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IMPACT ASSESSMENT OF COOPERATIVE INTELLIGENT SERVICES ON THE TEN-T ROAD NETWORK OF HUNGARY

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Abstract

Cooperative intelligent transport systems and services (C-ITS) are based on periodical data sharing between cooperative V2X communication units (in-vehicle and roadside units, ITS stations) via a short-range ad-hoc network. All participants are able to acquire information several times per second from others such as position, speed and driving direction as well as intentions and event triggered messages like incidents and emergency braking. Roadside infrastructure can share traffic information like road works or speed limits.
As such, C-ITS improves road safety and effectiveness of the transportation system while reduces harmful environmental effects. Transportation authorities and road network operators use cost-benefit analysis to decide on necessary developments. Taking into account only the momentary statistical renewal rate of the vehicle fleet (disregarding all handheld devices), a fully capable operation of such a system can only be predicted in more than 10 years.
An overview of existing C-ITS use cases throughout Europe and a simplified comparative analysis of estimated costs and quantifiable benefits of such a system in Hungary is presented in this article. Our research assigned the first developments (i.e. technologies and use cases) in the next 1-3 year period to prepare certain parts of the public road network for CAV testing.

Keywords: C-ITS, Day1 services, C-ITS benefits, C-ITS costs, C-ITS development

1 Methodology

To conduct the assessment described above, a collection of available and documented use cases is needed to understand and study the basic goals and parameters of any measures, including all the experience on deployment and operation [1]. This information helped us to define and analyse costs and benefits of possible development scenarios in Hungary, and to decide which C-ITS use cases worth to apply throughout the country based on its cost-benefit ratio. After calculating these indicators, it is possible to propose a strategy to be followed in the first years of C-ITS development.

2 C-ITS service as groups of use cases

Certain groups of use cases are feasible using the same infrastructure and hardware/software tools, so they are much more efficient than standalone use cases [3]. A step-by-step method was defined in the EU C-ITS strategy introducing Day1, Day1.5, Day2, Day3 and Day4 groups of C-ITS use cases (see Fig. 1). The simultaneous development, standardization (both

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in-vehicle and roadside), pilot projects and implementation of use case bundles can keep up pace with the development and uptake of the technologies used.
Day1 services focus on exchanging information enhancing foresighted driving. Day2 services improve the service quality and share perception and awareness information. Day3+ adds further sophisticated services like sharing intentions, supporting negotiation and cooperation that paves the way towards cooperative accident-free automated driving. The deployment of the cooperative V2X services proceeds in different innovation phases, starting with Day1, a basic set of information and warning services support low penetration rates of C-ITS capable road users during the market introduction. A few Day1 services are already available in cooperative V2X vehicles on certain European roads. Services related to Day2 and Day3+ phases are investigated in R&D projects that are generating the knowledge for developing related customised functions and standards (see Fig.1).

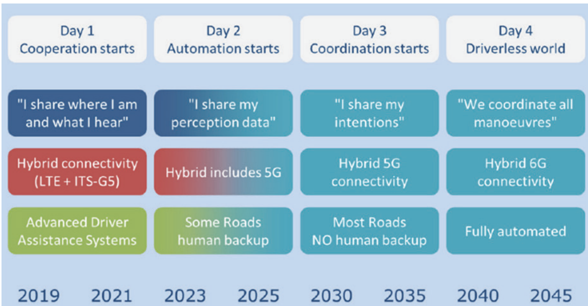

Figure 1 C-ITS services as suggested in the EU C-ITS strategy

Now we are focusing on Day1 and Day1.5 services listed in Table 1. Day1.5 services are feasible where Day1 services are using the same technology, networks and interfaces. The difference is the sphere where the benefits are realized since Day1 services generates social benefits while Day1.5 services mostly add value for individual users (parking information, charging stations, navigation services) or extend the user group to the vulnerable road users. Day1 and Day1.5 services present their warnings, instructions and information on a screen inside the target vehicle. Using these services, no automation level over SAE2 assumed since they do not trigger automatic longitudinal or lateral manoeuvres.

Table 1 List of Day1 and Day1.5 C-ITS services

	Day1 services	Type	Focus area	Bundle
1	Emergency brake light	V2V	Safety	1
2	Emergency vehicle approaching	V2V	Safety	1
3	Emergency vehicle approaching	V2V	Safety	1
4	Traffic jam ahead warning	V2V	Safety	1
5	Hazardous location notification	V2I	Motorway	2
6	Road works warning	V2I	Motorway	2
7	Weather conditions	V2I	Motorway	2
8	In-vehicle signage	V2I	Motorway	2
9	In-vehicle speed limits	V2I	Motorway	2
10	Probe vehicle data: CAM aggregation	V2I	Motorway	2
11	Shockwave Damping	V2I	Motorway	2
12	Green Light Optimal Speed Advisory (GLOSA)	V2I	Urban	3
13	Signal violation	V2I	Urban	3
14	Traffic signal priority request by designated vehicles	V2I	Urban	3
	Day1.5 services	Type	Focus area	Bundle
15	Off street parking information	V2I	Parking	4
16	On street parking information and management	V2I	Parking	4
17	Park & Ride information	V2I	Parking	4
18	Information on AFV fuelling & charging stations	V2I	Routing	5
19	Traffic information and smart routing	V2I	Routing	5
20	Zone access control for urban areas	V2I	Routing	5

3 Impact assessment and results

In the course of the impact assessment, expected costs and expected social benefits of the introduction of C-ITS Day1 services were quantified based on the methodology of RICARDO-TFT-TEPR 2018 (R-T-T-2018) [4].
In our calculations, we took into account the regulatory environment of Policy Option 2 (PO2). PO2 specifies C-ITS services, common service profiles and compliance with C-ITS policies in a legally binding delegated regulation. This policy has a strong emphasis on coordination and standardization but does not include an obligation to deploy Day1 V2V services, and does not create legal bodies to perform security and compliance assessment tasks.

3.1 List of considered services and road network (scope) to be implemented

As an initial step in the impact assessment, the range of services and network elements to be taken into consideration were defined. In the calculations only Bundle1 and Bundle2 measures of Day1 services were examined, and the effects of the three sequential scenarios built from them:

- In the Baseline scenario (case without the project), the measures of Bundle 1 will work with a modest penetration, and the already established V2I services will be maintained in the future but will not be expanded.

- In Option A, V2V measures of Bundle 1 will work with more ambitious penetration rates, and services of Bundle 2 will be built on the entire TEN-T core network.
- In Option B, the measures of Bundle 1 and Bundle 2 will be available on both TEN-T core and comprehensive network (gradually, but with full development over a few years).

3.2 Socio-economic conditions, traffic forecasts

Socio-economic conditions (general assumptions) primarily determine the number of vehicles and the uptake rate of in-vehicle equipment. The number of vehicles equipped with C-ITS unit on the national road network depends on:
- the long-term trend of the country's GDP forecasts;
- the country's population forecast;
- motorization trends (based on the relation of GDP to the degree of motorization);
- the penetration rate of C-ITS equipment, which is strongly influenced by the policy option considered (PO2).

Social, economic and traffic development data were taken from the National Traffic Survey [OCF-2016] [6]. The change in the number of passenger cars was calculated as the product of the population and the expected degree of motorization. In the case of heavy goods vehicles, the OCF-2016 study points to the peculiarity that the rearrangement of the transport market among vehicle categories predicts different fleet developments for vehicles smaller and larger than 3.5t. It is estimated that the number of vans is growing dynamically, while the number of heavy goods vehicles is expected to stagnate and fall slightly - in line with international trends. The characteristic feature of the traffic development is that the projected passenger and heavy truck traffic on the motorways is constantly increasing, but on the main road network it decreases significantly, while the traffic performance of vans increases on both types of roads. Further general assumptions:
- the calculation of social costs and benefits does not take into account changes in GDP and inflation,
- costs incurred and social benefits are expressed in real terms, at 2015 price level, in Euros,
- the evaluation period runs from 2020 to 2030.

3.3 In-vehicle and road-side C-ITS equipment

The baseline scenario is a case in which "no further EU action" takes place beyond the ongoing EU C-ITS activities. Only developments that have already been initiated by national or regional authorities are expected - these will be continued throughout the evaluation period (until 2030).
In the case of vehicles, new factory-fitted vehicles reach 100 % uptake in 4 facelift (mid-model) cycles. (Model facelift cycle in the PO2 environment is 4 years for cars and 5 years for trucks). Retrofitting is only possible through smartphones via downloaded application, so ITS devices are unable to deliver the safety V2V services of Bundle 1, but V2I services are available, and a maximum penetration of 95 % can be assumed. Figure 2 illustrates the development of passenger car and heavy goods vehicle equipment.

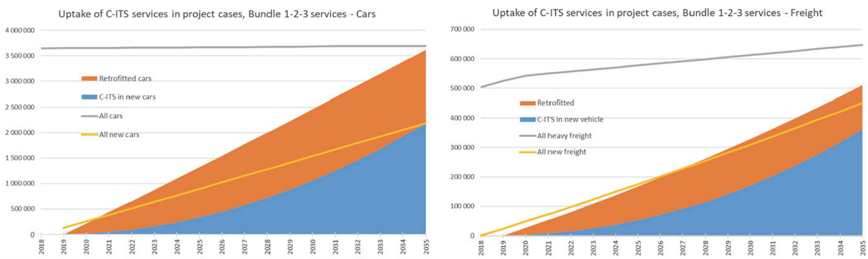

Figure 2 Uptake of C-ITS sub-systems in the Hungarian fleet

In project scenario, the pace of the deployment of road-side units (RSU) on the TEN-T core network starts from the 2020 deployment level and follows the trend of European front runner countries (Figure 3). On other motorways a 4-year lag was considered and 50 % of the growth of TEN-T core network was applied, on other rural roads 25 % of the growth of these TEN-T core network elements were taken into account.

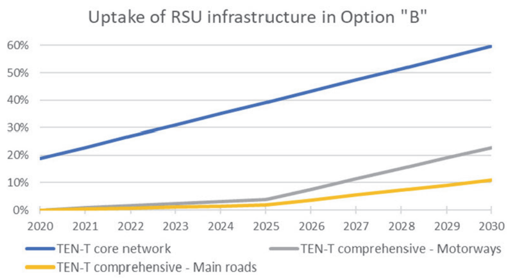

Figure 3 Uptake of road-side unit infrastructure

3.4 Investment and operation costs, social benefits

The following costs are incurred in setting up and operating C-ITS systems:
- Central ITS sub-systems (installation, operation);
- Personal ITS sub-systems, i.e. smartphones, that can be used for V2I communication and in the future also for V2V communication (app development, software update, operation). They are currently unable to communicate with low latency through 3G/4G, so this study does not count on personal Day1 V2V services.
- In-vehicle ITS subsystems – the study does not consider a retrofitted in-vehicle ITS sub-system (installation, operation, maintenance, software update);
- Roadside ITS subsystems– beacons on gantries, columns, smart traffic lights (installation, operation, maintenance).

Various forms of costs were accounted for: upfront costs, ongoing costs and replacement costs – when it was necessary. The costs were borne by various actors. Figure 4. shows the distribution of the costs among the mentioned objects.

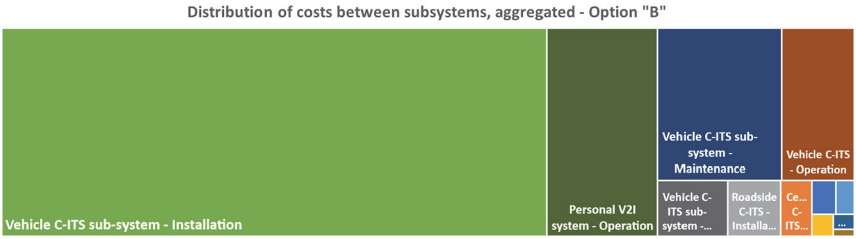

Figure 4 Distribution of costs among subsystems

Summarizing the costs, it can be stated (Figure 4.) that:
- the largest part of the costs (64 %) is for the purchase and then maintenance of in-vehicle systems.
- the operation of communication equipment is also a significant item (~ 20 %, mainly data flow);
- the deployment of TEN-T comprehensive network elements involves relatively low additional costs in case of an already the existing TEN-T core network C-ITS system.

The external social impacts of C-ITS systems may include:
- increase in transport efficiency (increase in average speed, %),
- change in fuel consumption (%),
- change in pollutant emissions (NOX, CO, VOC, PM %)
- change in accident risk (%).

The measures in Bundle1 and Bundle2 of Day1 services have a predominant impact on road safety, so accident savings were quantified. According to the R-T-T 2018 study, each measure helps to reduce the number of accidents. As the individual influence of each factor is difficult to separate, there are some overlapping impacts. To avoid multiple counting, the cumulated effect on traffic accidents is reduced by 10 % at the end of the calculation.
The number of injuries was taken into account on the basis of specific injury indexes calculated from accidents on the examined road network in 2016-2018. The decrease in the number of injuries compared to the baseline case in the core years is shown in Table 2.

Table 2 Impacts of Bundle 1. and 2. services on traffic safety

	Project A: TEN-T core network			Project B: TEN-T core+compl		
Decrease in the number of injured	2020	2025	2030	2020	2025	2030
Fatality	0,09	1,92	6,84	0,09	1,99	7,53
Severe injury	0,39	8,55	30,33	0,39	8,79	32,94
Slight injury	1,11	24,46	87,97	1,11	24,74	91,46

3.5 Results

The order of magnitude of the costs and benefits is the same, but the totally aggregated costs are about three times over the calculated benefits. Both the costs and benefits increase with the deployment of the network and the penetration of in-vehicle devices. Compared to Option "A", the cost of Option "B" is slightly higher, but the benefits of Option "B" are significantly higher. In-vehicle costs are, of course, inseparable from the introduction of C-ITS services, but the last pair of figures illustrates the cash-flow diagram of the implementation of the C-ITS system with a free ("swallowed") on-board device. Note that the cost of on-board units is borne by each vehicle owner, so it is shared among a large number of users, while installation of the infrastructure of each service is entirely service provider or road operator responsibility.

Figure 5 Cash-flow diagrams of feasible options

4 Conclusions

Assessing the calculation of costs and benefits of Day1 C-ITS services above, our conclusions are as follows:

1. A strong prerequisite to start any C-ITS service is an OBU in all possible vehicles;
2. The up-front cost of OBUs is huge – but beyond this threshold, additional services and social benefits can be offered “cheaply”.
3. A first wave of easily deployable services will induce benefits in the field of traffic safety.
4. It is clear that the service area and the number of services can also be extended relatively cheap after the first areas are covered with the first group of services.

There are further considerations with effect on the costs and benefits:

- Based on traffic counts done in 2019, the official traffic prediction for Hungary (made in 2016 and only upscaled in 2018) seems to be underestimating road traffic on motorways and first-class main roads. Greater traffic performance with the same costs of C-ITS development means greater benefits for the society.
- Statistical Value of Life (SVL) used to calculate benefits from the accidents that do not happen in the future is a thin ice to walk on. We kept the values from the R-T-T 2018 study applied for the whole EU. However, there is a newly published “Handbook on the external costs of transport, 2019” since, with significantly (30-50 %) higher SVL values. Our estimation seems to be too conservative in this respect.
- We see an „early market” phenomenon regarding the OBUs. When implementing C-ITS systems, the early adopters pay most of the price of technical development and starting series

production. Most probably, after the first years of investments into such systems, prices of on-board and roadside units will drop significantly (at least by 50 %).
- This is a forward-looking, preventive development. There are further developments with significant benefits that can be realized on the same communication infrastructure with the same interfaces where only application development (“software”) is necessary.
- The only benefits in our calculation were the accidents that will not happen thanks to the new C-ITS systems. No other benefits like less congested hours (time savings multiplied by time value) or smaller environmental impacts were calculated – just because that would be another study. But we can assume that only the time spared without the congestions after the accidents withheld has a time value of the same order of magnitude as the benefit from the lower number of accidents themselves.

These considerations suggest that the real benefits of such a C-ITS project described above are significantly higher while the costs can be much lower than calculated.

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