R5G ROUTE 5e GENERATION

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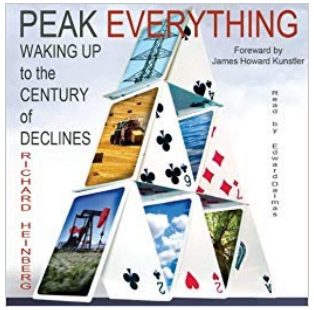
Technological Advances in VI_2E Interaction Model for the Design and Management of NextGen Transport Infrastructures

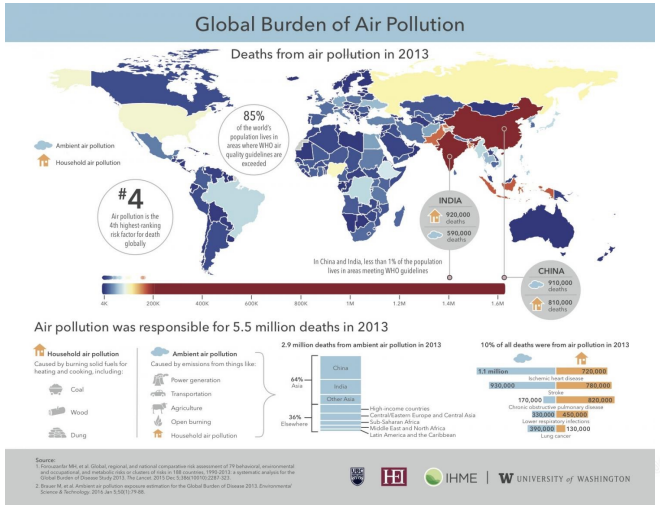
Université Gustave Eiffel

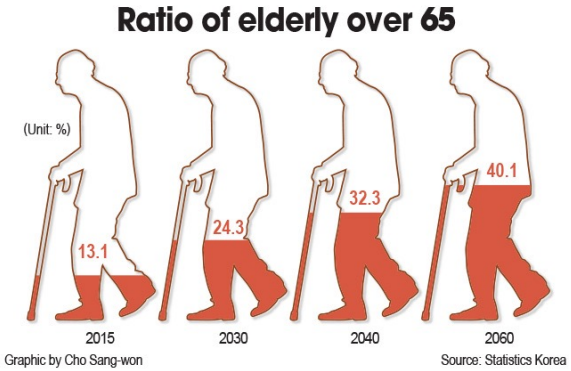
SOCIAL ISSUES RELATING TO MOTORWAY MOBILITY | 1

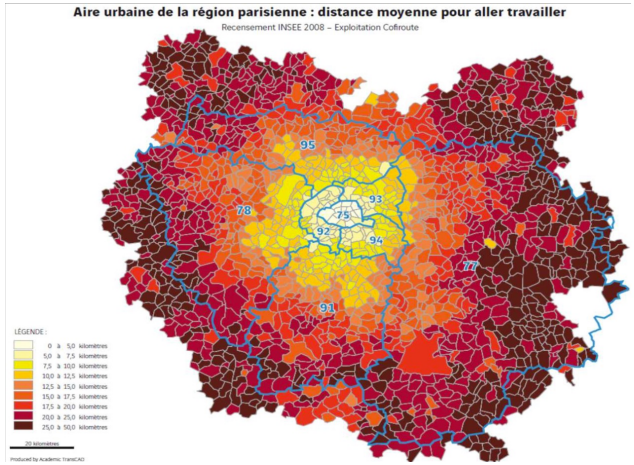
A NEXUS OF SOCIETAL CHALLENGES

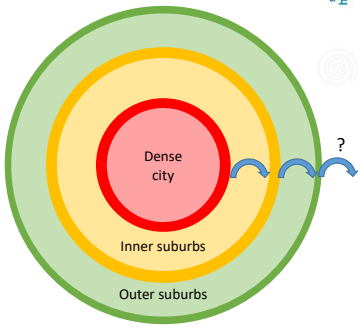
- Scarcity of resources
- Aging of population
- Biodiversity loss
- Climate change
- Finance crisis
- Urban sprawl
- Air pollution
- Congestion
- Etc.











THE ROUTE 5e GÉNÉRATION PROGRAM - R5G (2011-2021) | 2

STATE OF THE ART

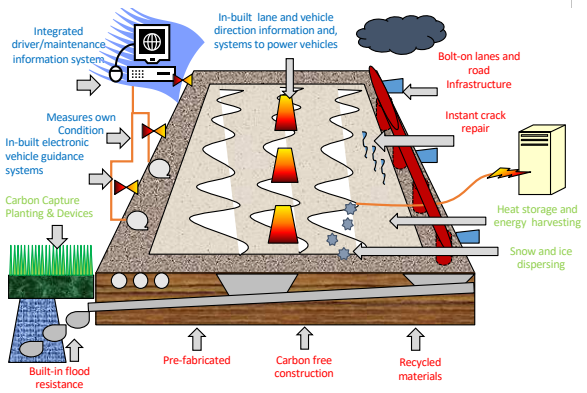
THREE TECHNOLOGICAL PARADIGM SHIFTS AND FOUR GENERATIONS OF ROADS

- 1st road generation: The pathway
- 2nd road generation: The roman road
- 3rd road generation: The smooth road
- 4th road generation: The motorway
  - First development in the early 20th century
  - Full development of freeway from the 60s-70s
  - Mitigation and adaptation since the 80s
- 5th road generation – R5G ©?
  - The Forever Open Road: A road infrastructure that takes the best of existing technologies and the best of those to come.

19th-20th century

End of 20th century

Porzamparc
Atelier Grand Paris

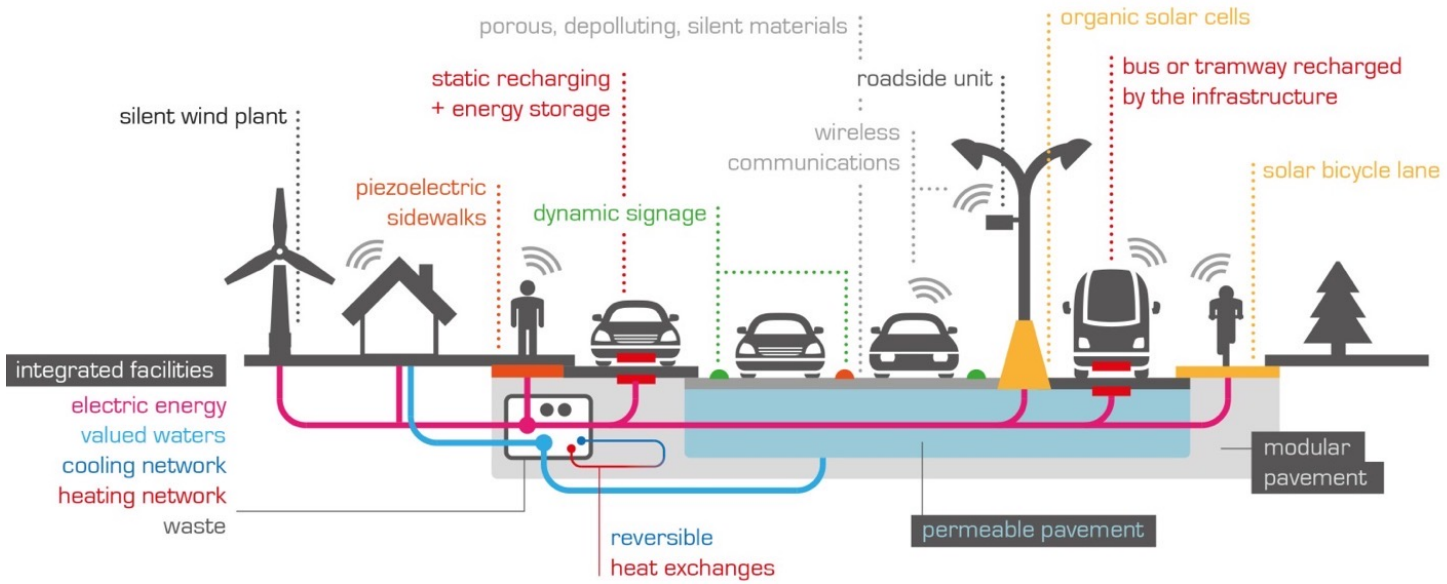


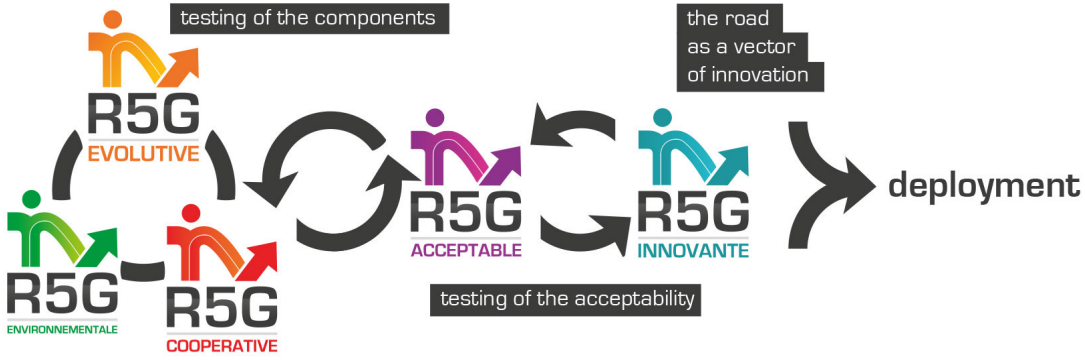
21st century

THE 5TH GENERATION ROAD (2011)

THE R5G CONCEPT

- R5G project aims at integrating the different components of the Forever Open Road following a systemic approach to design and build full scale demonstrators of the next generation road





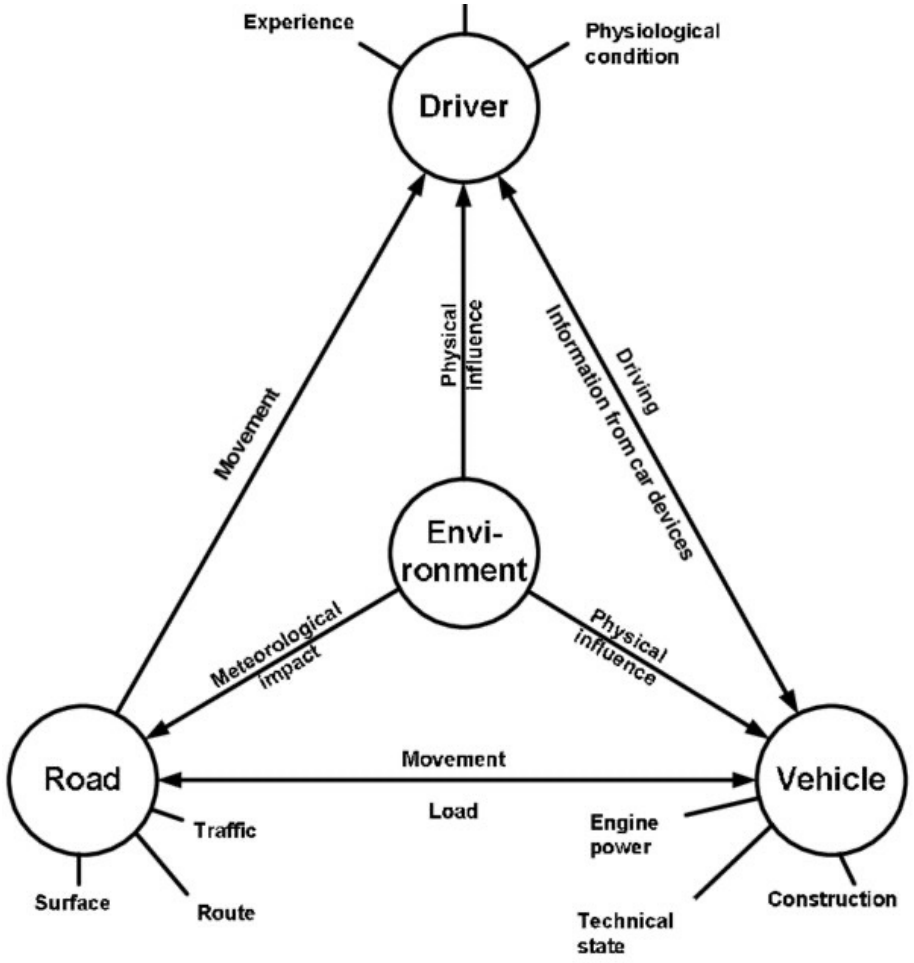
La roadmap "évolutions de la route" : route de 5e génération : route communicante / Nicolas Hautière *in Revue générale des routes et de l'aménagement (RGRA), (2018)955 (Juin 2018)*

CLASSICAL ROAD DESIGN RELIES ON THE VEHICLE-INFRASTRUCTURE-CONDUCTOR (VIC) INTERACTIONS MODEL

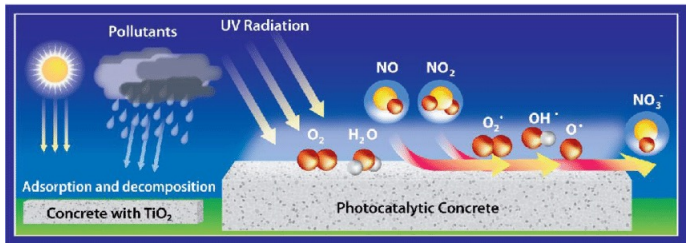
Few key considerations

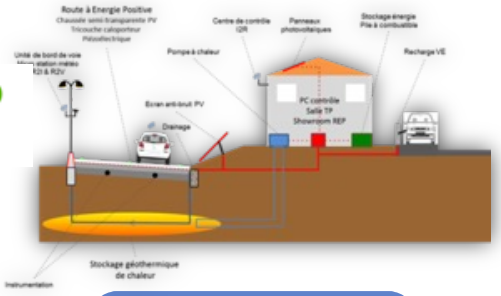
- The limitations of the drivers are sources of accidents
- Environment impacts road state
- Energy is considered as an external entity

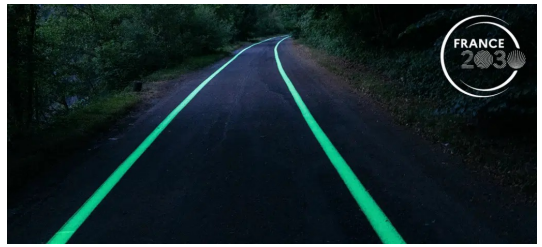
Automatization and energy integration are the two main drivers of change

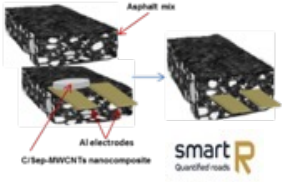


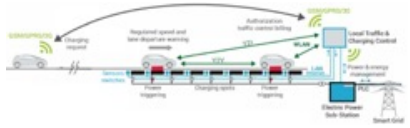
TOWARDS ENERGY INTEGRATED ROADS (2017–2022)

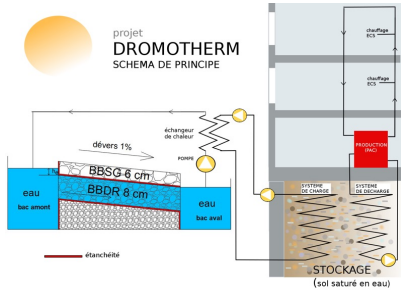












Urban & Transport Planning

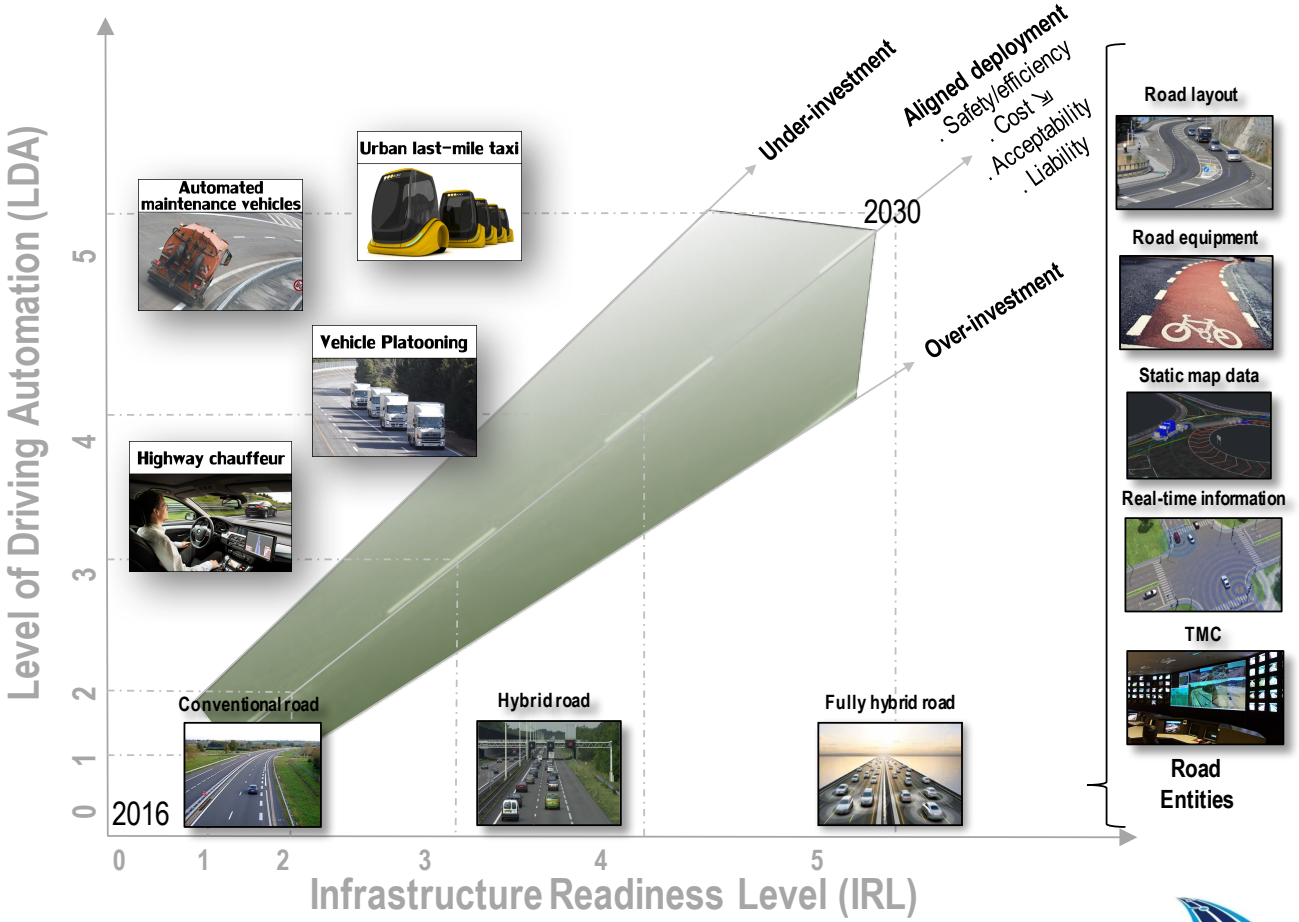
Energy Harvesting

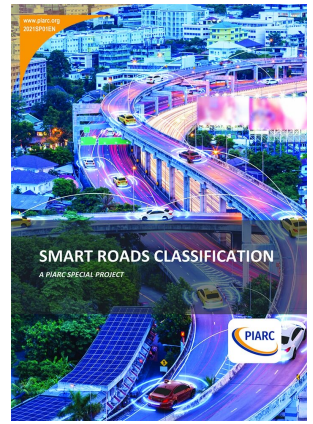
Energy Storage

Energy Transfer

SHM

TOWARDS AUTOMATED ROADS AND STREETS (2018–2023)





	Level	Name	Description	Digital information provided to AVs: Digital map with static road signs	VMS, warnings, incidents, weather	Microscopic traffic situation	Guidance: speed, gap, lane advice
Conventional infrastructure	E	Conventional infrastructure / no AV support	Conventional infrastructure without digital information. AVs need to recognise road geometry and road signs.				
	D	Static digital information / Map support	Digital map data is available with static road signs. Map data could be complemented by physical reference points (landmarks signs). Traffic lights, short term road works and VMS need to be recognized by AVs.	X			
Digital infrastructure	C	Dynamic digital information	All dynamic and static infrastructure information is available in digital form and can be provided to AVs.	X	X		
	B	Cooperative perception	Infrastructure is capable of perceiving microscopic traffic situations and providing this data to AVs in real-time.	X	X	X	
	A	Cooperative driving	Based on the real-time information on vehicle movements, the infrastructure is able to guide AVs (groups of vehicles or single vehicles) in order to optimize the overall traffic flow.	X	X	X	X

Figure 3 – Levels of the Infrastructure Support for Automated Driving (ISA Levels)

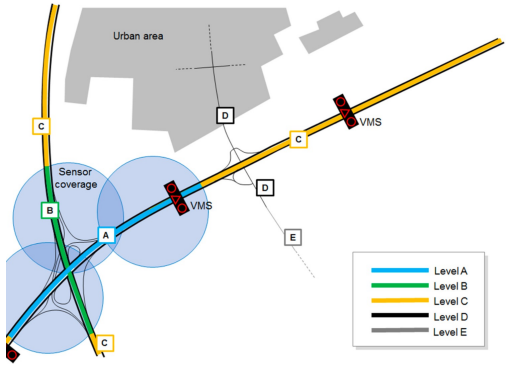


Figure 4 – Examples of ISA Levels assigned to a road network

OECD

International Transport Forum

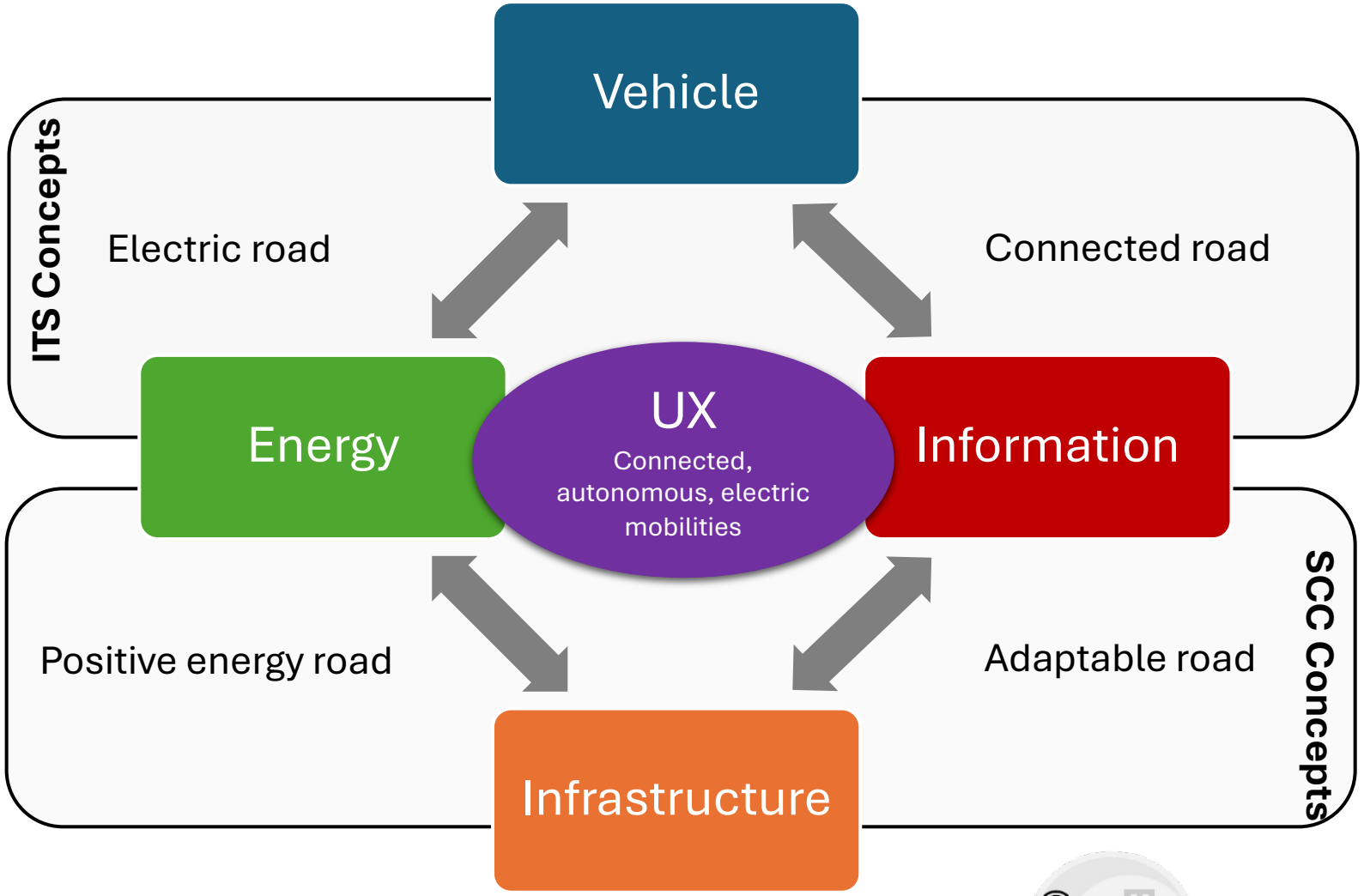
ITF Working Group
Preparing Transport Infrastructure for Autonomous Mobility

AUGMENTED CCAM

INFRAMIX

Gruyer, D., Orfila, O., Glaser, S., Hedhli, A., Hautière, N. and Rakotonirain, A. “Are Connected and Autonomous Vehicles the silver bullet for future transportation issues? Benefits and weaknesses on Safety, Consumption, and Traffic congestion.”, in Frontiers in Sustainable Cities, Special Collection "Advances in Road Safety Planning", 8th January 2021.

FROM THE VIC TO THE VI$_2$E INTERACTIONS MODEL



Less CO_2
Less emissions
ERS=C--

INCIT-EV

Smart and clean energy
E+

wattway by COLAS
POWER ROAD by Eurovia

Mastered congestion
Increased safety
C-

Projet SCOOP véhicules et routes connectés connected vehicles and roads

ENSEMBLE

Optimized use and maintenance
C-

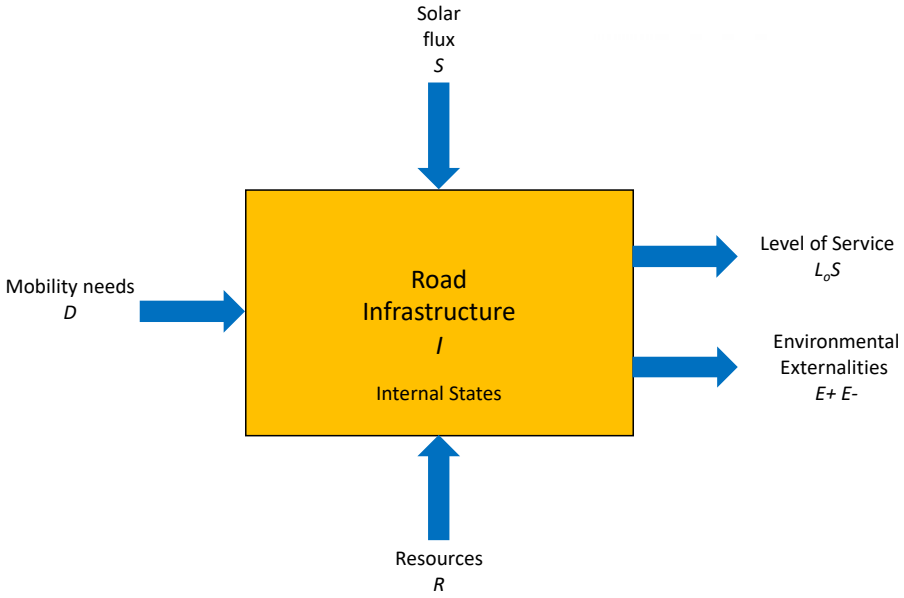
ALTAROAD

Less rolling resistance E-

I-STREET

FORECASTING APPROACH: OPTIMIZATION OF THE SoS VI_2E

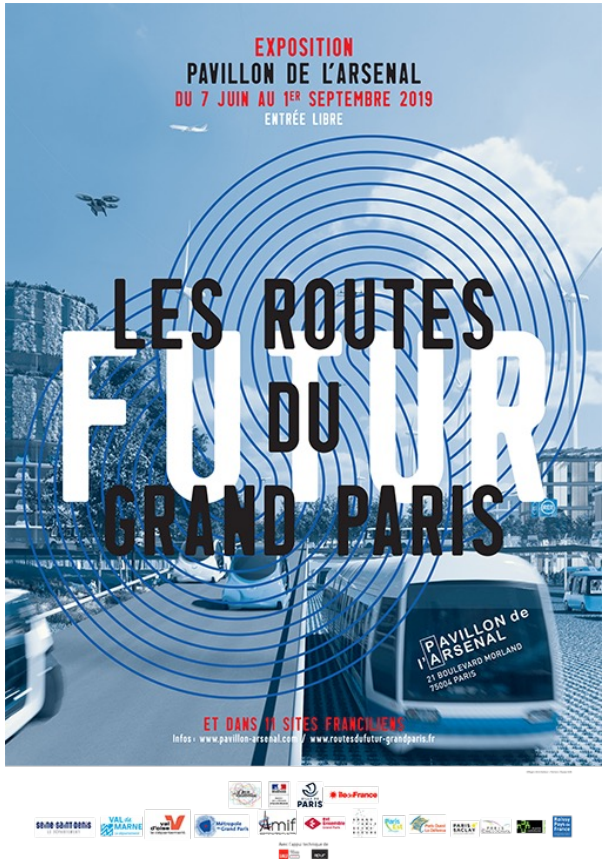
- We are collectively inventing the E+C- regulation of the road through new interactions between the components of the R5G
- On the one hand, the energy integrated road produces and transfers decarbonized energy to road and street components, generating E+ and C-.
- On the other, the automated road generates C- through the new functions and services it implements.

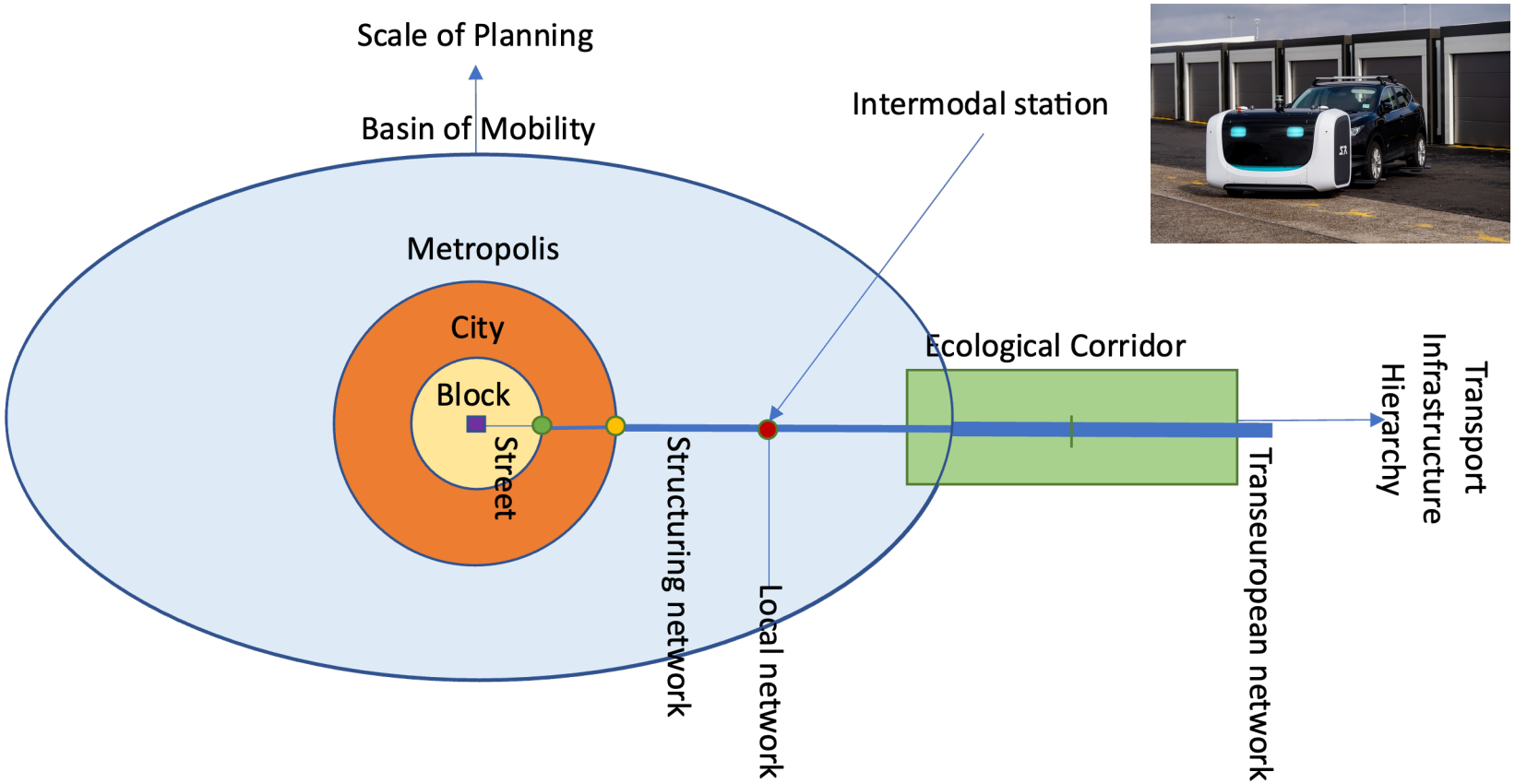


$$I_D^*(H_i,T) = \arg \max_{I \in \{C,K\}_S^{H_i}} \int_I \int_0^T f(L_oS, C_T, R, E, t)dtdi$$

C,K: available Concept and Knowledge
H: timespan
C_T: TCO

THE R5G *fab* AIMS TO ACCELERATE THE PROJECTS OF TERRITORIES (2019)





- The main reason for the requests for intervention are the metropolitan thromboses: Bordeaux, Nantes, Lyon, Lille, Paris, Strasbourg, Marseille...
- The transformation of VSAs into a new type of urban boulevard, the adaptation of networks to new forms of mobility or positive health streets are the main requests.

Hautière, N., Décarbonation des mobilités et infrastructures de transport. Trajectoire(s), novembre 2022, pages 82-84

FRANCE 2030

PROGRAMME DE RECHERCHE

DIGITALISATION ET DECARBONATION DES MOBILITES

FROM THE R5G PROJECT TO THE TRÂCE PROJECT (2022-NOW)

ROAD SYSTEM TRAJECTORIES IN THE ANTHROPOCENE

3

PERI-URBAN NETWORKS: FROM MULTIMODAL MOTORWAYS TO ROAD TRAINS

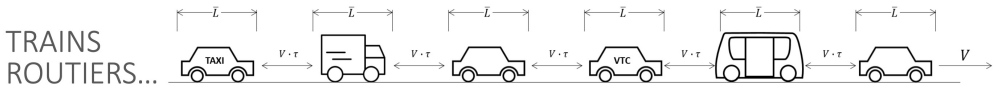
- On peri-urban motorway networks, the challenge is to develop the infrastructure to enable them to accommodate means of transport with higher occupancy rates
- As automation progresses, it is possible to envisage the transformation of dedicated lanes into real road trains, probably decarbonised

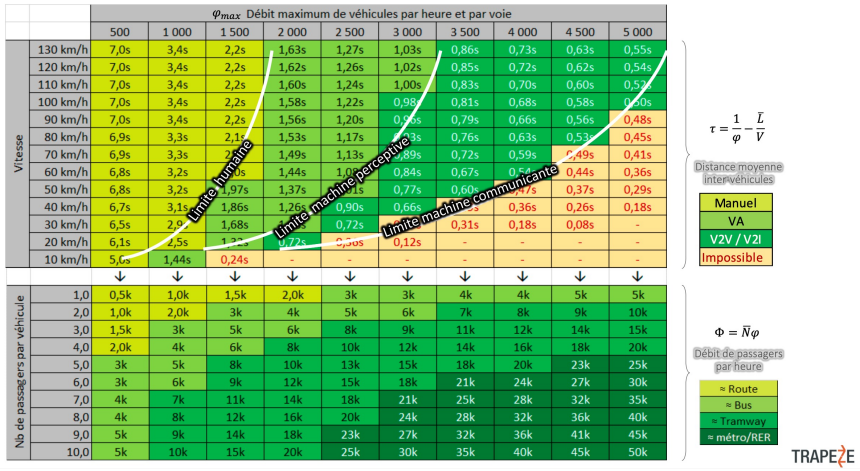
Current situation

Coach on auxiliary lane

Carpool lane

Future situation





Projets MOB-AUTO²

TRAPEZE

Source : Laurent Taupin - ECOV

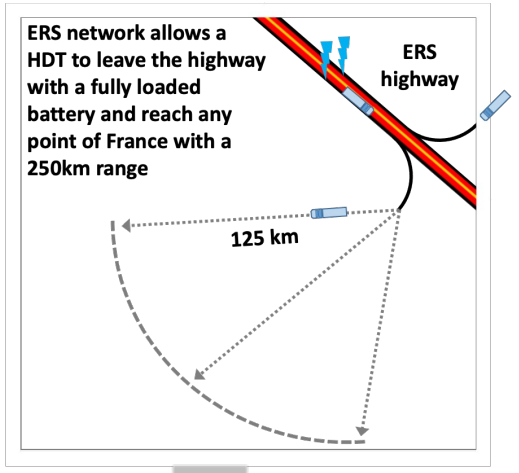
LONG-DISTANCE NETWORKS: AUTOMATION AND DECARBONISATION OF FREIGHT TRANSPORT

TRUCK PLATOONING

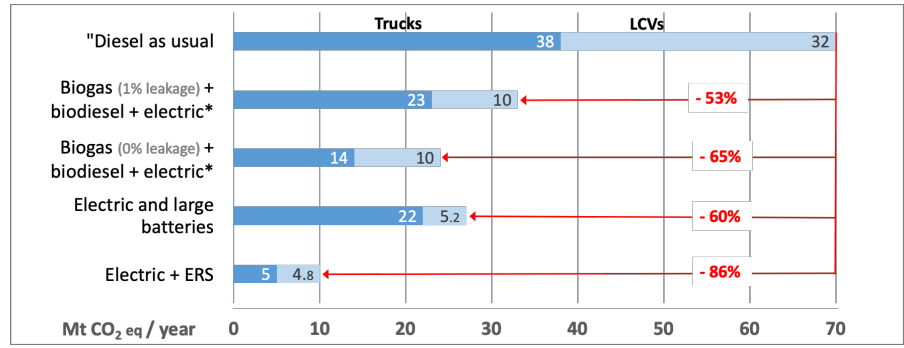
- Reduction of costs and delays
- Improved productivity
- Reduced driver anxiety
- Increased safety through fewer human errors
- Reduced emissions and fuel consumption (10%)
- Increased road capacity, reduced congestion

A63 Automated Test Site for CCAM

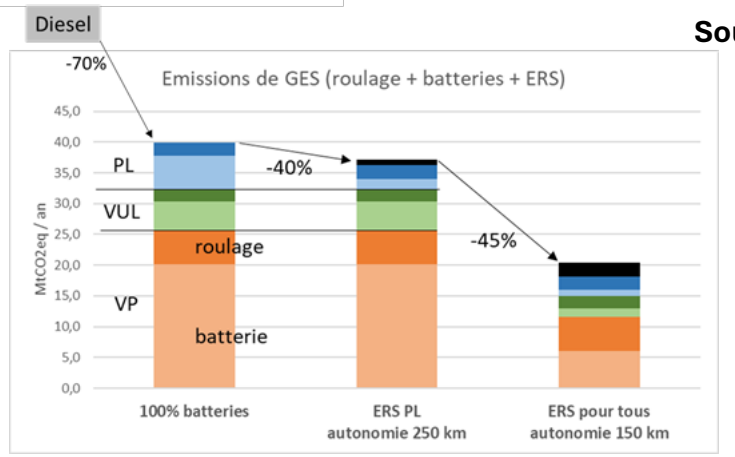
ELECTRIC ROAD SYSTEMS

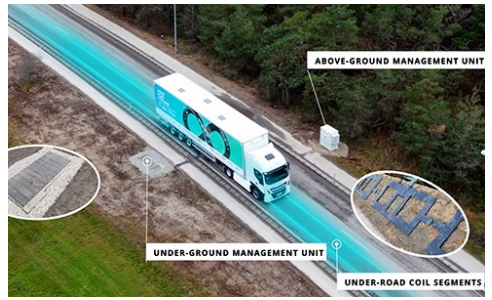


GHG emission gaps /year in Life Cycle Analysis (2040) France data



Source : Pelata et al., 2021





Source : F. Perdu, 2021

FRANCE 2030

eRoad MontBlanc

Charge As You Drive
Less Battery. More Range. For All

LOCAL NETWORKS: IMPROVING TERRITORIAL SUPPLY

Autonomous shuttles & Robotaxis

Ultralight trains

Take advantage of autonomous mobility solutions to decarbonise everyday mobility and adapt at least the existing infrastructures in a cross-modal way.

Cœur de Brenne – ENA Project

expérimentations navettes autonomes

Rambouillet –TORNADO Project

FRANCE 2030

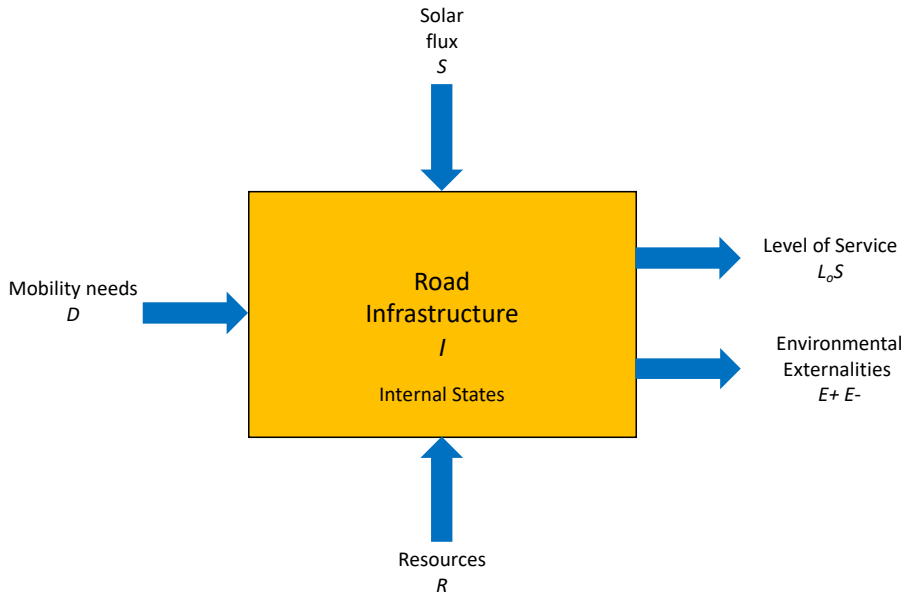
Projet RIMA

FERROMOBILE

FRANCE 2030

NEW RADICAL REGULATIONS MEAN WE MUST NOW ADOPT A BACKCASTING APPROACH

- Net zero Roads until 2050
  - Zero emissions
  - Zero artificialization
  - Zero accident
  - Zero net loss of biodiversity
  - …
- This makes it possible to draw up a more global framework for thinking about the role of infrastructures in decarbonizing the green corridors crossed by transport infrastructures, including NBS.



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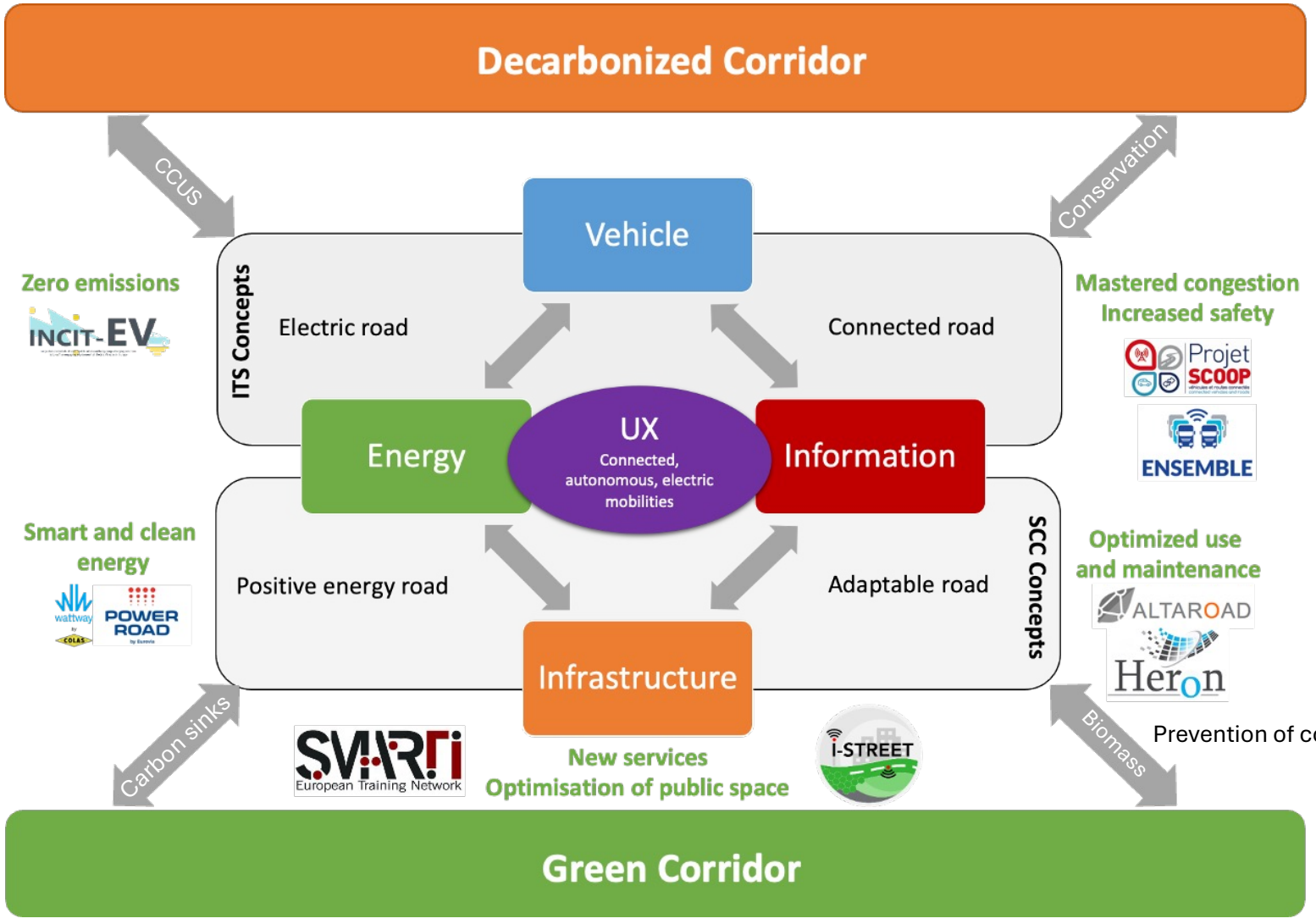
where Sum $f(E_i)$->0 until 2050

C,K: available Concept and Knowledge
H: timespan
C_T: TCO

THE VI$_2$E MODEL ENABLES A SYMBIOSIS BETWEEN TRANSPORT INFRAS AND ENVIRONMENT WITH ADDITIONAL INTERACTIONS



ipbes

IENE
Infrastructure & Ecology Network Europe

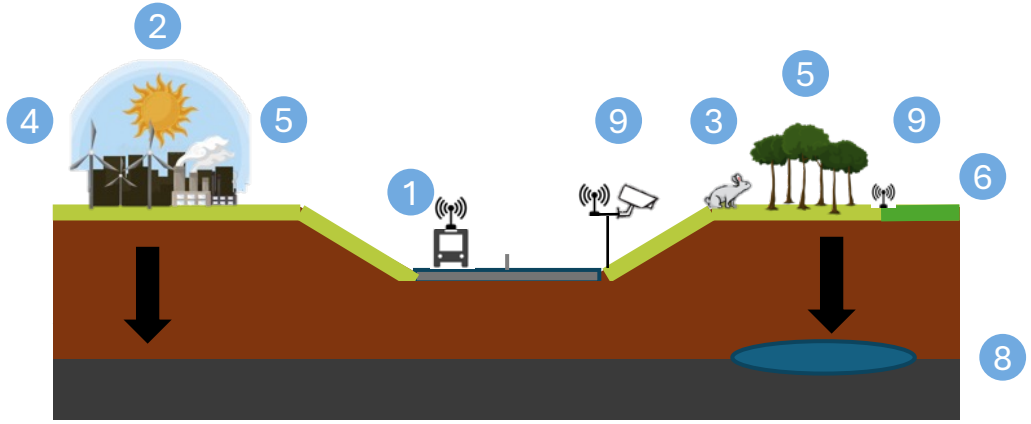
BISON
BIODIVERSITY AND INFRASTRUCTURE SYNERGIES AND OPPORTUNITIES FOR EUROPEAN TRANSPORT NETWORKS

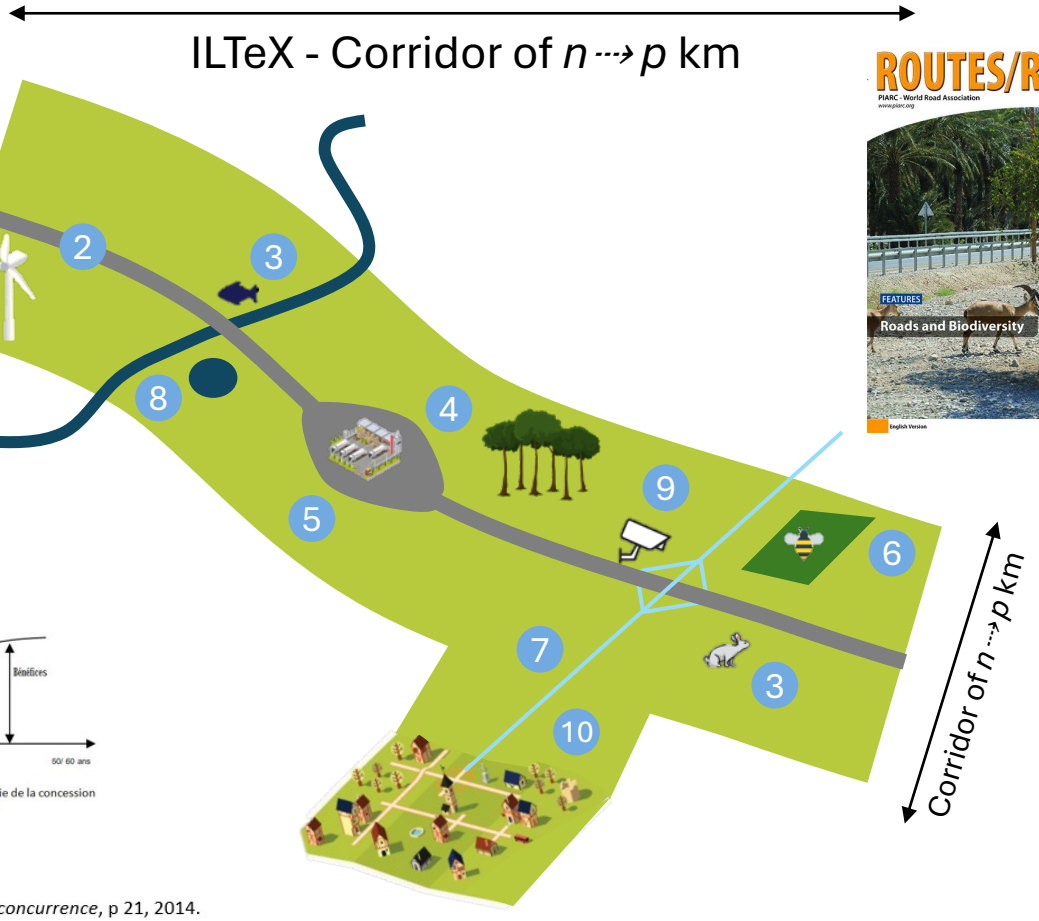
ITTECOP

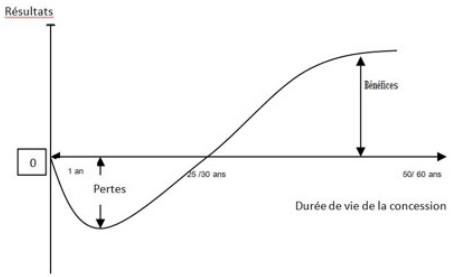
TRAVISIONS 2022

IDENTIFIED AREAS OF R&I

1. Progressively rethinking and adapting infrastructures to robomobility while developing TCS
2. Contribute to the development of a new energy mix
3. Monitor general trends in the state of biodiversity and transform ILTeXs into habitats or corridors for biodiversity
4. Capture, store and valorise CO_2 on ILTeXs
5. Develop bioenergies associated with carbon capture and storage
6. Contribute to the agro-ecological transition
7. Developing a local circular economy for carbon-free and bio-based materials
8. Preserving water resources and helping to clean them up
9. Observe the region opportunistically, monitoring general trends in the state of biodiversity conservation
10. Co-construct local governance







Source : *Rapport de l'Autorité de la concurrence*, p 21, 2014.

CONCLUSION AND PERSPECTIVES

- New-generation roads and streets will be increasingly automated and energy-integrated to meet societal challenges.
- The R5G project aims to design demonstrators of the roads of the future throughout France, and to assess their ability to meet the challenges facing society today.
- The various French regions are working in this direction, as demonstrated by the "Routes du futur du Grand Paris" competition organized by the Forum Métropolitain du Grand Paris, which aims to solve the challenges of periurban mobility in everyday life, in particular by massifying urban freeways.
- In intercity areas, the challenge is not only to decarbonize long-distance freight transport, but also to rethink the relationship between freeways and territories, and to propose a "closed" approach between town and country, making it possible to achieve the SDGs.
- In urban environments, the challenge is to successfully transform urban arteries into health-positive streets.
- In this context, digital technology is seen as an essential solution, alongside the development of new materials and processes to improve the resilience of roads to climatic and man-made hazards.