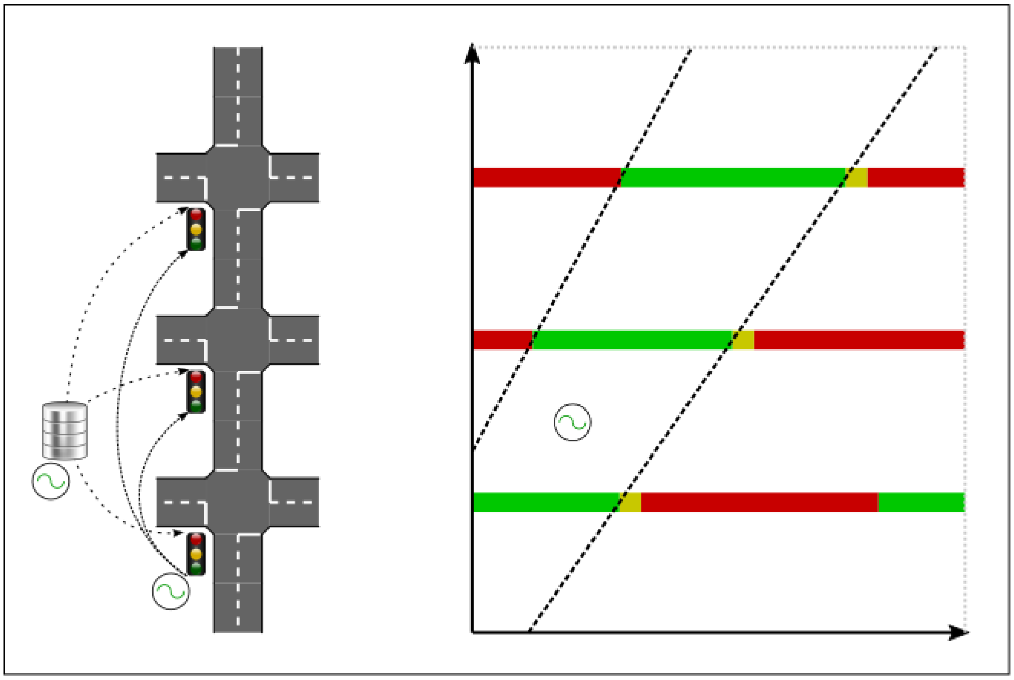
In the current situation the road user is not informed of the green wave in most cases. In some cases there can be a static or dynamic sign alongside the road, sometimes even with a dynamic speed advice.

In the current situations there are two types of implementation of green waves, centralized or decentralized. In a decentralized implementation there’s one master TLC and one or more slave TLC(s). The master TLC initiates the Green Wave, the slave TLC(s) are coordinated by the master TLC. In a centralized implementation the Green Wave is generated from the central software and distributed to the coordinated intersections.

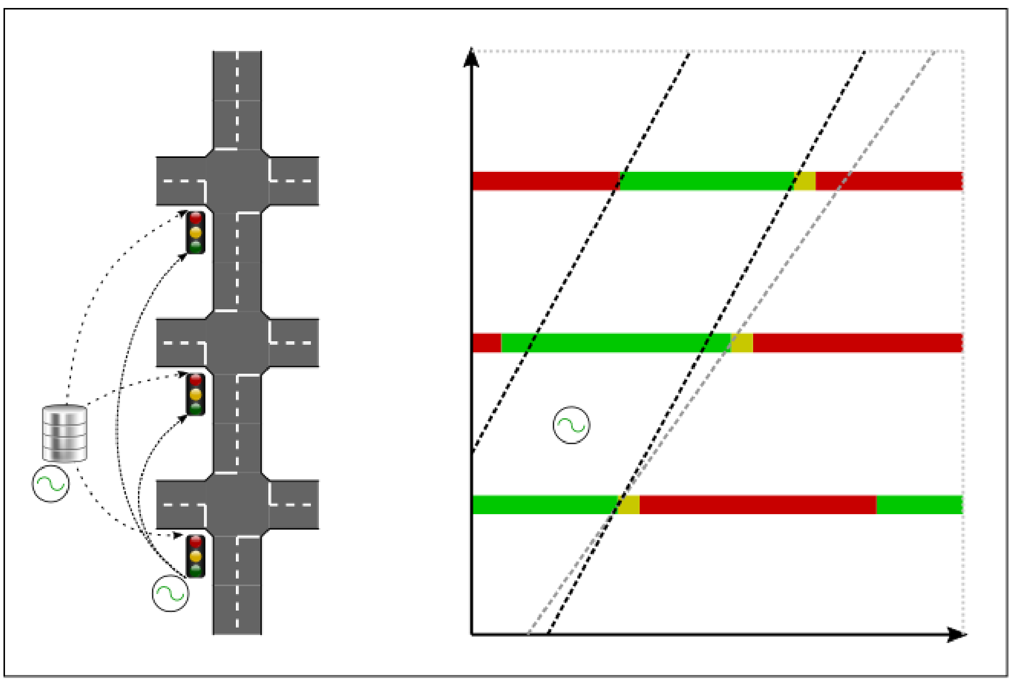
The compacter the Platoons of vehicles are that make use of the Green Wave the better the benefits of the Green Wave will be. Unfortunately, platoons diffuse over time and/or distance due to speed differences. This effect causes the Green Wave to have longer green times further along the route. While gaps between vehicles have increased the throughput will go down. As a result waiting times on conflicting directions will increase.

In the current situation vehicles and platoons of vehicles (based on the gap time/distance) are measured using loop detectors.

In the picture below the current Green Wave is visualized. The Green Wave can be implemented decentralized or centralized. Green Times further along the route are longer to capture the diffused platoon.



In the picture below the Cooperative Green Wave is visualized. The implementation of the Green Wave can still be decentralized or centralized. The Green Time further along the route are not longer, platoon diffusion is minimalized.



### 5.1.3 Objective:

The objectives for the cooperative Green Wave are to improve the benefits of the Green Wave by:

- Using vehicle data to improve the benefit of the Green Wave

    - Increased throughput for vehicles travelling along with the Green Wave
    - Decreased waiting times for vehicles on conflicting directions
- Introducing the Green Wave indicator in vehicle. This leads to:
    - Continuous confirmation of the Green Wave indication
    - Decreasing platoon diffusion
    - Replacing the need for signs alongside the road
- Introducing the ability to support traffic control dynamics
    - In case of a priority request from a conflicting direction the road user can be informed that the Green Wave has been disrupted..

### 5.1.4 Source:

Beter Benutten

### 5.1.5 Intended audience

Beter Benutten

## 5.2 Description Use-Case

There are three aspects to the cooperative Green Wave:

1. Use vehicle data (ETSI Cooperative Awareness Messages) to improve the benefit of the Green Wave
2. Introduce the Green Wave indicator in vehicle
3. Introduce the ability to support traffic control dynamics

### 5.2.1 Use Vehicle data

The efficiency of the Green Wave algorithm can be improved with more detailed information of traffic. Loss times and platoons can more accurately be determined using vehicle data.

In a decentralized implementation the vehicle data will be sent to the iTLC and processed there. Due to the local nature of this implementation this is not possible using connected infrastructure.

In a centralized implementation the vehicle data needs to be sent to the central system. This can be done though connected infrastructure or using cooperative infrastructure through the iTLC. The central algorithm can utilize Vehicle data from all intersections in the Green Wave and can thus have a positive impact on all intersections in the Green Wave.

Transition phase

Any amount of C-ITS vehicles can be used to improve the Green Wave. But, in order to have a significant effect the majority of vehicles should be C-ITS vehicles. At some point the current way of measuring traffic through loop detectors doesn't add information anymore.

### 5.2.2 Green Wave indicator in vehicle

By bringing the Green Wave indicator in the vehicle, the road user is continuously informed of the status of the Green Wave. This improves the comfort for the road user. The C-ITS vehicle can use the Green Wave indicator to determine a speed advisory. This also introduces the ability to influence the behavior of the drivers and to keep the platoon compact. That way the longer green times further along the route can be reduced.

At longer distances from the intersection(s) the indicator should be communicated using connected infrastructure. Nearby the intersection(s) cooperative infrastructure should be used.

Transition phase

This aspect of the Green Wave will show results with small amounts of C-ITS vehicles. The C-ITS vehicles will influence the traffic flow since other vehicles (none C-ITS) have to adjust their speed as well. At some point, adding more C-ITS vehicles doesn't increase the Green Wave efficiency anymore.

### 5.2.3 Support traffic control dynamics

The continuous in vehicle Green Wave indicator introduces the ability to support traffic control dynamics. It allows for more flexible use of the Green Wave. For instance, when an emergency vehicle gets priority on a conflicting direction, the road users can immediately be informed of the fact that they are not in the Green Wave anymore. In the current situation this is impossible.

This functionality is time-critical. Due to latency of connected infrastructure this is only feasible using cooperative infrastructure.

Transition phase

In situations with dynamic signs alongside the road this aspect can only be used with a high number of C-ITS vehicles. However, in situations with no signs alongside the road, this aspect of the Cooperative Green Wave is not dependent on the number of C-ITS vehicles.

## 5.3 Target System (as applicable)

Intelligent Traffic Light Controller

Traffic Control System

## 5.4 Implementation environment (as applicable)

Signalized intersection

## 5.5 Actors (as applicable)

| **External entity** | | |
|---|---|---|
| Traffic Engineer | | |
| | Role | Defines & maintains the Green Wave functionality |
| Maintenance Engineer | | |
| | Role | n/a |
| Installation Engineer | | |
| | Role | Installs the Green Wave functionality in I-TLC |
| Road traffic manager | | |
| | Role | Decides on policies with regard to Green Waves |
| Operator | | |
| | Role | n/a |
| Traffic Control System | | |
| | Role | Controls the Green Wave in a central environment |
| Traffic Management System | | |

| | | |
|---|---|---|
| | Role | n/a |
| Traffic Data Centre | | |
| | Role | Designs the Green Wave. |
| Service Provider | | |
| | Role | The Service Provider distributes the Green Wave indicator through connected infrastructure. |
| C-ITS Vehicle | | |
| | Role | Receives the Green Wave indicator from the iTLC and provides vehicle data to the Green Wave algorithm |
| Other Vehicle | | |
| | Role | n/a |
| Road user | | |
| | Role | n/a |

## 5.6 Pre-conditions (if any)

Intelligent TLC:

- Is running in mode Control
- Is part of a Green Wave
- Is capable of retrieving vehicle information; depending on interface already tailored to the filtering needs
- Is able to map vehicle information on signalgroups (topology)
- The knowledge of the intersection topology should be identical across all actors in this use-case (i.e. Intelligent Traffic Light Controller, Road user, C-ITS vehicle, Traffic Data Centre, Service Provider). In case of dynamically assigned directions the topology should be updated frequently (at least every 5 seconds).

C-ITS Vehicle

- Provides position, direction and speed information on regular basis

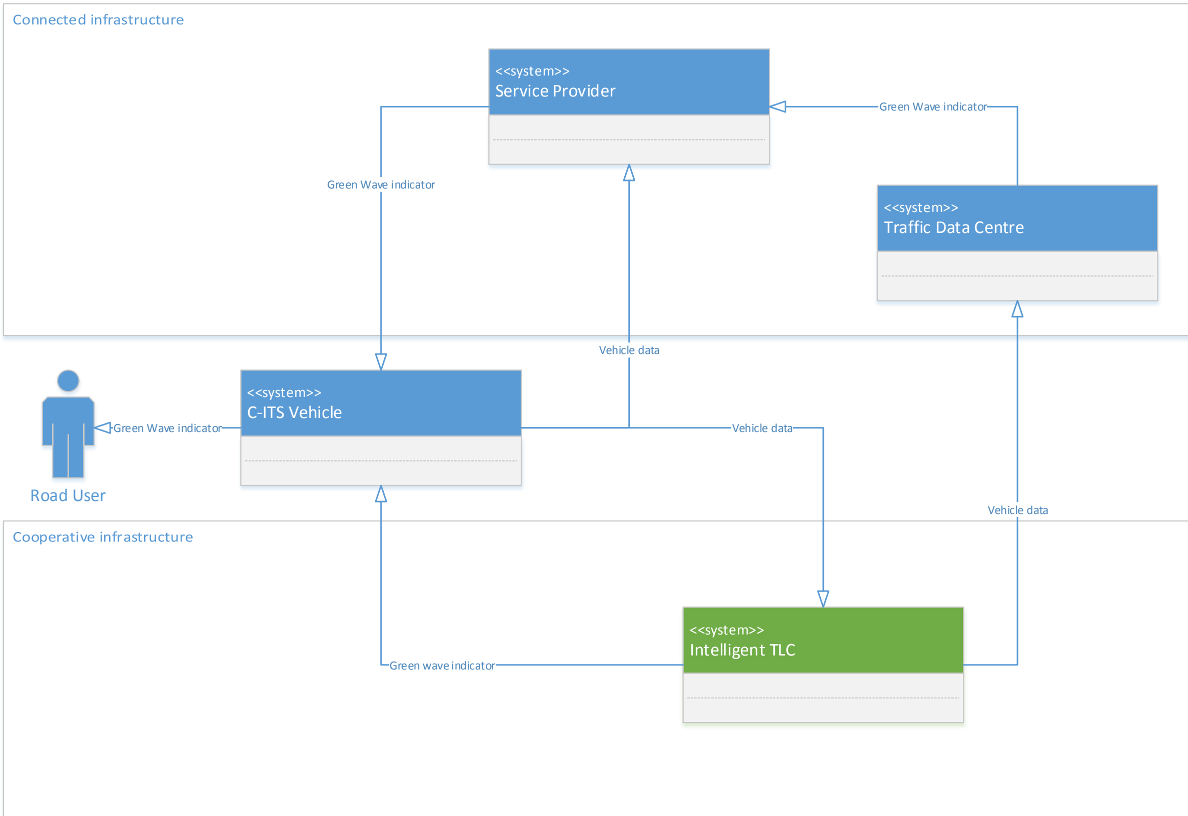
Green Wave:

- should be present
- The Green Wave algorithm is able to determine the Green Wave status each direction up to 30 seconds ahead
- The Green Wave algorithm is able to use vehicle data to optimize the Green Wave

## 5.7 Triggers conditions (if any)

The Green Wave is triggered by the Green Wave algorithm. This may depend on day of week, time of day, traffic conditions.

## 5.8 Use-Case Diagram (if any)




## 5.9 Normal Flow (as applicable)

### 5.9.1 Use vehicle data

Cooperative infrastructure

- A C-ITS vehicle approaches an iTLC with a Green Wave (centralized or decentralized)
- The C-ITS vehicle sends vehicle data (CAM) to the iTLC
- The iTLC processes the vehicle data (CAM)
- The iTLC sends the processed vehicle data to the Green Wave algorithm (centralized or decentralized)
- The Green Wave algorithm uses the processed vehicle data to optimize the Green Wave

Connected infrastructure

At this point it’s not foreseen that Service Providers will push vehicle data to the iTLC.

### 5.9.2 Green Wave indicator in vehicle

Cooperative infrastructure

- The Green Wave algorithm determines the Green Wave status and timing
- The Green Wave status and timing is broadcasted in a SPAT message

- An approaching C-ITS vehicle in the range of the cooperative broadcast receives the SPAT message with the Green Wave status and timing
- The C-ITS vehicle can show an indicator in the vehicle indicating the presence and status of the Green Wave
- Based on the direction of travel and the distance to the intersection the C-ITS vehicle can calculate an appropriate speed advice

Connected infrastructure

- The Green Wave algorithm determines the Green Wave status and timing
- The Service Provider retrieves the status of the Green Wave from the Traffic Data Centre
- A C-ITS vehicle sends vehicle data to the Service Provider
- Based on the position of the C-ITS Vehicle the Service Provider sends the Green Wave status to the C-ITS vehicle
- The C-ITS vehicle displays the Green Wave status indicator
- The Road User uses the indicator to adjust the speed of the C-ITS Vehicle

### 5.9.3 Support traffic control dynamics

Cooperative infrastructure

- Something (for instance an approaching emergency vehicle) interrupts the Green Wave
- The Green Wave algorithm determines the Green Wave status and timing
- The Green Wave status and timing is broadcasted in a SPAT message
- An approaching C-ITS vehicle in the range of the cooperative broadcast receives the SPAT message with the Green Wave status and timing
- The C-ITS vehicle can show an indicator in the vehicle indicating the presence and status of the Green Wave
- Based on the direction of travel and the distance to the intersection the C-ITS vehicle can calculate an appropriate speed advice

Connected infrastructure

- Something (for instance an approaching emergency vehicle) interrupts the Green Wave
- The Green Wave algorithm determines the Green Wave status and timing
- The Service Provider retrieves the status of the Green Wave from the Traffic Data Centre
- A C-ITS vehicle sends vehicle data to the Service Provider
- Based on the position of the C-ITS Vehicle the Service Provider sends the Green Wave status to the C-ITS vehicle
- The C-ITS vehicle displays the Green Wave status indicator
- The Road User uses the indicator to adjust the speed of the C-ITS Vehicle

### 5.9.4 Alternative flow (if any)

## 5.10 Post-conditions (if any)

N/A

## 5.11 Terminiation conditions (if any)

The Green Wave is not active, or not applicable for the approaching C-ITS Vehicle.

## 5.12 Use-Case Illustration (as applicable)

N/A

## 5.13 Potential requirements (as applicable)

See Pre-conditions.

## 5.14 Linked use cases (as applicable)

U08-a and U08-b.

## 5.15 Nederlandse samenvatting

Het doel van de coöperatieve groene golf is om de positieve effecten van de groene golf te verbeteren en de negatieve bijeffecten te verminderen. De huidige implementatie van een groene golf is in de meeste gevallen niet direct zichtbaar voor een weggebruiker. Soms staat er een bord langs de weg, soms met een dynamische adviessnelheid. Een groene golf kent in principe twee implementatievormen, centraal en decentraal. Bij de centrale implementatie worden verschillende VRA's aangestuurd door een centraal algoritme, bij een decentrale implementatie fungeert één VRA als zogenaamde master die de groene golf naar de andere VRA's coördineert. Bij toepassing van een groene golf is het doel een peloton in zijn geheel over een streng van verkeerslichten door te laten rijden zonder dat er gestopt hoeft te worden voor een rood licht. Gedurende het traject treedt peloton-diffusie op; het peloton wordt minder compact. Dit heeft als gevolg dat de groentijden stroomafwaarts langer moeten zijn om het peloton door te kunnen laten rijden. Dit kan zorgen voor extra wachttijden op conflicterende zijrichtingen.

The objectives for the cooperative Green Wave are to improve the benefits of the Green Wave by:

Het doel van de coöperatieve groene golf is het verbeteren van de positieve effecten door:

1. Voertuiggegevens te gebruiken om de groene golf te optimaliseren
    a. Waardoor de doorstroming verbeterd
    b. En wachttijden op conflicterende richtingen verminderen
2. Het introduceren van een groene golf indicator in het voertuig
    a. Waardoor een weggebruik continue terugkoppeling heeft van de groene golf
    b. Hierdoor kan het peloton compacter gehouden worden
    c. En zijn er geen borden langs de weg meer nodig
3. Het introduceren van ondersteuning voor verkeersregeldynamica
    a. In geval van het vroegtijdig afbreken van de groene golf, door bijvoorbeeld een prioriteitsingreep van een hulpdienst, kan de weggebruiker hierop geattendeerd worden

Door gebruik te maken van voertuiggegevens kunnen pelotons nauwkeuriger bepaald worden. Ook wachttijden op conflicterende zijrichtingen kunnen nauwkeuriger bepaald worden. Dit geeft demogelijkheid het groene golf algoritme te optimaliseren.

Doordat weggebruikers in een groene golf voortdurend kunnen zien of ze nog steeds in de groene golf zitten kun je hun gedrag en snelheid beïnvloeden. Hierdoor ontstaat de mogelijkheid het peloton compact te houden. Dit zorgt er weer voor dat de langere groentijden stroomafwaarts niet meer nodig zijn. En doordat de groene golf indicator in het voertuig aanwezig is verdwijnt het nut van het plaatsen van borden langs de weg.

# 6 Use-Case U04-A “Green extension heavy goods vehicles”

## 6.1 Introduction Use-Case

### 6.1.1 Use case ID:

U04-a: Green extension heavy goods vehicles.

### 6.1.2 Background:

Acceleration of heavy good vehicles (HGV’s) increases the emission and traffic congestion at an intersection. This use case aims to reduce the number of stops of these vehicles. Possible side effects are: reduction of fuel, travel times and HGV red light violation (safety aspect).

At this moment HGV’s are detected with dedicated loops at 300m from the intersection. The HGV driver is informed about the green extension state with a special roadside sign.

### 6.1.3 Objective:

Extend the green phase of lanes in such a way that approaching heavy goods vehicles can pass the intersection without stopping.

### 6.1.4 Source:

ISO 19091 (v 5.14), Use Case PR3 (Localized Freight Signal Priority)

Compass 4D: “Energy Efficient Intersection Service”,

https://nl.wikipedia.org/wiki/Tovergroen

## 6.2 Description Use-Case

Approaching heavy goods vehicles may be detected as such by the Intelligent TLC. This information is used by the Intelligent TLC to estimate if it can provide green light phase extension at which such a vehicle can pass the intersection without stopping.

If such a passage is possible, the Intelligent TLC informs the driver of the vehicle (equivalent of sign used in a non-ITS environment).

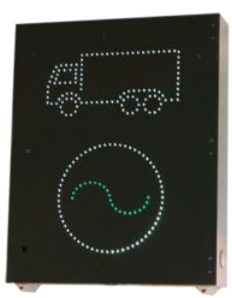


*Figure 4 : sign used in non-ITS environment to inform drivers of HGV's*

### 6.2.1 Transition phase

As long as not all TLC’s and HGV’s are equipped with C-ITS technology dedicated detection loops and roadside signs remain necessary for green extension on HGV’s.

### 6.2.2 End situation

When C-ITS technology is commonly used in HGV's as well as in TLC's features like green light optimal speed advise (GLOSA) and intelligent start-stop systems will be possible in HGV's. No dedicated detection loops and road signs are needed anymore.

## 6.3 Target System

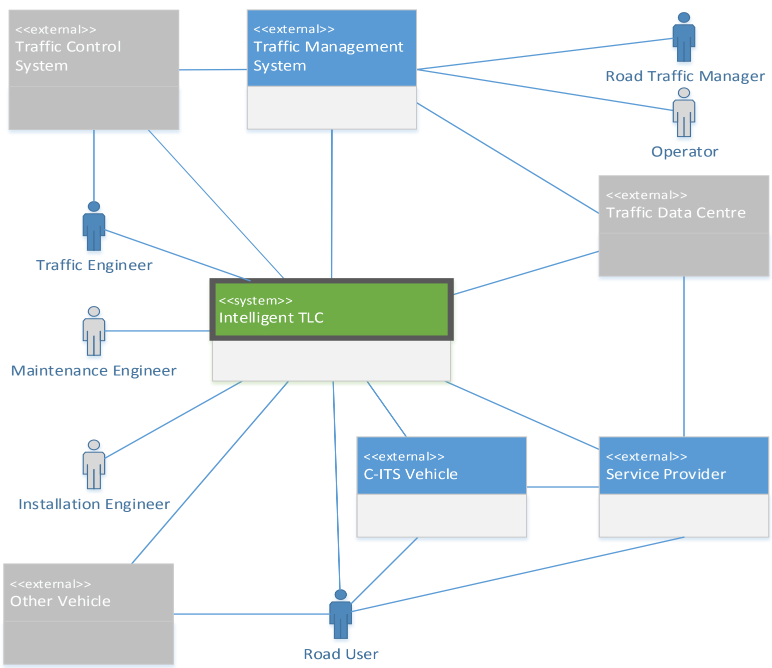
The target system consists of an Intelligent TLC and a C-ITS HGV (driven by a Road User).

## 6.4 Implementation environment

Signalized intersections.

## 6.5 Actors

The figure and table below shows and lists all actors in context of the intelligent TLC. For each actor taking part in this use-case, their role is described.




| External entity | | |
|---|---|---|
| Traffic Engineer | | |
| | Role | Responsible for providing the iTLC with the green extension functionality. |
| Road traffic manager | | |
| | Role | Decides if/when the green extension functionality as described in this use-case is oprational or not. |
| Traffic Management System | | |
| | Role | System through which the green extension functionality will be enabled or disabled. |
| Service Provider | | |

| | | |
|---|---|---|
| | Role | In a connected environment the service provider sends a green extension request to the iTLC based on the heading, position and speed supplied by the HGV. |
| C-ITS Vehicle | | |
| | Role | In this case: A heavy goods vehicle which notifies its approach to the intelligent TLC (doing an implicit green extension request) and informs the driver about the green extension state. |
| Road user | | |
| | Role | Driver of the heavy goods vehicle; acts on green extension signage. |

## 6.6 Pre-conditions

Intelligent TLC:

- Is in a controlling state.
- The lane on which the HGV approaches has already a green light.
- Traffic situation allows green extension, no standing or slow moving traffic on the green extension intended lane.
- Is capable of receiving information from C-ITS Vehicles.
- Is capable of sending information about the extended green state.
- Is equipped with the extended green functionality.

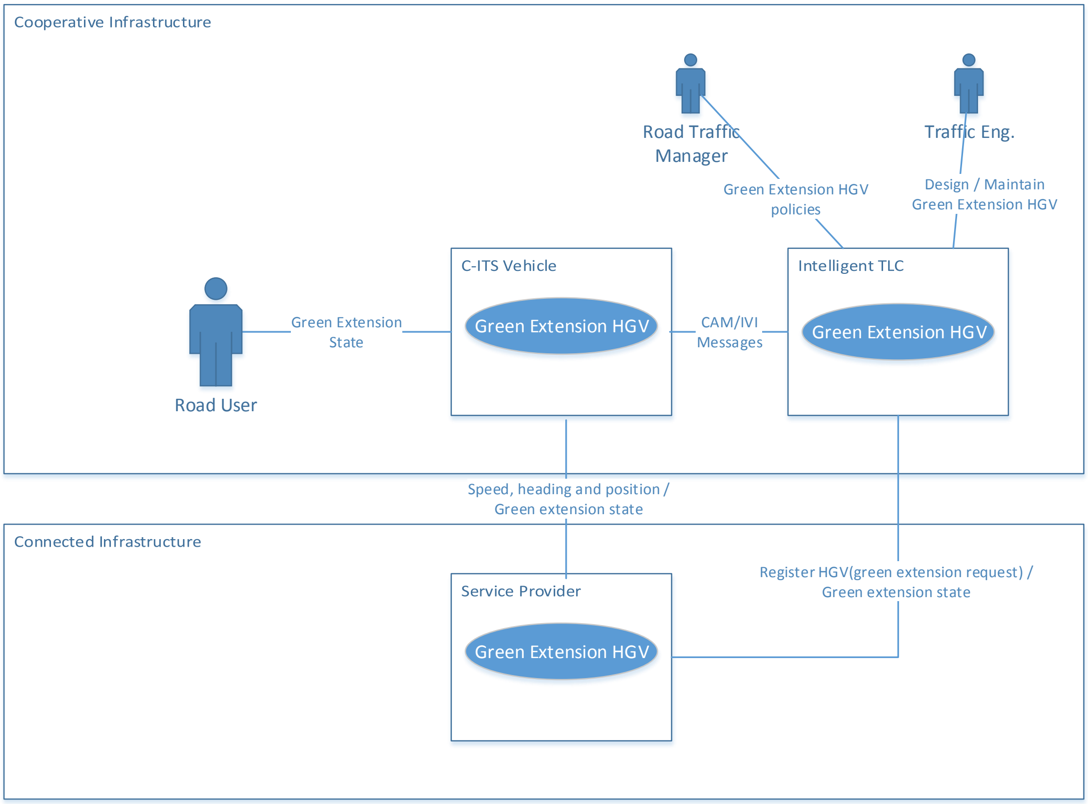
C-ITS Vehicle:

- Is capable of sending information about its properties (speed, position, heading, …).
- Is able to receive information about the extended green state, In Vehicle Information (IVI) messages.
- Is able to inform the driver of the HGV.

## 6.7 Triggers conditions

Heavy goods vehicle is approaching intersection.

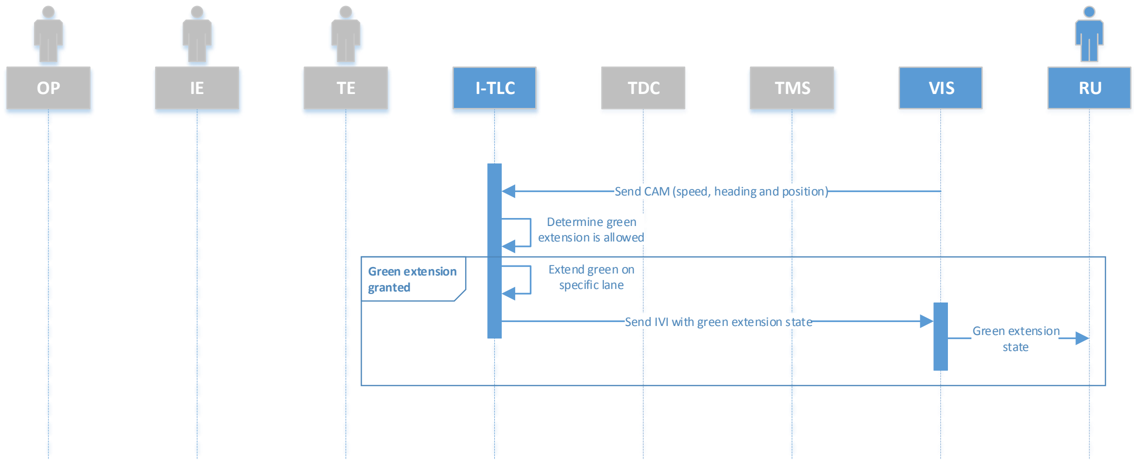
## 6.8 Use-Case Diagram




## 6.9 Normal Flow

### 6.9.1 Cooperative: Short range wireless communication (e.g. ITS G5)

- A C-ITS vehicle (HGV, in this case) approaches the signalized intersection
- The HGV periodically broadcasts information about its speed, heading and position (CAM message).
- The Intelligent TLC receives this information from the HGV
- The Intelligent TLC determines if green extension for this vehicle is possible. Conditions are determined by road traffic manager.
- If applicable, the Intelligent TLC will realize a stop-free passing of the HGV by extending the green phase of applicable lane.
- The Intelligent TLC sends updated information about the state of the green extension (by use of IVI).
- The HGV informs the Road User.




### 6.9.2 Connected: Cellular network (e.g. 3G/4G)

- A C-ITS vehicle (HGV, in this case) sends information about its speed, heading and position to the Service Provider
- The Service Provider determines if the HGV is approaching a signalized intersection.
- If so, the Service Provider determines if a priority-request for this vehicle is applicable based on geographical location of the HGV related to the TLC.
- The Service Provider sends a HGV presence to the Intelligent TLC
- The Intelligent TLC determines if green extension is allowed, if so it will realize a stop-free passing of the HGV by extending the greenphase of applicable signalgroup.
- The Intelligent TLC sends updated information about Signalphase and timing and prioritizationstatus (VLOG) to the Service Provider
- The Service Provider sends the Signalphase and Timing information together with the prioritizationstatus to the HGV.
- The HGV receives this information and informs the Road User.

Note: Due to the local characteristics of this use case a cooperative implementation is preferable.

### 6.9.3 Alternative flow: green phase extension not possible.

It's possible that a stop-free passing of a HGV cannot be realized by the Intelligent TLC. In this case, its traffic control algorithm will not adjust signalphase-timings due to an approaching HGV. No confirmation of any kind will be sent to the driver of the HGV equal to an intersection with no green extension functionality.

### 6.9.4 Alternative flow: Communication failure between HGV and iTLC.

It's possible that due to a technical failure in a cooperative environment as well as in a connected environment the communication between the HGV and iTLC is lost. In this case, the traffic control algorithm will not adjust signalphase-timings due to an approaching HGV. No confirmation of any kind will be sent to the driver of the HGV equal to an intersection with no green extension functionality.

## 6.10 Post-conditions

- Road User has been informed by the HGV about granted green extension.
- The greenphase extension has been executed. Traffic control (signalphase timing) has returned to normal operation.

## 6.11 Terminiation conditions

When one or more of the following conditions occur, it's possible that a stop-free passing of the HGV cannot be guaranteed anymore. The driver of the HGV should therefore be informed (revoke stop-free passing message):

- A change of priority due to an approaching HGV is conflicted by a request with a higher priority (for example, from an Emergency Vehicle).
- A technical failure of the Intelligent TLC, resulting in a reset or shutdown

## 6.12 Use-Case Illustration

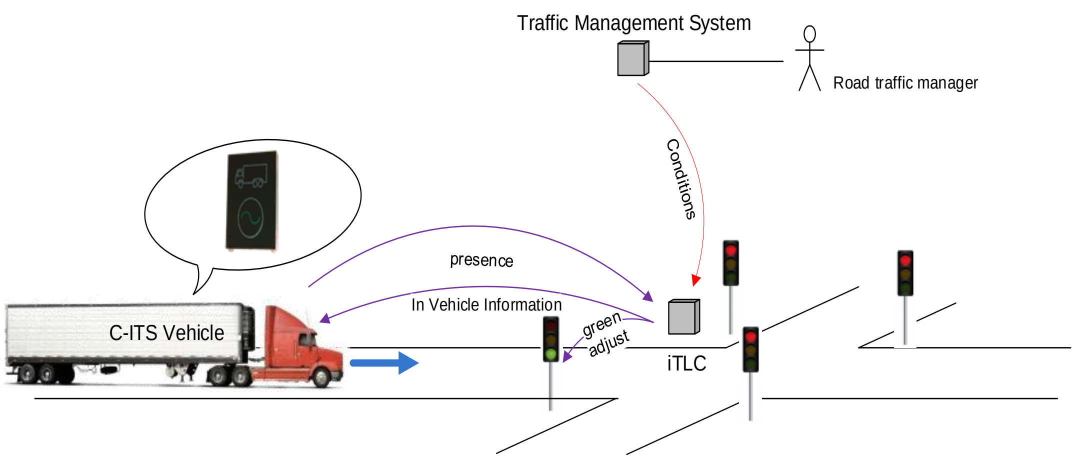



*Figure 1: Connected: using short range wireless communication (e.g. ITS-G5)*

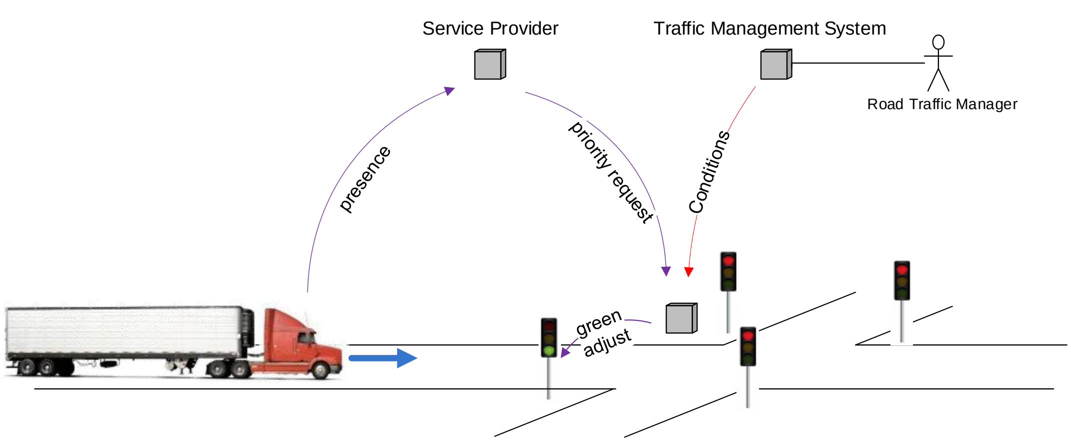



*Figure 2: Connected: using a cellular communication network.*

## 6.13 Potential requirements

t.b.d.

## 6.14 Linked use cases

UC05-A: Conditional priority for public transport

## 6.15 Nederlandse samenvatting

Het verlengen van de groenfase voor naderend zwaar vrachtverkeer heeft als doel de uitstoot en oponthoud bij een kruising, t.g.v. het onnodig moeten optrekken, te verminderen. Bijkomende voordelen zijn: besparing op brandstof en reductie van reistijden.

Op dit moment wordt zwaar vrachtverkeer met speciale lussen op 300m van de kruising gedetecteerd. De bestuurder van de vrachtauto wordt d.m.v. een speciaal “tovergoen” bord langs de kant van de weg geïnformeerd over het al dan niet verlengen van het groen (tovergroen).

Door toepassing van coöperatieve of connected technologie kunnen op termijn de detectielussen voor zwaar vrachtverkeer en “tovergroen” borden komen te vervallen. De zwaar beladen vrachtwagen meldt zich, langs een coöperatief of connected pad, als dusdanig aan bij de VRA en de VRA zal langs dezelfde weg de status van het al dan niet verlengen van de groenfase terugkoppelen.

Andere voordelen en mogelijkheden van het gebruik van coöperatieve of connected technologie zijn:

- Nauwere samenwerking tussen het voertuig en de VRA, vanaf het moment van aanmelden tot aan het passeren van de stopstreep.
- Optimaal snelheidsadvies voor groen.
- Het gebruik van intelligente start-stop systemen.

# 7 Use case U05-A “Conditional priority for public transport”

## 7.1 Introduction Use-Case

### 7.1.1 Use case ID:

U05-a: Conditional priority for public transport

### 7.1.2 Background:

In order to meet the time schedule of a public transport (PT) vehicle it may be necessary that a PT vehicle passes an intersection with priority on other vehicles (with exception of emergency vehicles). Possible side effect are: public transport promotion, reduction of cost and reduction of emission.

At this moment dedicated hardware is needed, like KAR or VECOM, to realise this kind of conditional priority where VECOM also needs additional loops at the intersection.

### 7.1.3 Objective:

Give green priority to public transport vehicles in such a way that they can pass the intersection without stopping. Priority conditions are usually based on punctuality.

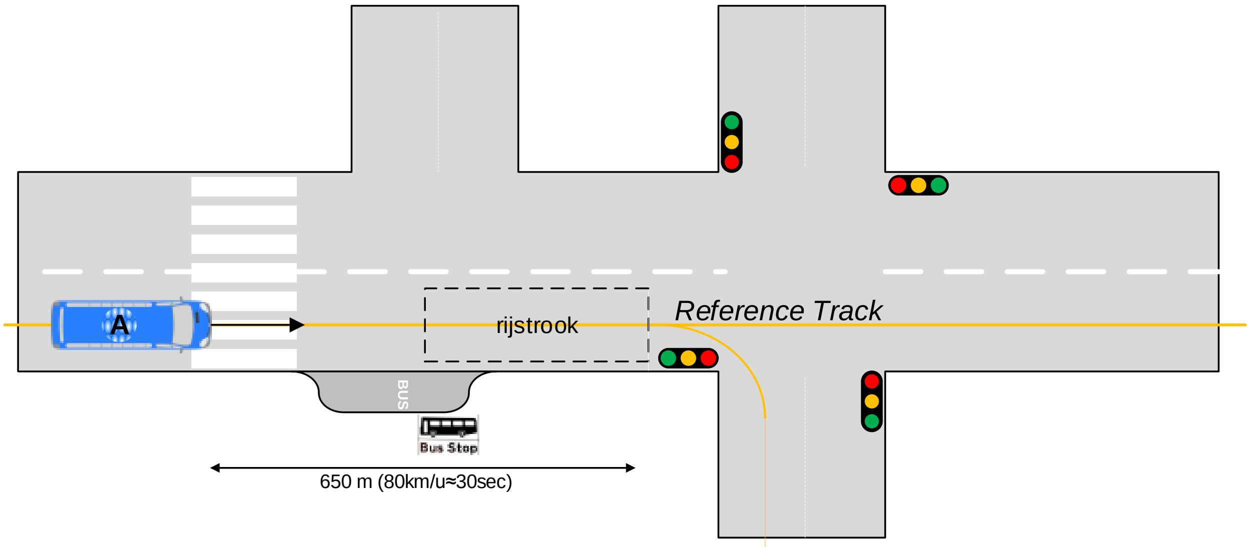
By using C-ITS technology in a public transport vehicle it can communicate with future-proof multipurpose C-ITS technology present at signalized intersections.

### 7.1.4 Source:

- ISO 19091 (v 5.14), Use Case PR1 (Localized Public Transport Signal Priority)
- ISO 19091 (v 5.14), Use Case PR1a (Localized Transit Signal Priority – Near Side Stop)
- ISO 19091 (v 5.14), Use Case PR2 (Public Transport Signal Priority along an arterial)
- ISO 19091 Annex D (v012) sections 1.3.3.1 and 1.3.3.2.
- Compass 4D D2.1 User Requirements and Specifications section 3.3 (EEIS)
- Compass 4D D2.3.2 Detailed Technical Architecture per Pilot Site: Copenhagen (DK) section 2.2.3 (EEIS)
- SAE J2735 Appendix H (MAP and SPAT message use)

## 7.2 Description Use-Case

Public transport vehicles can request green priority at a iTLC to improve the progression over the intersection being approached. When priority is requested by the public transport vehicle the priority response status is reported by intelligent TLC by sending a signal phase and timing message. The ITS vehicle notifies/informs the driver about the status of priority handling.




Due to the local characteristics of this use case this use case only describes the preferable cooperative path and not the connected path.

### 7.2.1 Transition phase

The idea is to keep the transition phase as short as possible. First all relevant iTLC's will be equipped with C-ITS technology before the public transport vehicles switch over to C-ITS technology. So C-ITS technology will replace the KAR and VECOM technology in public transport vehicles and not extend it.

### 7.2.2 End situation

When C-ITS technology is commonly used in traffic light controllers as well as in public transport vehicles other features like green light optimized speed advise (GLOSA) and intelligent start-stop systems will be possible in public transport vehicles. The iTLC and surrounding vehicles can provide the C-ITS PT Vehicle with more detailed information about the intersection state:

- Signal and phase timing.
- Events on conflicting lanes.
- Events on its own lane.
- Weather conditions.
- Etc.

## 7.3 Target System

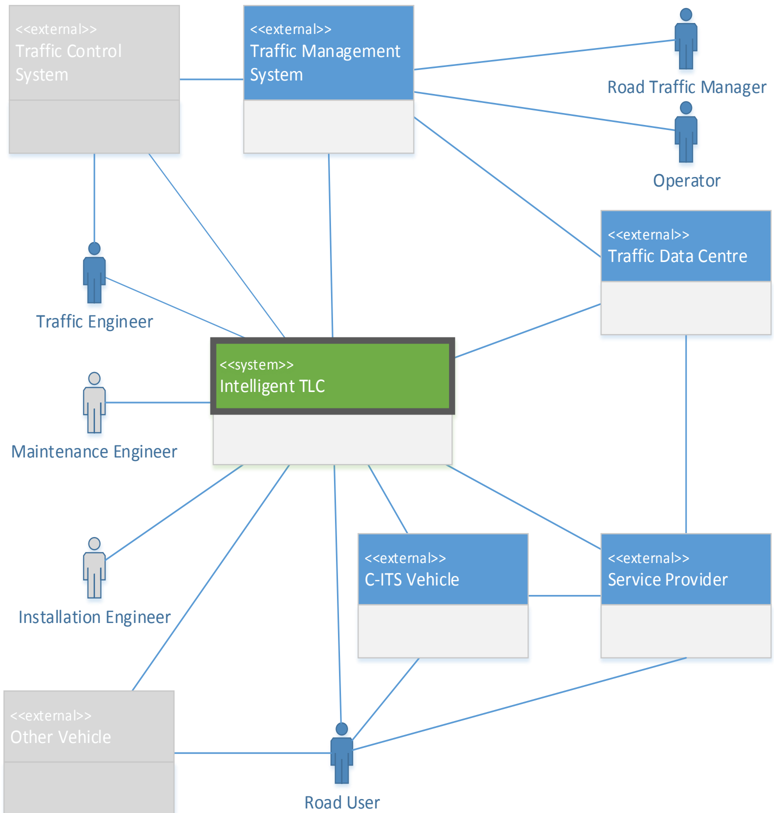
The target system consists of an Intelligent TLC.

## 7.4 Implementation environment

Selected iTLC signalized intersections.

## 7.5 Actors

The figure and table below shows and lists all actors in context of the intelligent TLC. For each actor taking part in this use-case, their role is described.




| External entity | | |
|---|---|---|
| Traffic Engineer | | |
| | Role | Responsible for providing the iTLC with the conditional public transport priority functionality. |
| Road traffic manager | | |
| | Role | Determines thepublic transport priority policies |
| Operator | | |
| | Role | Adapts if necessary the public transport priority conditions (i.e. line numbers). |
| Traffic Management System | | |
| | Role | System through which public transport priority conditions can be altered (i.e. line number). |
| Traffic Data Centre | | |
| | Role | Collects data about Public Transport Vehicles crossing the intersection (Line number, prioritization handling, etc) |
| Service Provider | | |
| | Role | In a role of a public transport company the service provider evaluates Public Transport data. |
| C-ITS Vehicle | | |
| | Role | A public transport vehicle which notifies its approach to the intelligent TLC, submitting a green priority request, and informs the driver about the |

| | | |
|---|---|---|
| | | green extension state. |
| Road user | | |
| | Role | Driver of the public transport vehicle; acts on green priority state.(see Appendix B) |

## 7.6 Pre-conditions

Intelligent TLC:

- Is in a controlling state.
- Traffic situation on intersection allows priority for public transport.
- Is capable of receiving information from C-ITS Vehicles (CAM message).
- Is sending information about the green priority state (SPAT message).
- Is sending intersections geographical data (MAP message).
- Is equipped with the conditional public transport priority functionality.
- The conditions for green priority are properly set.

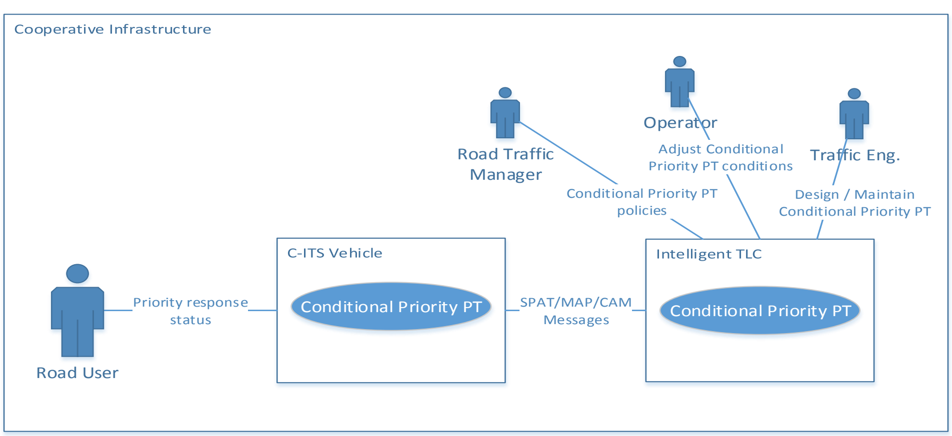
C-ITS PT vehicle:

- Is able to receive the intersections geographical data (MAP message) in order to calculate the distance to the stopline.
- Is able to send a priority request (CAM message with PT container).
- Is able to receive information about the green priority status (SPAT message)
- Is able to inform the driver of the public transport vehicle about the green priority state.

## 7.7 Triggers conditions

Public transport vehicle approaching an intersection submitting a priority request.

## 7.8 Use-Case Diagram



## 7.9 Normal Flow

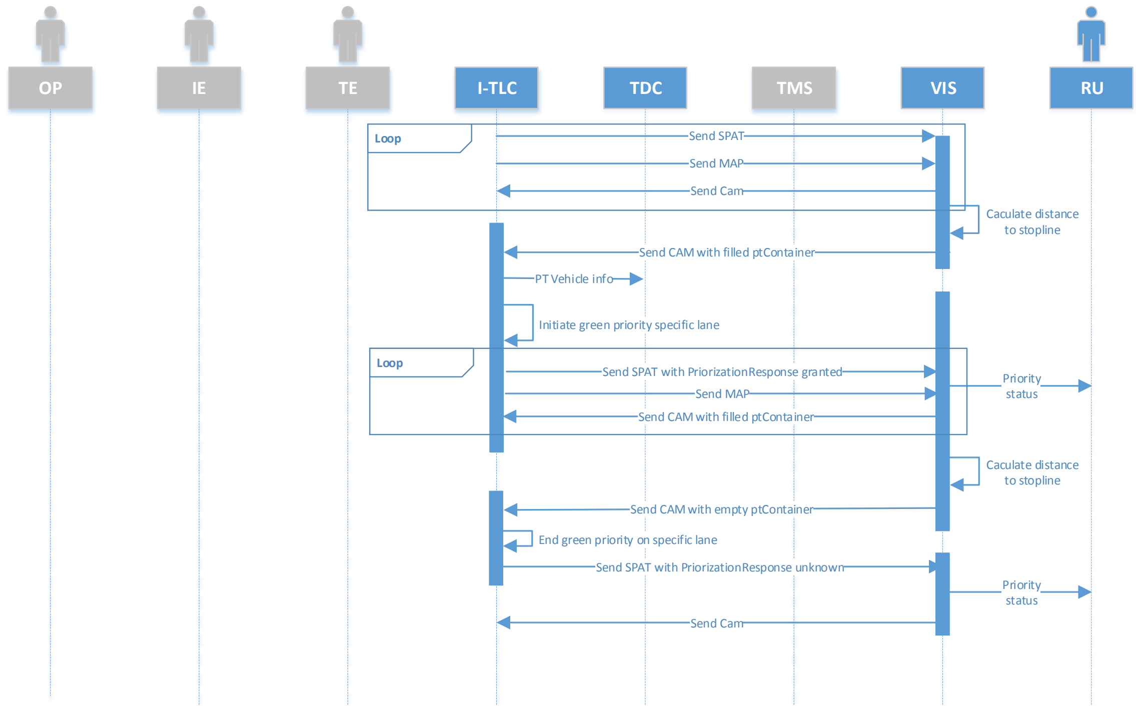
The normal and alternative flows are described from the C-ITS public transport vehicle point of view as well as the iTLC point of view. For a description of a CAM message see appendix A. For a description of CAM-SPAT priority request-reply see Appendix B.

C-ITS Public Transport vehicle:

- C-ITS PT vehicle calculates distance to intersection based on the topology data.
- Dependant on distance or calculated time to the stop line it sends a priority request towards the iTLC and fixes its station ID.
- While waiting at the bus stop it sets the embarkation status.
- When embarkation is finished it resets embarkation status.
- Receive signal phase and timing from the iTLC (SPAT message) and checks for active prioritizations related to its own station ID.
- Retrieve prioritization state, signalgroup id (cleared lane) and predicted timing from SPAT message.
- Inform driver by displaying priority response status.
- After passing stopline (determined by ego position relative to the received topology data) stop the priority request.

iTLC:

- Receives priority request from PT vehicle.
- Desides on public transport vehicle data (line number, punctuality, etc) and conditions set by the road traffic manager that green priority is granted
- Transmits prioritizationStatus and signalGroup-information (estimated time-to-green) as part of SPAT message.
- Realizes green priority and extension on the direction the prioritized C-ITS vehicle is approaching. Each approaching public transport vehicle on the same lane gets its own priority status.
- Decide if priority request is ended.
- Stops green priority.




## 7.9.1 Alternative flow

### *7.9.1.1 Priorization request not granted.*

Prioritization-request may be rejected by the TLC when e.g. it's not possible to intervene signalisation in time.

C-ITS PT vehicle:

- No change in use-case flow.
-

iTLC:

- Green priority is not granted.
- Transmits priorization status "rejected".
- Continues regular traffic control.

### *7.9.1.2 PT vehicle leaves expected route.*

A situation may occur in which a PT-vehicle deviates from the expected route. In this situation, it must be possible to cancel a running greentime-extension in the TLC.

C-ITS PT vehicle:

- May stop transmitting PtContainer while deviating from route.

iTLC:

- Notifies stop of receiving PtContainer.
- Remove station id related prioritization status from SPAT message.
- Ends the priority-handling procedure and switches to regular traffic-control.

## 7.10 Post-conditions

- Priority handling has finished and normal traffic control flow is being executed.

## 7.11 Terminiation conditions

Due to various reasons, a iTLC may postpone, reject or abort the signal intervention as requested by a C-ITS PT vehicle. As an example: a TLC can decide to abort the green priority and extension for a emergency vehicle approaching on a conflicting lane.

C-ITS PT vehicle:

- No change in use-case flow.
- Possible feature : extra (audible) warning signal to driver when a formerly granted request has been withdrawn.

iTLC:

- Aborts green priority.
- Reports Prioritization status “watchOtherTraffic” or “rejected”.
- Sets priority to emergency vehicle.

## 7.12 Use-Case Illustration

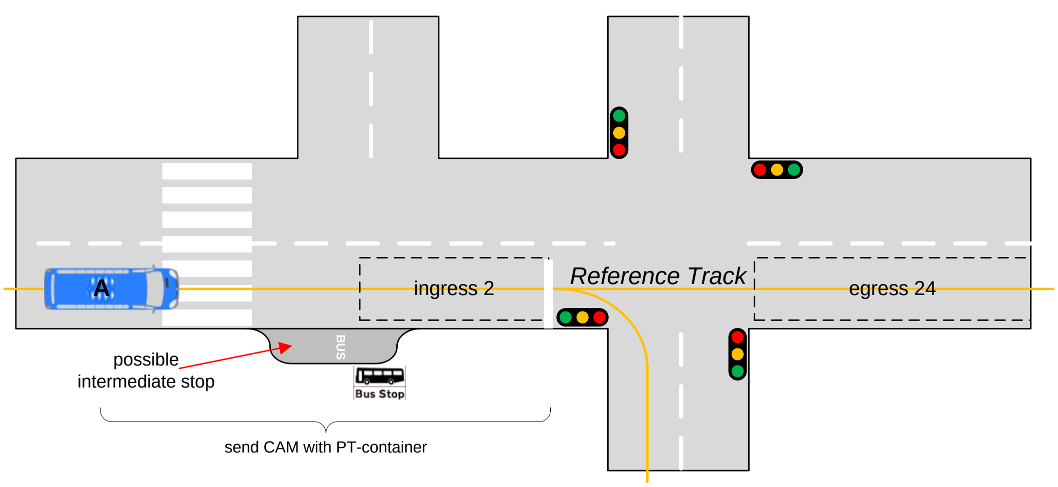



*Figure 3: Use case normal flow.*

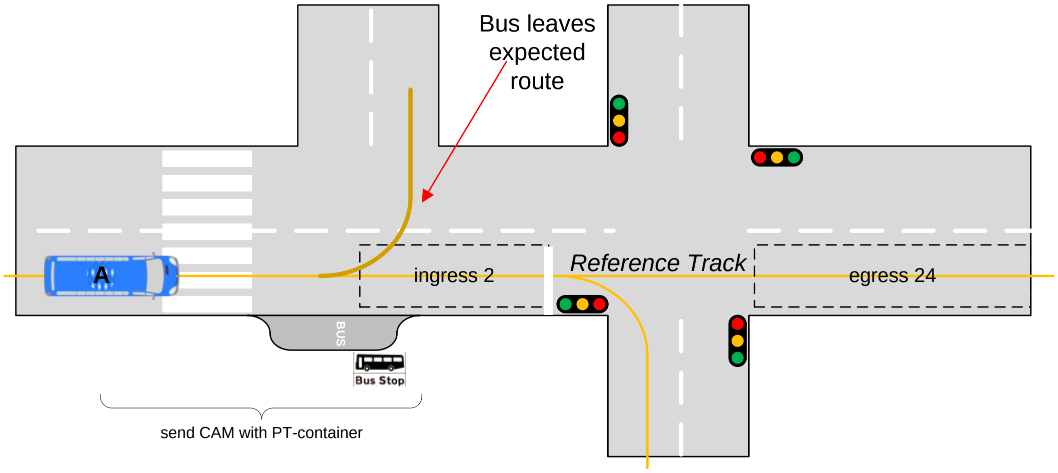



*Figure 4: Use case alternative flow, pt vehicle leaves expected route.*

## 7.13 Potential requirements (as applicable)

N/A

## 7.14 Linked use cases (as applicable)

U08-a: Tijd tot groen voor adviessnelheid

## 7.15 Nederlandse samenvatting

Om het openbaar vervoer volgens de dienstregeling te kunnen laten rijden kan het op basis van stiptheid noodzakelijk zijn om een OV voertuig met prioriteit boven ander voertuigen (met uitzondering van hulpdiensten) over de kruising te leiden. Bijkomende voordelen zijn: promotie van het openbaar vervoer en vermindering van uitstoot.

Op dit moment is special apparatuur noodzakelijk, zoals KAR en VECOM, om geconditioneerde prioriteit te kunnen realiseren. Daarbij heeft VECOM zelfs nog speciale lussen in het wegdek nodig.

Door gebruik te maken van coöperatieve technologie kan openbaar vervoer prioriteit aanvragen via toekomstvaste, voor meerdere doeleinden geschikte, coöperatieve technologie aanwezig op geregelde kruisingen. Er vindt een nauwere samenwerking plaats tussen het OV voertuig en de VRA, de chauffeur wordt continu op de hoogte gehouden over de status van de prioriteitsaanvraag.

Wanneer C-ITS technologie algemeen gebruikt wordt in VRA's en in openbaar vervoer zullen toepassingen als "optimaal snelheidsadvies voor groen" en intelligente start-stop systemen tot de mogelijkheden behoren in het openbaar vervoer. Ook overig verkeer kan het openbaar vervoer voorzien van gedetailleerde informatie over de toestand van het kruispunt:

- Signaalgroep toestand en timing.
- Gebeurtenissen op conflicterende richtingen.
- Gebeurtenissen op eigen richting.
- Weersomstandigheden.
- Etc.

Document: U08-A, U08-B, U07-B, U07-I, U04-A, U05-A

Het idee is om de overgang naar een ITS omgeving zo kort mogelijk te houden. Eerst zullen alle relevante VRA’s worden uitgevoerd met C-ITS technologie alvorens het openbaar vervoer overstapt naar C-ITS technologie. C-ITS technologie zal dus KAR en VECOM vervangen en geen uitbreiding zijn op.

# 8 Appendix U08-A Implementation details

| Design TTG() | |
|---|---|
| Description: | The Time To Green function will be designed by the Traffic Engineer using input from the Road Traffic Manager concerning broad cast policies.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | |
| Target: | Traffic Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain TTG() | |
|---|---|
| Description: | The Time To Green function that has been designed and implemented may need to be optimized due to e.g. changing traffic conditions.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Traffic Engineer |
| Target: | Traffic Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Maintain Topology() | |
|---|---|
| Description: | The Topology of the intersection may need to be changed temporary due roadworks.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | Installation Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| Install TTG() | |
|---|---|
| Description: | The Time To Green function in the iTLC will be installed in the TLC.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | iTLC |
| Interface: | ?? |
| Message: | - |

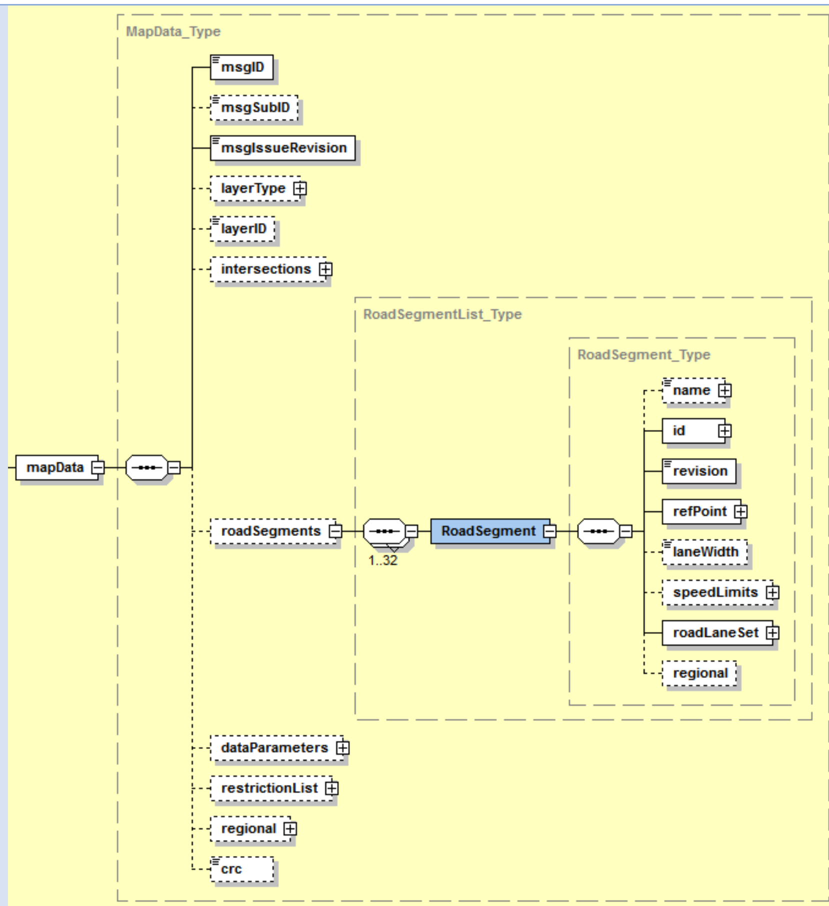
| | |
|---|---|
| Frequency: | - |

| **Install Topology()** | |
|---|---|
| Description: | The geographical layout of the intersection is made available in the iTLC<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | iTLC |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| **Activate TTG()** | |
|---|---|
| Description: | The Time To Green function in the iTLC will be enabled. |
| Source: | Traffic Control<br>Internal iTLC scheduler |
| Target: | iTLC |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTG ( True ) |
| Frequency: | - |

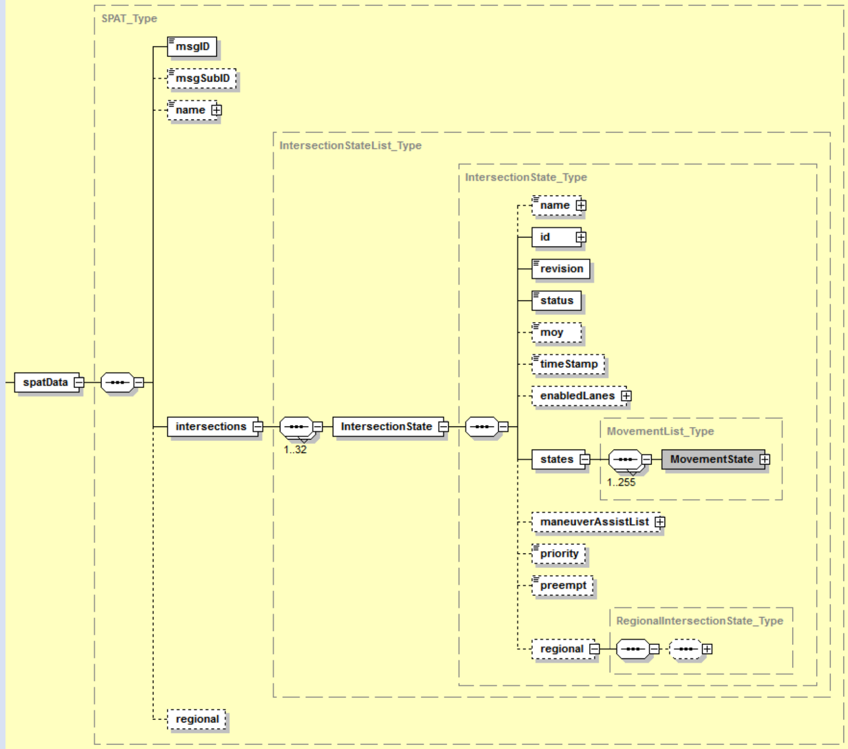
| **Deactivate TTG()** | |
|---|---|
| Description: | The Time To Green function in the iTLC will be disabled. |
| Source: | Traffic Control<br>Internal iTLC scheduler |
| Target: | iTLC |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTG ( False ) |
| Frequency: | |

| **Topology()** | |
|---|---|
| Description: | The iTLC will provide the topology of the intersection.<br><br>The message is formatted according de definitions provided by ETSI and described in ASN.1 definitions ETSI, 04-Nov-2015<br><br>The SPAT information is embedded in an XML data message and will be protected by ASN.1 UPER-encoding.<br><br>Excerpt: |

| | |
|---|---|
| |  |
| Source: | iTLC |
| Target: | VIS ( via UDP)<br>TDC (via TCP) |
| Interface: | UDP & TCP |
| Message: | mapData-P |
| Frequency: | Every 2 seconds |



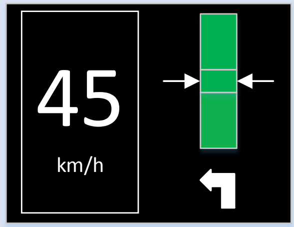
| **Signal Phase & Timing()** | |
|---|---|
| Description: | The TLC will provide the current Sign Group State and provide the calculated signal group state for (3) complete switching cycles of the intersection.<br><br>The message is formatted according de definitions provided by ETSI and described in ASN.1 definitions ETSI, 04-Nov-2015<br><br>The SPAT information is embedded in an XML data message and will be protected by ASN.1 UPER-encoding.<br><br>Excerpt: |

| | |
|---|---|
| |  |
| Source: | iTLC |
| Target: | VIS ( via UDP)<br>TDC (via TCP) |
| Interface: | UDP & TCP |
| Message: | signalPhaseAndTimingMessage-P |
| Frequency: | Every 1 second. |



| Calculate Speed advice() | |
|---|---|
| Description: | Calculate the optimal speed for the vehicle to reach the intersection when the green phase of the signal group has started.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Source: | VIS |
| Target: | VIS |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| Speed advice() |
|---|

| | |
|---|---|
| Description: | Provide the Road User with an optimal speed enabling the road user to adjust the vehicle speed to reach the intersection when the signal group will turn to green.<br><br><br><br><br>This is a function in the VIS and the implementation is out of scope of this document.<br><br>Currently the implementation of the speed adjustment is left to the Road User. In the (near) future the implementation of the speed adjustment could be done by an automated vehicle driving system. |
| Source: | VIS |
| Target: | Road User |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| **Time to Green()** | |
|---|---|
| Description: | Provide the Road user the timeframe for the signal group to turn no green.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Source: | VIS |
| Target: | Road User |
| Interface: | - |
| Message: | - |
| Frequency: | - |

# 9 Appendix U08-B Implementation details

| **Design TTR()** | |
|---|---|
| Description: | The Time to Red function will be designed by the Traffic Engineer using input from the Road Traffic Manager concerning broad cast policies.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | |
| Target: | Traffic Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| **Maintain TTR()** | |
|---|---|
| Description: | The Time to Red function that has been designed and implemented may need to be optimized due to e.g. changing traffic conditions.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Traffic Engineer |
| Target: | Traffic Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| **Maintain Topology()** | |
|---|---|
| Description: | The Topology of the intersection may need to be changed temporary due roadworks.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | Installation Engineer |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

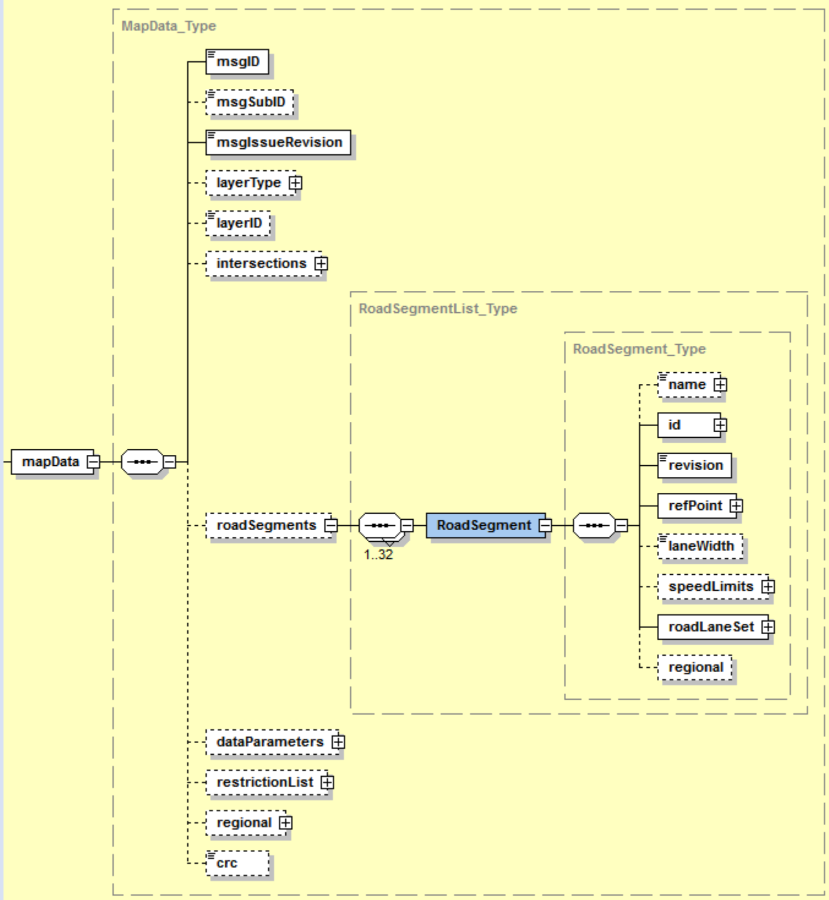
| **Install TTR()** | |
|---|---|
| Description: | The Time to Red function in the iTLC will be installed in the TLC.<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | iTLC |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| **Install Topology()** | |
|---|---|
| Description: | The geographical layout of the intersection is made available in the iTLC<br><br>This is in essence a pre-condition for the entire use-case and as such will not be elaborated. |
| Source: | Installation Engineer |
| Target: | iTLC |
| Interface: | ?? |
| Message: | - |
| Frequency: | - |

| **Activate TTR()** | |
|---|---|
| Description: | The Time to Red function in the iTLC will be enabled. |
| Source: | Traffic Control<br>Internal iTLC scheduler |
| Target: | iTLC |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTR ( True ) |
| Frequency: | - |

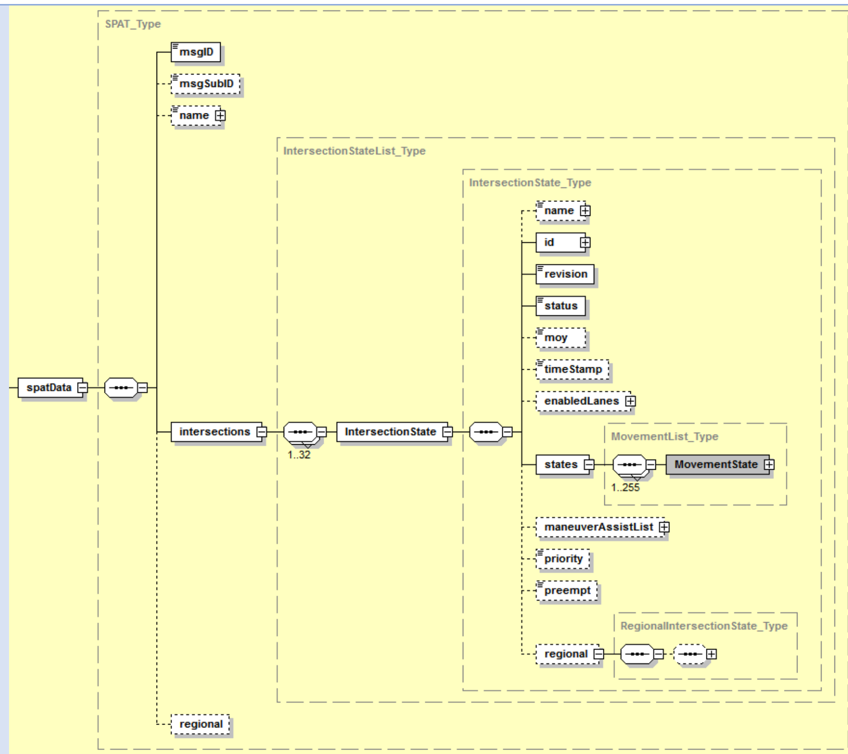
| **Deactivate TTR()** | |
|---|---|
| Description: | The Time to Red function in the iTLC will be disabled. |
| Source: | Traffic Control<br>Internal iTLC scheduler |
| Target: | iTLC |
| Interface: | IVERA-APP<br>TCS-IF |
| Message: | TTR ( False ) |
| Frequency: | |

| **Topology()** | |
|---|---|
| Description: | The iTLC will provide the topology of the intersection.<br><br>The message is formatted according de definitions provided by ETSI and described in ASN.1 definitions ETSI, 04-Nov-2015<br><br>The SPAT information is embedded in an XML data message and will be protected by ASN.1 UPER-encoding.<br><br>Excerpt: |




| | |
|---|---|
| Source: | iTLC |
| Target: | VIS ( via UDP)<br>TDC (via TCP) |
| Interface: | UDP & TCP |
| Message: | mapData-P |
| Frequency: | Every 2 seconds |

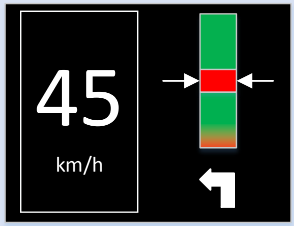
| Signal Phase & Timing() | |
|---|---|
| Description: | The TLC will provide the current Sign Group State and provide the calculated signal group state for (3) complete switching cycles of the intersection.<br><br>The message is formatted according de definitions provided by ETSI and described in ASN.1 definitions ETSI, 04-Nov-2015<br><br>The SPAT information is embedded in an XML data message and will be protected by ASN.1 UPER-encoding.<br><br>Excerpt: |




| | |
|---|---|
| Source: | iTLC |
| Target: | VIS ( via UDP)<br>TDC (via TCP) |
| Interface: | UDP & TCP |
| Message: | signalPhaseAndTimingMessage-P |
| Frequency: | Every 1 second. |

| **Calculate Speed advice()** | |
|---|---|
| Description: | Calculate the optimal speed for the vehicle to reach the intersection when the green phase of the signal group has started.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Source: | VIS |
| Target: | VIS |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| **Speed advice()** |
|---|

| | |
|---|---|
| Description: | Provide the Road User with an optimal speed enabling the road user to adjust the vehicle speed to reach the intersection when the signal group will turn to green.<br><br>This is a function in the VIS and the implementation is out of scope of this document.<br><br>Currently the implementation of the speed adjustment is left to the Road User. In the (near) future the implementation of the speed adjustment could be done by an automated vehicle driving system. |
| Source: | VIS |
| Target: | Road User |
| Interface: | - |
| Message: | - |
| Frequency: | - |

| **Time to Red()** | |
|---|---|
| Description: | Provide the Road user the timeframe for the signal group to turn no green.<br><br>This is a function in the VIS and the implementation is out of scope of this document. |
| Source: | VIS |
| Target: | Road User |
| Interface: | - |
| Message: | - |
| Frequency: | - |

# 10 Appendix U07-B Implementation details

# 11 Appendix U07-I Implementation details

# 12 Appendix U04-A Implementation details

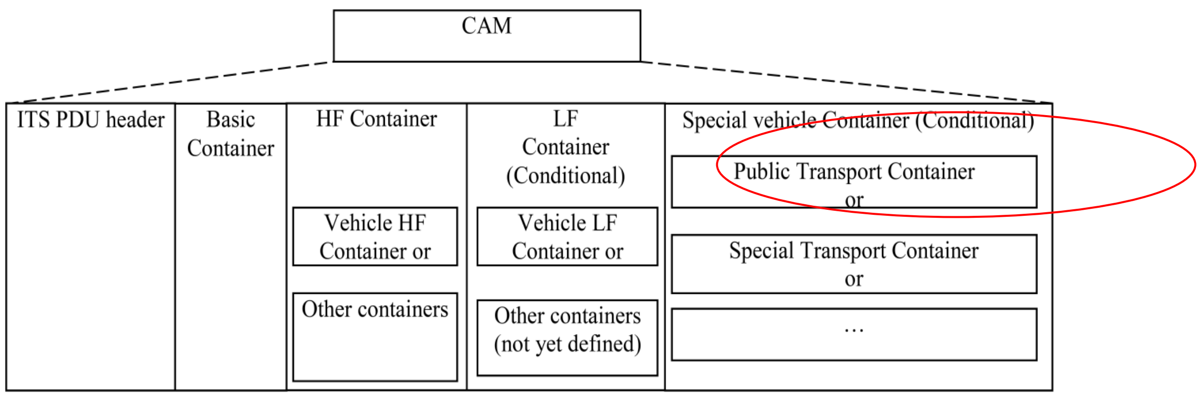
# 13 Appendix U05-A CAM - Public Transport Container

For now, in EU there's no dedicated ITS-message for "priority request" (whereas for the US the ITS-messages SRM and SSM are defined for respectively requesting and the status of signal prioritisation).

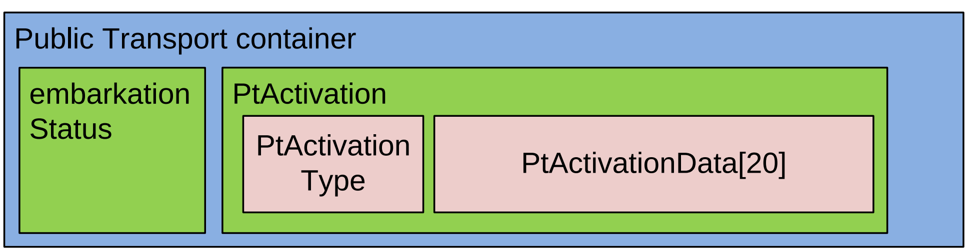
Therefore, a CAM-message with a Public Transport Container is being used.

This container can be used to send dedicated information about the Public Transport vehicle. The formatting is not yet standardized for each EU-country.

Below, the Public Transport Container within a CAM-message is depicted:




The container itself consists of the following data-elements:




The embarkationStatus indicates whether a Public Transport-vehicle is waiting at a busstop.

The PtActivationType-field indicates the way of formatting (coding) of the PtActivationData, whereas the PtActivationData itself contains the public-transport information about the vehicle.

To be able to include the PublicTransport-container in a CAM-message, the vehicleRole (part of the LF Container) must be set to value 'publicTransport' (1).

Contents of PtActivationData can be:

- Deviation from TimeTable, or Punctionality/Accuracy
- Priority

- Line number
- Heading (short future path): e.g. egress-lanenumber

# 14 Appendix U05-A CAM – SPAT priority request – response

An implicit priority request from the public transport vehicle towards the iTLC is done by filling the public transport container in the CAM message (see table below). The iTLC responds with the PrioritizationResponseStatus set in the SPAT message. The priority request is withdrawn by clearing the public transport container. Note that the stationID in the SPAT message, with the priority request response, must correspond to the stationID in CAM message with the public transport container filled. This way several public transport vehicles approaching the intersection can be handled separately with their stationID as reference. As long as the priority handling is active the station ID must be fixed.

CooperativeAwerenessMessage(CAM)
- ItsPduHeader
  - protocolVersion
  - messageID
  - StationID
- CoopAwareness
  - Camparameters
    - LowFrequencyContainer (OPTIONAL)
      - BasicVehicleContainerLowFrequency
        - VehicleRole
          - publicTransport 1
    - SpecicialVehicleContainter (OPTIONAL)
      - PublicTransportContainer
        - EmbarkationStatus
        - DF_PtActivation (OPTIONAL)
          - PtActivationType
          - PtActivationData

MSG_SignalPhaseAndTiming Message (SPAT)
- DF_IntersectionStateList
  - DF_IntersectionState
    - DF_Regional_IntersectionState (OPTIONAL)
      - DF_REG_IntersectionState_EU
        - DF_PrioritizationResponseList_EU [1..10]
          - DF_PrioritizationResponse_EU

DE_StationID

DE_PrioritizationResponseStatus

| | |
|---|---|
| unknown | 0 |
| requested | 1 |
| processing | 2 |
| watchOtherTraffic | 3 |
| granted | 4 |
| rejected | 5 |
| maxPresence | 6 |

DE_SignalGroupID