# Long Distance Freight Transport Research

**Paving the way for infrastructure and LDFT cooperation**

**<u>Status: final</u>**

Date: 24.06.2024

ERTRAC Working Group Long Distance Freight Transport

# 1 Context and problem statement

## 1.1 Aging road infrastructure with severe budget constraints

**Figure 1: European bituminous road, after winter.**

**Figure 2: Country: Germany, Leverkusen, construction Year: 1965, traffic: 111.900 vehicles per day, closed from 09-2016 until 2020.**

**Road infrastructure is aging, and maintaining the level of service that is expected by the road users seems currently impossible because of budget-related issues.**

For the last decades, the budget allocated to this type of infrastructure in Europe has not been sufficient for maintaining and undertaking all usual repair actions (Figure 1). As a consequence, even less budget is available for rehabilitation, strengthening or replacement (Figure 2), which are in fact necessary actions in order to support the increasing applied loads, both in terms of man-made actions (traffic loads, amongst which is the need for higher axle and total loads to enable zero emission trucks and increased logistics efficiency) and environmental actions (due to climate change, e.g. greater load amplitudes with higher frequencies) on an infrastructure which enters the second half of its life.

The increased need for maintenance is enlarging budget demands. Making road users pay more is not easily accepted, as evidenced by the reaction with the introduction of truck tolls. This implies that other means to finance the maintenance, the repair or the strengthening of the road infrastructure should be proposed.

Increasing designed efficiency is another solution. **Optimization of the infrastructure-vehicle ecosystem is possible**, both in terms of management of traffic [1] or of the road infrastructure [2]. This is the concept of Intelligent Access or Performance-Based Standards[3]. Moreover, new tools and technologies for road infrastructure management and monitoring appear, making it possible to better analyze the structural health of infrastructure and its maintenance if traffic levels are known (e.g. iSHM [4] or optimized maintenance planning[5]). However, this might be possible only if information on, e.g., the truck and its cargo

[1] ITF (2019), "High Capacity Transport: Towards Efficient, Safe and Sustainable Road Freight", International Transport Forum Policy Papers, No. 69, OECD Publishing, Paris. https://www.itf-oecd.org/sites/default/files/docs/high-capacity-transport.pdf

[2] ITF (2018), "Polices to Extend the Life of Road Assets", ITF Research Reports, OECD Publishing, Paris. https://www.itf-oecd.org/sites/default/files/docs/policies-extend-life-road-assets.pdf

[3] CEDR (2022), « Intelligent Access (IA): current NRA practices « , CEDR's Secretary General. https://www.cedr.eu/docs/view/62a343fc227be-en

[4] Gkoumas, K. et al., Indirect structural health monitoring (iSHM) of transport infrastructure in the digital age, Publications Office of the European Union, Luxembourg, 2023, ISBN 978-92-76-61977-2, doi:10.2760/364830, JRC131885. https://publications.jrc.ec.europa.eu/repository/bitstream/JRC131885/JRC131885_01.pdf

[5] European Asphalt Pavement Association (EAPA). High-performance Asphalt Pavements – adapting for future road networks. EAPA Technical Review (2021) 22 pages. https://eapa.org/download/12741/

is available: indeed, traffic volume, traffic mix (ratio of cars and trucks), traffic loads, etc. are the information that is needed to understand maintenance needs and safety issues for the network.

## 1.2 New infrastructures: energy and information

Other infrastructures will be appearing, adding to the existing maintenance and investment problem.

**Infrastructure linked to the production and movement of energy carriers, e.g. hydrogen or electricity, needs to be catered for.** There are several alternative technologies [6] that need to be made available to users at a given time and at a given location in the network, which requires well-organized energy transport, storage and charging solutions[7]. In order not to slow down the trend towards the decarbonization of freight transport, these solutions must be available soon, in the needed time frame, whilst being safe, secure, resilient, adaptable and affordable. This means large investments which need to be decided, and whose risks need to be managed.

**As transport and energy infrastructure, digital infrastructure is more and more a given for roads users and managers.** Indeed, data sharing infrastructure is infrastructure[8] (Figure 3). Moreover, road users, may they be private persons or companies, expect a level of service from the road infrastructure that can be achieved only by data sharing: e.g. it is important for truck drivers, shippers, carriers to know where and how many parking slots are available on the road network. It is also essential for the actors to know when and where charging stations will be available, and at which rate. The interactions between these different types of infrastructure (road, energy and digital) need to be better understood, managed and optimized, and research in this field should be pursued.

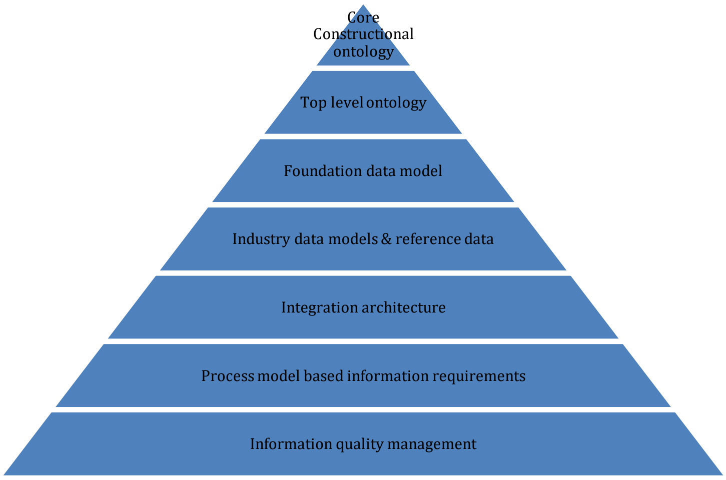


Figure 3: Data sharing infrastructure.

**Smart and smarter infrastructure, vehicles, and goods**

Currently, new vehicles are connected, with innovative services and interactions[9]. Their digital structure is generally summarized by “layers” (strategical/tactical/operational layer, see Figure 4 for an example of representation of the layers and their interfaces, as used within the EU project ENSEMBLE on platooning).

[6] Future Fuels: FVV Fuels Study IV Project no. 1378, The Transformation of Mobility to the GHG-neutral Post-fossil Age, Final report. https://www.efuel-alliance.eu/fileadmin/Downloads/FVV__Future_Fuels__StudyIV_The_Transformation_of_Mobility__H1269_2021-10__EN_compressed.pdf

[7] Electric road systems – A route to Net Zero. A PIARC technical report. 2023R30EN. https://www.piarc.org/ressources/publications/source/2/ff184df-42699-2023R30EN-Electric-Road-Systems-A-Route-to-Net-Zero-PIARC-Technical-Report.pdf

[8] Infrastructure 4.0: Achieving Better Outcomes with Technology and Systems Thinking, White Paper, May 2021, World economic forum, https://www3.weforum.org/docs/WEF_Infrastructure_Technology_Adoption_2021.pdf

[9] ERTRAC, Long Distance Freight Transport, A roadmap for System integration of Road Transport, 2019. https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-Long-duty-Freight-Transport-Roadmap-2019.pdf

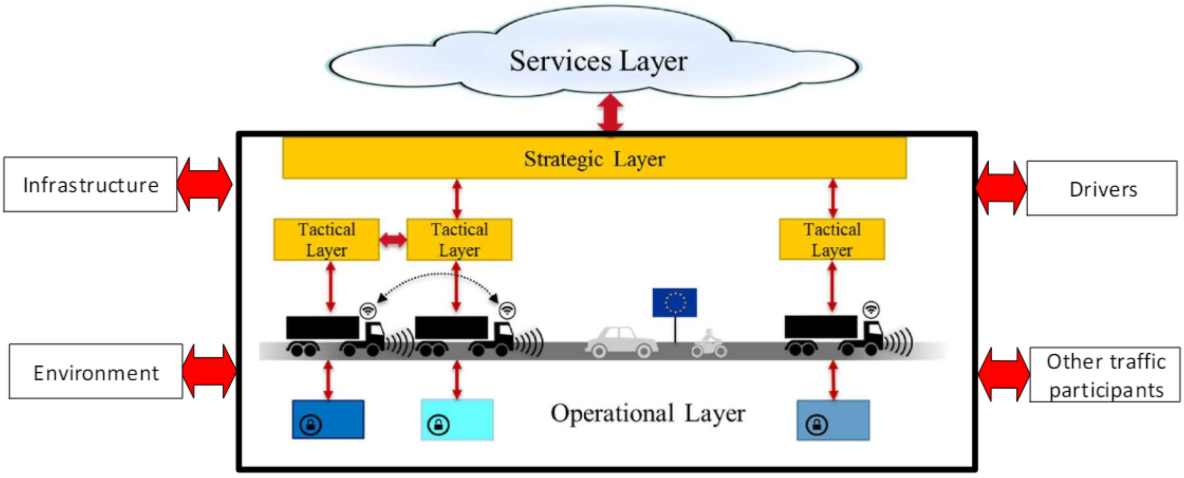


**Figure 4: Interfaces of the heavy vehicle with the environment, as defined in EU project ENSEMBLE[10].**

This representation shows an arrangement of communication between vehicles and OEMs that is technically feasible. Data exchange is mature for freight transport services – e.g. to make the multi-fleet logistics system work with fuel economy and fleet management services, driver times, diagnostic services, etc. Much more could be done to enable automation use cases as well. Bottlenecks are not only a matter of technology maturity but also of end user's business cases and societal acceptance.

These vehicles and their utilization **are optimized, but in "silos"**:

- The vehicles themselves are optimized, individually, in terms of safety (e.g. emergency braking, obstacle detection, etc.), fuel economy and emissions. Exiting the conditions of the optimization (e.g. driving in a platoon) degrades the optimization.
- The freight traffic is optimized, in terms of speeds, routing of transport and access management, but this is often company specific or with standards that are not used by all the stakeholders or governed by the parties in individual transport agreements. Some services, such as Origin-Destination analysis, volume of carried goods, etc., are now provided by 3rd parties, but access by externals to company-internal data is can sometimes be poor, from the quantity or from the quality perspective. The EU data act introduces new framework conditions for data sharing, which may should improve the accessibility of this data.
- Shippers, hauliers and LSPs, optimize the routes and their parameters (departure, freight, drivers, etc.) supported by Transport Management Systems[11] (TMS) and optimize dynamically when possible, for example using the ETA (Expected Time of Arrival) of their trucks.

**These technologies and the associated services are part of a fast evolving ecosystem, which is also affected by the demands for decarbonization and the use of alternative fuels.**

Nevertheless, all stakeholders agree that more **connectivity is needed** as is better management of these increasing data volumes. There should be communication outside the traffic system (Figure 4), and not only outside the service layer (which could perhaps include maintenance services), but also with the whole supply chain perspective, e.g. via the concept of Smart Freight (goods-vehicle-infrastructure). The

[10] Vissers, J., et al., (2018) V1 Platooning use-cases, scenario definition and Platooning Levels D2.2 of H2020 project ENSEMBLE, (www.platooningensemble.eu ). https://platooningensemble.eu/storage/uploads/documents/2021/03/24/ENSEMBLE-D2.2_V1-Platooning-use-cases,-scenario-definition-and-platooning-levels_FINAL.pdf

[11] Gunnar Stefansson, Kenth Lumsden, Performance issues of Smart Transportation Management systems, International Journal of Productivity and Performance Management, Vol. 58 No. 1, 2009, pp. 54-70. DOI 10.1108/17410400910921083

information exchanges between goods, vehicles and infrastructure that will be identified are specific to the use case, based on stakeholders' needs. Fleet managers, for example, want to know the status of individual trucks, whilst planners want to know where individual trucks are at a given time and where they are going with which cargo, moving towards Smart Freight. Alternatively, drivers need routing information. The sources of data differ: cross-service-layers information sharing will be required. Figure 5 illustrates this complexity for the specific case of truck platooning.

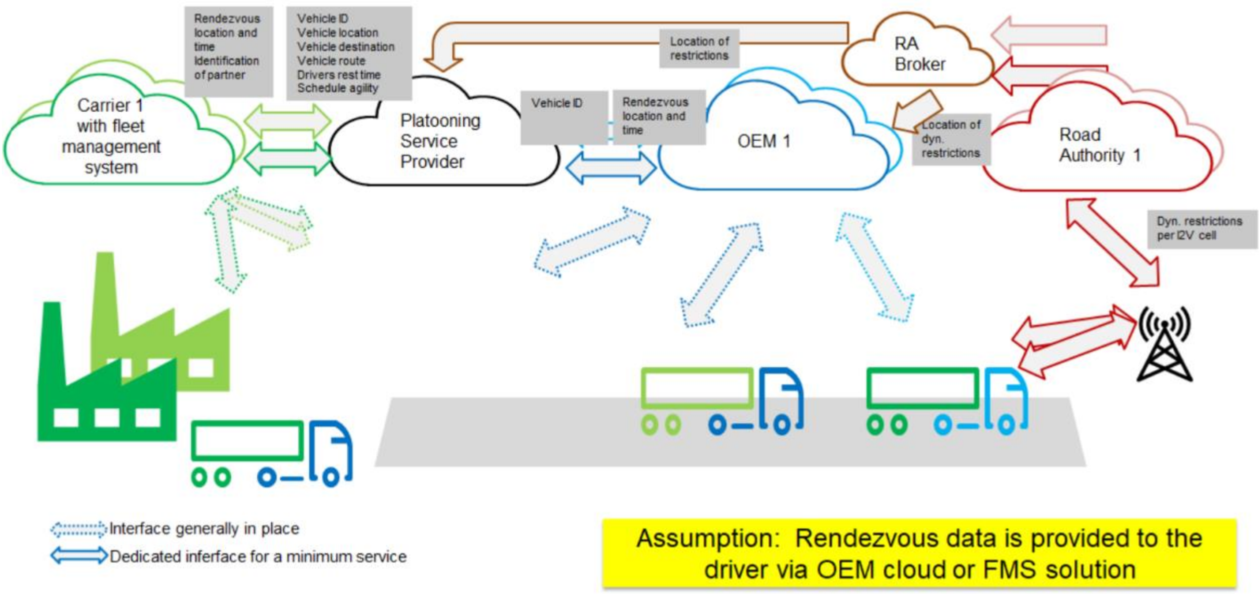


**Figure 5: Data exchanges to be catered for in the case of truck platooning[12].**

Also, beyond the transport domain, logistics processes, terminal operations and shippers/receivers operations can derive value from cargo- and predictive trip information (Figure 6). Future traffic data can be inferred only if the current situation is well known, and after learning over long periods of time. Therefore C-ITS would contribute to this Smart Freight roadmap.

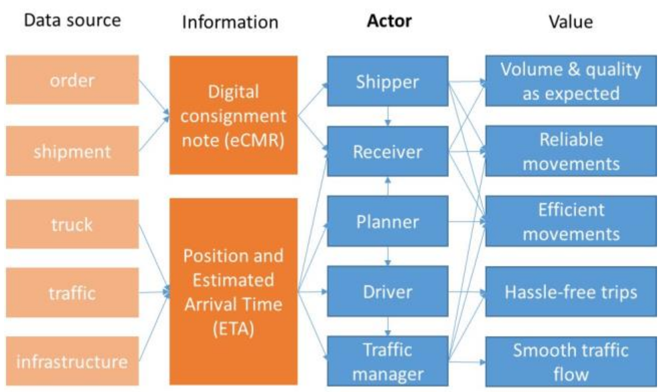


**Figure 6: Example of logistics benefits from digital transport information[13].**

[12] Lützner, J. (2021). Service and Strategic Layer Design. D4.2 of H2020 project ENSEMBLE, (www.platooningensemble.eu ). https://platooningensemble.eu/storage/uploads/documents/2023/03/13/ENSEMBLE-D4.2-Service-and-Strategic-Layer-Design_FINAL.pdf

[13] Vanga, R., Thiyagarajan, N., S. Gelper, Y.Maknoon, M.B, Duinkerken, L.A. Tavasszy (2023), A data-to-value framework for freight ITS: insights from a living lab, Paper presented at WCTR 2023

Eventually, the optimization of road freight transport will converge with the establishment of the system-optimal Physical Internet, into a well synchronized, smart and seamless network, with road infrastructure corridors and hubs integrated into its structure[14]. The information need between infrastructures and its users is then mutual:

- The trend towards automation[15] implies a need for more information: on one side, some lower-level types of automation (e.g. platooning or driver help) will need communication between vehicles. In addition, higher levels of automation will need information from the infrastructure[16]. Indeed, for cooperative driving, the infrastructure must be able to guide vehicles to optimize the traffic flow, with guidance (on speed, gap, and any other parameters needed to optimize the flow and ensure safety for all road users).
- On the other side, the infrastructure needs information about the vehicles and loads carried to better manage them, and deal with heavy traffic, which is evolving in time and therefore differs from the analysis and bearing capacity analysis' that may have been done in the past:
    - gross weights of vehicles have increased compared to the weights assumed when dimensioning infrastructures;
    - dimensions have changed in some cases to simplify traffic for new freight segments (e.g. increased lengths for combined transport);
    - truck designs have adopted better aerodynamic features[17] or zero emission possibilities, and the maximum allowed loads have been increased.

The above mutuality could lead to win-win situations[18] , where improved travel conditions may be granted to vehicles sharing information to the infrastructure. We explore this in the following.

# 2 Prospects for infrastructure-vehicle cooperation

## 2.1 Principles

**Infrastructure-vehicle cooperation (IVC) will bring benefits**, both directly and indirectly for the various involved stakeholders. Indeed, IVC is directly related to infrastructure (i.e. access and maintenance) and vehicles (i.e. operation and maintenance), but it will also influence the traffic and the transport system, and the supply chains using it.

In order to ensure this overall benefit, all stakeholders, such as carriers, shippers, and service providers, need to be involved to achieve system optimization. It is necessary to **consider all three components of the material flow/transport/infrastructure system**, see Figure 7. The economic impacts (investments and benefits) for all parties need to be considered, and the interfaces need to be carefully designed to ensure optimal efficiency, balanced gains and resilience, for example through the concept of Physical Internet[19].

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[14] Corridors, Hubs and Synchromodality, Research & Innovation Roadmap, Alice, 2022. https://www.etp-logistics.eu/wp-content/uploads/2022/08/Corridors-Hubs-and-Synchromodalit-Roadmap.pdf
[15] ERTRAC, Connected, Cooperative and Automated Mobility Roadmap, 2022. https://www.ertrac.org/wp-content/uploads/2022/07/ERTRAC-CCAM-Roadmap-V10.pdf
[16] Classification of Readiness of European Highways for Adopting Connected, Automated and Electric Vehicles, EAPA, 2020. https://164.wpcdnnode.com/eapa.org/wp-content/uploads/2020/11/EAPA-classification-of-Roads-2020-final.pdf
[17] Directive (UE) 2015/719
[18] ITF (2018), "Polices to Extend the Life of Road Assets", ITF Research Reports, OECD Publishing, Paris. https://www.itf-oecd.org/policies-extend-life-road-assets
[19] Roadmap to the Physical Internet, Alice, 2020. https://www.etp-logistics.eu/wp-content/uploads/2022/11/Roadmap-to-Physical-Intenet-Executive-Version_Final-web.pdf

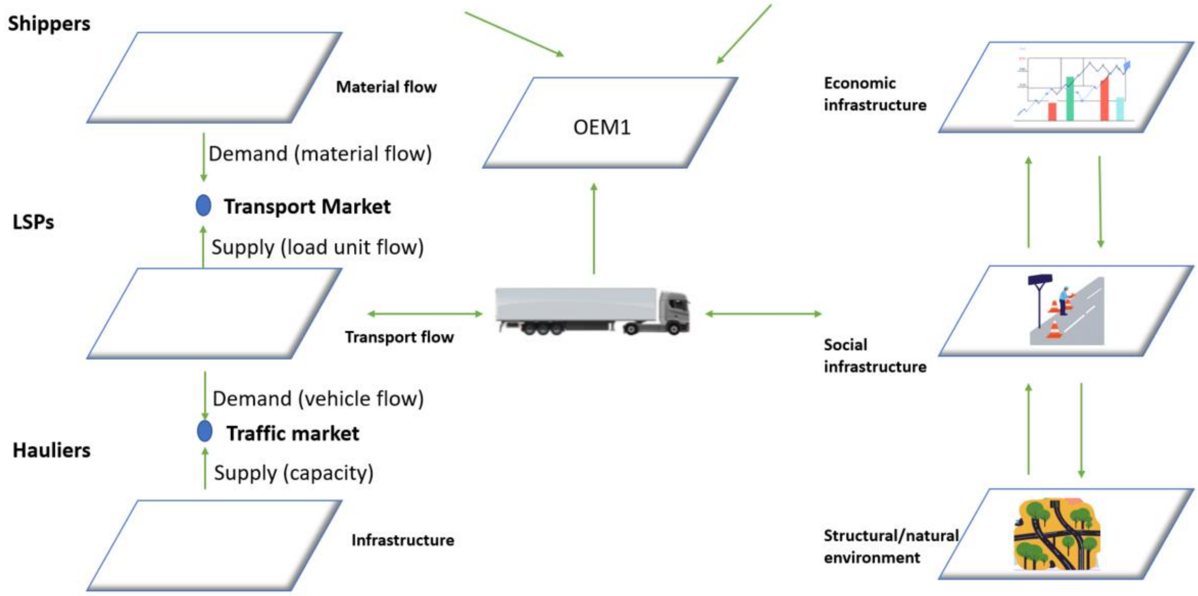


**Figure 7: Example of representations of stakeholders in the ecosystem [left part of the diagram has been adapted from Wandel et al., 1992[20]]**

The future of the material flow/transport/infrastructure system is uncertain. The vehicle is at the centre of this stage, and, as already introduced above, several strategic changes will determine its position:

- **Energy consumption and its supply will change**: predictions show a mix of possible solutions.
- **Adaptation in weights and dimensions of trucks are foreseen**, which challenge the adaptability of physical infrastructure (road infrastructure, logistics centres, etc.), digital infrastructure (associated management tools) and access management.
- **The level of automation of vehicles trucks will change**, with transition phase between today to the level 4 of automation. Not only leveraging all benefits of automation, but improving and securing the next step in this automation trajectory needs data exchange between infrastructure, vehicles and freight.

## 2.2 (Some) key issues

Whilst research shows that IVC would lead to societal benefits[21], these are not all of the same type and do not provide benefit to the same stakeholders in the same shares. In particular, whilst business benefits are needed to ensure the viability and the growth of IVC, impacts on health, inclusivity, etc. need to be considered carefully, especially with the target of decarbonization and long-term objectives[22]. To do that and to optimize the whole system, **broadly agreed methods to assess the impacts of IVC are needed**.

[20]Wandel, S., Ruijgrok, C, & Nemoto, T.: Changes in road freight transport, advanced logistics and information technology, Published in ROAD TRANSPORT RESEARCH advanced logistics and road freight transport, OECD1992.

[21] Schmidt, F. & Mascalchi, E. (2022). Recommendations and Roadmap. D6.9 of H2020 project ENSEMBLE, (www.platooningensemble.eu), https://platooningensemble.eu/storage/uploads/documents/2023/03/13/ENSEMBLE-D6.9-Recommandations-&-roadmap_FINAL.pdf

[22] Internalisation of external effects in European freight corridors, International Transport Forum, 2013. https://www.oecd-ilibrary.org/fr/internalisation-of-external-effects-in-european-freight-corridors_5k46l8wpzf7b.pdf?itemId=%2Fcontent%2Fpaper%2F5k46l8wpzf7b-en&mimeType=pdf

Whilst the current situation can be described to some extent with existing data and some predictions about the long-term situation on vehicles/automation levels/energy consumption and supply may be assumed, **there are the transition phases to be tackled**. These situations will need to be handled while ensuring safety and preparing the future steps in the traffic evolution and possible IVC. In particular, while maintaining and improving the current situation, investments will need to be prepared for the future.

IVC will involve new **challenges around data creating, storage, treatment and analysis:** the acquisition or creation phase is linked to the sharp development of new sensors, which are connected, autonomous, smart with delocalized learning power. In terms of storage, the issue is linked with data servers and trust issues, which are due not only to cybersecurity concerns. Interoperability and compatibility of data from the various stakeholders is a need, while it is not only a technical, software-related issue, but also implies a consistent approach to data modelling, shared reference data and common security, access and quality protocols.

Adaptation to **climate change** will need mitigation and adaptation measures to increase resilience to this change and other latent changes, but thinking and organizing will also have to deal with **disruptive events, like extreme weather events and human threats**, which are not predicted with the same tools and cannot -generally- be dealt with in the same manner as slow, constant changes. Environment of the whole traffic system is evolving, fast and also sometimes in disruptive ways, and these new conditions have to be considered.

## 2.3 Bottlenecks and challenges

The bottlenecks on the route to IVC are numerous, and a non-exhaustive list can be given here:

- The **relevance of the economic model of IVC** needs to be questioned: benefits for the business partners have to be there to ensure the implementation and generalization of IVC, but the other stakeholders need also to benefit from IVC, in a not-too-far-away future.
- There is **European (and even a local) fragmentation** in regulations, approaches and uses cases linked to IVC. A common or modular system with common parts needs to be derived in order to implemented Europeans actions.
    - Digitally available traffic regulations are crucial for autonomous driving at all levels, and such regulations need to be smart so that you know how different regulations « works » together.
    - Connected to this first point, the standards for the information that is sent back and forth must consider safety/security concerns.
- Materials and energy may be scarce in Europe, hence **European material and energy sovereignty** must be considered, especially in the case where external factors restrict sources or acceptable conditions (monetization, political, etc.).
    - For each of the three parts of the service/vehicle/infrastructure ecosystem, there are **different timelines**, both within these elements and within different countries in Europe. In particular, vehicles do have a shorter life than road infrastructure, and their technological evolution is also faster. Moreover, in some countries, IVC is already more implemented than in others.
- **The acceptability of policies and regulations about information exchange** needs to be ensured, especially in the case of situations involving humans and/or insurance linked issues.
  *Who takes the responsibility in case of failure (for example, a bridge failure)? What are the rules in terms of road infrastructure monitoring and with which reporting procedures? How to plan for preventive maintenance?*

We know that road managers will not always share the data showing the overweight traffic (being measured by road infrastructure monitoring system), as this is not mandated to prevent consequences of overweight. As stakeholders are able to “sell” data, relevant stakeholders might be able to “demand” the data. “Handling” of data and information are both a challenge and a solution. Therefore, some basic questions arise: which data should be shared with whom, where should the data be stored and who should do that, what type of standards do we need, etc.

- **Cybersecurity threats** are real, and should be treated carefully, in particular by sharing only what needs to be shared with the relevant stakeholders.
- **The infrastructure, both physical and digital, is exposed to higher loads,** of course in terms of traffic loads but also in terms of climatic/environmental loadings. Whilst design rules integrate safety margins, these margins have been now used-up by increased loadings and damaged structures or materials.
- **The social acceptance of incentives or consequences** needs to be ensured, in particular to ensure inclusivity. Indeed, some prices - for freight transport, for tolls - might increase, whilst others decrease, because of IVC.
- **Trust** is needed to share information.

**IVC may be one of the drivers for decarbonization, if implemented smartly. Therefore, it can be considered as one piece of the bigger puzzle of decarbonization.** The R&D in IVC needs are linked to these issues, and some major ones are highlighted hereafter.

# 3 R&D needs

Intentionally, we list here three major research needs, which should be investigated by both desk studies and experimental studies obtained through living labs/use cases, with some conclusions in terms of the generalization of the results to open roads implementation.

- **Global assessment framework for benefit-driven use cases of Infrastructure-Vehicle-Cooperation**, which would combine the impacts in all domains: economics/business, safety for the drivers but also the other road users, environment (emissions, noise, etc.), life quality (acceptance for drivers, impact on other road users, etc.), etc. In particular, the impact on business/economics has to be considered very carefully to:
    - Develop a framework which is compliant with analyses and tools that are already used by the various stakeholders (TCO/Total Cost of Ownership by OEMs, LCA/Lifecycle analysis by road authorities).
    - Make it possible to define the possible shares on investments and benefits between stakeholders. This is a critical task as some stakeholders will have higher investments than others, and the process should be equitable to bring forward the real implementation of IVC.
    - Implement a tool making it possible to apply this assessment in a practical way, for different stakeholders. For example, the particular issues of cities and big metropoles, where climate neutrality might be the most important factor, have to be taken into account. This implies that the assessment should make it possible to introduce weighting factors, and provide decision making help. For example, cities would want 1) an assessment of the status of the infrastructure and 2) advice for decision making in achieving their climate neutrality. For example, *“How should I invest or update my infrastructure to reduce the CO2 emission in my city?”*

- This research can then assess **how IVC can support proactive road traffic management that can facilitate transport planning, monitor and forecast energy requirements, predict accident risk and facilitate automation.** This will be accomplished by integrating real-time traffic data, infrastructure information, and historical data, supporting real-time operations, maintenance and investment decisions.

Therefore, the core work will be defining proper measurements units and indicators, which will assess the expected impacts at all levels of the transport system (Figure 7) and, in particular, some of which will accelerate decarbonization and bring positive effects on global health and safety.

- The **impact of IVC on humans (drivers, road users, logistics and the population in general)** needs to be investigated, in terms of:
  - The impact on truck drivers, but also how the role of the truck drivers will change and it is necessary to understand what he/she can be doing to facilitate/prepare the future. The impact is quantitative (because of the shortage of truck drivers and, therefore the business side of the equation) and qualitative (what tasks can be done, acceptance of automation and/or even more the daily job of truck driver, etc.)
  - The safety of the redefined system,
  - The role of the other workers in the whole ecosystem: for example, what will be the impact on logistics workers whose work will be more and more online? As a consequence, what will be the role of NRAs linked to data management and analysis?
  - How will the new energies and technologies reshape the future logistics patterns? What will be the re-arrangement of fleets, how will workers and entities cope with change?

- **Analysis of regulatory and technological frameworks:** the technology bricks are ready, and will be able to follow the needs from the stakeholders and the users. For implementation, the issue are the hurdles imposed by the fragmentation of:
  - Regulation: some more clarity is required to enable the testing of automated vehicles (both among countries or even smaller geographical elements, and amongst layers of intercorrelated rules/regulations/guidelines),
  - The technological frameworks, where the interfaces must be studied and smoothed out.

This analysis should be done by desk studies, but also by implementation in living labs and open roads at a larger scale. The R&D call should allow disruptive innovations in case they are proposed.