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Inventory, modelling and assessment of New and Emerging Technologies and Trends (NETT) in the transport sector

A methodology for the Transport Research and Innovation Monitoring and Information System (TRIMIS)

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Foreword

In 2017, the European Commission (EC) adopted the Strategic Transport Research and Innovation Agenda (STRIA) as part of the "Europe on the move" package, which highlights main transport research and innovation (R&I) areas and priorities for clean, connected and competitive mobility to complement the 2015 Strategic Energy Technology Plan.

The EC Joint Research Centre (JRC) has developed the Transport Research and Innovation Monitoring and Information System (TRIMIS) to support the implementation of STRIA. TRIMIS provides an effective monitoring and information mechanism that assists the development and updating of STRIA and supports transport R&I.

TRIMIS monitors developments in transport R&I and related sectors to assess the status of new technologies and their possible future exploitation. It involves the creation of a transport R&I database (i.e. data collection and setting up of a database) and the assessment of the innovation capacity and technology performance of the transport sector. It will also monitor developments in EU and nationally funded R&I projects and identify new opportunities and technologies.

This report provides the methodological framework for the assessment of New and Emerging Technologies and Trends (NETT) in the transport sector. It provides the basis for the creation of an inventory and regular reporting on future and emerging technologies. In particular:

- identifies sources of information for the inventory building;
- provides the methodological steps for the identification, database building and categorisation of NETT in transport, including a taxonomy;
- provides a framework for the assessment of NETT in transport;
- identifies challenges and future steps in the process.

TRIMIS – including the work carried out for this report - has benefitted from ongoing work at the Joint Research Centre (JRC) on sustainable transport and sustainable energy systems. Synergies will continue to be explored with related projects on connected and automated transport, electrification, emissions control as well as initiatives in the context of the Strategic Energy Technology Plan, including Strategic Energy Technologies Information System (SETIS), available at: https://setis.ec.europa.eu. The JRC will further develop TRIMIS by adding more functionalities to the TRIMIS online platform and carrying out scientific research to analyse transport R&I in the areas covered by the STRIA roadmaps.

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The views expressed here are purely those of the authors and may not, under any circumstances, be regarded as an official position of the European Commission. The Joint Research Centre (JRC) is in charge of the development of Transport Research and Innovation Monitoring and Information System (TRIMIS), and the work has been carried out under the supervision of the Directorate-General for Mobility and Transport (DG MOVE) and the Directorate-General for Research and Innovation (DG RTD) that are co-leading the Strategic Transport Research and Innovation Agenda (STRIA).

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Abstract

The European Commission's Strategic Transport Research and Innovation Agenda (STRIA) has identified priority areas with specific actions for future R&I. The Transport Research and Innovation Monitoring and Information System (TRIMIS) supports STRIA by monitoring the status of transport research across Europe. One of the sub-tasks of TRIMIS is the creation of inventory and regular reporting on future and emerging technologies in the transport sector. This report provides the methodological framework for the inventory, modelling and assessment of New and Emerging Technologies and Trends (NETT) in the transport sector.

1. Introduction

In 2017, the European Commission (EC) adopted the Strategic Transport Research and Innovation Agenda (STRIA) as part of the "Europe on the move" package, which highlights main transport research and innovation (R&I) areas and priorities for clean, connected and competitive mobility to complement the 2015 Strategic Energy Technology Plan (European Commission, 2015, 2017a; 2017b).

In order to address current socio-economic challenges within an ever-changing complex and competitive environment, the transport sector requires new technological developments. This will be achieved through R&I that allows new quality standards in the mobility of people and goods thereby ensuring European competitiveness.

To decarbonise transport and mobility, the EC has identified the need to overcome barriers and seize opportunities arising through the promotion of transport R&I. Towards this goal, the STRIA has identified priority areas with specific actions for future R&I, outlined in seven roadmaps:

1. Cooperative, connected and automated transport
2. Transport electrification
3. Vehicle design and manufacturing
4. Low-emission alternative energy for transport
5. Network and traffic management systems
6. Smart mobility and services
7. Infrastructure

The EC Joint Research Centre (JRC) has developed the Transport Research and Innovation Monitoring and Information System (TRIMIS) to provide a holistic assessment of technology trends, transport R&I capacities, to publish information, data, and to develop analytical tools on the European transport system. TRIMIS has been funded under the Horizon 2020 Work Programme 2016-2017 on smart, green and integrated transport.

TRIMIS is a new tool that benefits the entire European transport system. It is an open-access information and knowledge management system that consists of a database of transport projects and programmes, as well as an inventory of transport technologies and innovations.

TRIMIS monitors developments in transport R&I and related sectors to assess the status of new technologies and their possible future implementation by creating a transport R&I database (i.e. data collection and setting up of a database) and by providing a continuous assessment of the transport sector and technology performance.

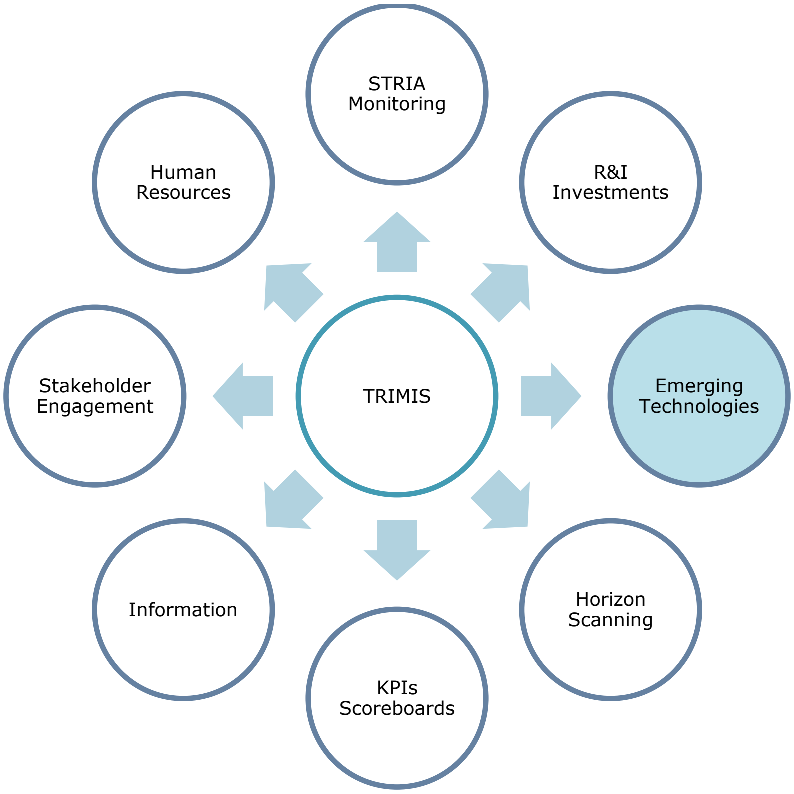
One of the sub-tasks of TRIMIS is the creation of inventory and regular reporting on future and emerging technologies in the transport sector, and it is the objective of this report: the methodological framework for the inventory, modelling and assessment of New and Emerging Technologies and Trends (NETT) in the transport sector.

1.1 Development of TRIMIS

TRIMIS has been developed as a policy tool to support the monitoring and implementation of the STRIA by mapping technology trends and R&I capacities in the European Union (EU) transport sector (see Figure 1).

It has been designed as an open-access information and knowledge management system and will undertake: horizon scanning, monitoring progress against STRIA roadmaps, mapping technologies and capacities in the EU transport sector and support information dissemination and the development of a set of policy tools. Besides acting as a general source of information and data on transport R&I, it facilitates information exchange between stakeholders.

Figure 1. TRIMIS main features and functionalities



Source: Tsakalidis et al., 2018a

TRIMIS focuses on a number of priority areas outlined in the seven STRIA roadmaps where public intervention at the European level can create added-value in order to overcome socio-economic weaknesses, increase competitiveness and meet goals of the EU energy and transport strategy. In particular, it covers the following aspects of the transport sector:

- Policies
- Data/analysis
- Funding Information of projects
- Public and private investments
- Capacity and technology mapping
- Horizon scanning
- News/updates

Moreover, TRIMIS tracks the status and developments in the field of transport, identifies innovative technologies and assesses their potential future impact. This process involves:

Updating and maintaining a transport R&I database that includes projects and programme on transport technologies and innovations. This repository provides an input for the assessment of Key Performance Indicators (KPIs) in transport R&I and links to established EU tools and initiatives, e.g. the Strategic Energy Technologies Information System (SETIS) and the Innovation Radar. It provides a communication channel between TRIMIS and transport stakeholders allowing additions and amendments to the database with an automated link to EC existing repositories, e.g. the Community Research and Development Information Service (CORDIS).

Monitoring and assessing transport sector technology performance using a set of KPIs to monitor the European innovation capacities for each STRIA roadmap. As well as monitoring the progress of European R&I projects to support the assessment of the transport sector performance and maturity status.

Identifying new technologies and opportunities that may have an impact on the transport sector through an inventory of scientific developments of new and emerging technologies relevant to the future of the EU transport sector.

Highlighting mature technologies that are close to market introduction.

TRIMIS aims to:

— monitor progress of the STRIA and supporting the development of STRIA roadmaps, and STRIA governance (Steering Group);
— prepare and update 'technology mapping' (state-of-the-art, barriers and potential of technologies) following the STRIA roadmaps structure;
— define and update 'capacities mapping' (financial and human resources);
— assess funded research projects in the field of transport (with a focus to the STRIA roadmaps);
— assist in reporting of progress of the STRIA against defined KPIs and scoreboards;
— identify opportunities for new STRIA roadmaps or revised structuring of existing ones;
— monitor socio-economic developments and assess their influence on transport technology and innovation; and
— facilitate the effective functioning of an extensive network of industry stakeholders, Member States experts and authorities, research organisations, industrial and financial communities, information collection points, etc.

The JRC is responsible for the development of TRIMIS under the supervision of the EC DG MOVE and the DG RTD that are co-chairing STRIA working group (WG). The WGs are composed of topic experts, who are mainly responsible for developing the STRIA roadmaps. The participants are thus specifically selected for each roadmap and come from various industries and MS.

1.2 Objectives of this report

The Inventory, Modelling and Assessment of New and Emerging Technologies and Trends (NETT) in the transport sector is a cornerstone of TRIMIS. This report:

— identifies sources of information for the inventory building;
— provides the methodological steps for the identification, database building and categorisation of NETT in transport, including a taxonomy;
— provides a framework for the assessment of NETT in transport;
— identifies challenges and future steps in the process.

The Inventory, Modelling and Assessment of NETT in the transport sector will benefit from other past and ongoing TRIMIS activities, in particular those related to:

— the development of a general methodological framework;
— the TRIMIS R&I database enhancement;
— the development and implementation of a horizon scanning process;
— the development of KPIs for monitoring the European R&I;
— the socio-economic assessment of transport R&I.

2. Towards the assessment of new and emerging technologies and trends in transport

This task will focus on the methodological identification, reporting and updating of NETT, along with their associated benefits, implementation challenges, and risks. In fact, one of the principal strategic objectives of TRIMIS is to "*follow up transport research and innovation actions and provide feedback to policy and decision makers*"[1]. In doing so, a repository of new and emerging technologies will be built and constantly updated.

This report forms an integral part of the TRIMIS methodology (Tsakalidis et al. 2018b), along with the horizon scanning methodology (under development) and the macro-level financial and socio-economic analysis methodology (Grosso et al. 2018).

2.1 Characteristics of the transport sector

The transport sector compared to other sectors presents some unique characteristics. In principle, it is intrinsically a very dynamic sector, even though the different modes of transport (air, water, and land transport) are nowadays consolidated, with mostly evolutionary improvements for what regards their capacity, efficiency, safety and reliability in the last years.

However, transport is strongly linked to broad societal changes emerging from ever-changing economies and geopolitical situation: the global economic crisis, limited resources and new vulnerabilities and uncertainties have a direct impact on the way people and goods move. The presence of interaction loops (e.g. demand-offer) and multiplicity of transport modes introduce loops within the process and are further complicated by new trending issues (e.g. globalisation, security, sustainability, climate change).

In the above sense, the transport system can be considered as an infrastructural and human system and it can be referred to as a Complex, Large-scale, Interconnected, Open, Socio-technical (CLIOS) system[2], including elements from the built environment and the socio-political domains. Any change in a transport subsystem, even if predictable separately, can be difficult to predict, especially when considering the interactions with the human agents.

Furthermore, transport technology, is more than technical hardware. It may often comprise technical elements, but the organisational innovations and new mobility concepts which do not require hardware modifications can be regarded as new technology because they aim to use the hardware in a different way (Weber et al. 1999). This also applies to the new business models emerging in the sector.

In particular, new technologies and transport trends add new levels of interaction with the society and users and may have considerable influence on people mobility and freight transfer services.

2.2 Technology readiness levels

NASA initially introduced readiness levels for space missions in the mid-70's, with reference to Technology Readiness Level[3] (TRL), as a method of testing technology maturity. Since then, the concept has been extended over the years to other fields with inherent risk, such as Intellectual Property (IP), manufacturing, framework, systems integration, commercialisation, market, consumer and society. Different agencies and institutions adopt different definitions for TRL.

[1] https://ec.europa.eu/transport/sites/transport/files/swd20170223-transportresearchandinnovationtomobilitypackage.pdf
[2] http://web.mit.edu/hsr-group/documents/clios.pdf
[3] https://www.nasa.gov/directorates/heo/scan/engineering/technology/txt_accordion1.html

Definitions of the TRL levels used by the European Commission can be found in General Annexes of the Framework Programmes[4].

In the assessment of R&I, it is important to consider readiness levels in order to anticipate the time of introduction of a new technology, its expansion, its smooth implementation and the impact to the society.

TRL in particular can be used to categorise a technology as "new" or "emerging", as it has been done for the Future and Emerging Technologies (FET) in the Low Carbon Energy Observatory (LCEO)[5] – see for example Moro et al. (2017).

2.3 Technology classification

It is common practice to classify new technologies according to their maturity level. In this way, it is possible to program future activities regarding the implementation and diffusion of these technologies and plan in advance incentives and financing campaigns.

A special category of new and emerging technologies are the Key Enabling Technologies (KET)[6]. KET are identified by the EC as a group of six technologies (micro and nanoelectronics, nanotechnology, industrial biotechnology, advanced materials, photonics, and advanced manufacturing technologies) that have applications in multiple industries including transport and help tackle societal challenges.

EC's Future and Emerging Technologies (FET)[7] focus on high risk, long term, multidisciplinary and collaborative frontier research with a high potential impact on technology, to benefit our economy and society. The idea is to convert proofs of concept into industrial applications and systems. In general, FET are new and emerging technologies characterised by low TRL levels, and eventually with a not well-defined societal impact.

2.4 R&I monitoring and reporting initiatives

R&I reporting is common practice for research agencies and institutions worldwide. Outcomes of the process are used at state and local level from public authorities, industry and academia. R&I reports are either separate publications or part of wider theme reports, usually dealing with envision of the future of specific sectors.

On a broader scope, on 5 June 2018 the European Competence Centre on Foresight[8] was launched, a dynamic collective intelligence system assessing 14 global megatrends, relevant for Europe's future.

The Joint Research Centre Research and Innovation Observatory[9] (RIO) is an initiative of the EC to monitor and analyse research and innovation developments at country and EU levels to support better policy making in Europe.

The annual European Innovation Scoreboard (EIS)[10] provides a comparative assessment of the research and innovation performance of the EU Member States and the relative strengths and weaknesses of their research and innovation systems.

[4] https://ec.europa.eu/research/participants/data/ref/h2020/other/wp/2018-2020/annexes/h2020-wp1820-annex-ga_en.pdf

[5] European Commission Joint Research Centre, Inception Plan for the Low Carbon Energy Observatory, JRC 98322, 2015 (restricted document)

[6] https://ec.europa.eu/growth/industry/policy/key-enabling-technologies_en

[7] https://ec.europa.eu/digital-single-market/en/future-emerging-technologies-fet

[8] http://europa.eu/!Th97qd

[9] https://rio.jrc.ec.europa.eu

[10] http://ec.europa.eu/growth/industry/innovation/facts-figures/scoreboards_en

2.5 NETT in the transport sector

Considering the specific characteristics of the transport sector, it is fundamental to appropriately define or frame the characteristics of NETT in transport. In fact, in other sectors principal benefits are basically unidimensional, in the sense that the direct benefit to the user is predominant, and other benefits are perceived at a lower level. An example to clarify the above comes from the energy sector: the principal benefit for the user in many cases is the energy itself, regardless of the source, while the latter has a societal impact. On the contrary, in most cases in the transport sector, the assessment of a technology encompasses different user-centred aspects (e.g. comfort, level of service, speed).

In this sense, while the technology assessment can be based on the TRL level, other aspects need to be considered in a later stage. As an example, the societal acceptance based on publicity (good or bad) can strongly influence the future implementation of a specific technology. This is the reason why a single event based on societal concerns (e.g. safety) may have a strong impact on the future of a technology.

The classification of a transport technology or trend as NETT will be performed after the assessment of a "technology innovation phase" phase, based on TRL levels (1-9).

An example mapping is as follows:

a. research/invention (TRL 1–2);

b. validation (TRL 3–4);

c. demonstration/prototyping/pilot production (TRL 5–7);

d. implementation (TRL 8–9).

Although NETT should cover lower TRL levels (TRL levels 1 to 4), technologies with a higher TRL level will be considered as well, using expert judgement, in cases where either there is a strong interest, or the possible impact is high, and, the demonstration or implementation phase can be anticipated to be lengthy.

The innovation phase level will be monitored and technologies that do not meet low TRL designation will be simply downgraded and not characterised as "new and emerging", while mature technologies close to introduction will be highlighted.

Regarding the assessment (or the possible impact):

— NETT should cover all technologies and trends (even those with low "foreseeable" impact). In fact, it is impossible to forecast exact impact (which depends on exogenous, many times unidentified factors). Therefore, ideas considered as radical or at a conceptual form should be also considered.

— A failed technology or trend can be a lesson for the future. There are many technologies in the transport sector that either failed (e.g. dial a ride, loosely seen as a predecessor to Uber) or did not materialise, because the enablers were not available at the time.

The technologies considered in the inventory will also span horizontal areas that are contributing in the transport R&I area as enablers or as possible challenges.

Finally, all possible resources and synergies within TRIMIS and the JRC will be pursued (for a list see Annex 1) for the development of the inventory.

3. Methodology for creating an inventory of NETT in transport

This section focuses on the development of the TRIMIS methodology for creating an inventory of NETT in the transport sector.

The experience and knowhow gained in the development of similar initiatives and in particular, the methodology used for the FET and non-FET (Future and Emerging Technologies) of the LCEO will be exploited. However, due to the fundamental differences in the technologies in the transport sector compared to the energy sector, and the added complexity (e.g. more direct interaction between users and technologies) additional resources and tailored approaches and synergies will be pursued.

The NETT inventory will not only include technologies in the strict sense but also innovation in the transport sector in general (including innovative transport trends and initiatives).

The entire process is based principally on the following activities (Figure 2):

— Horizon scanning

— Data collection (key process)

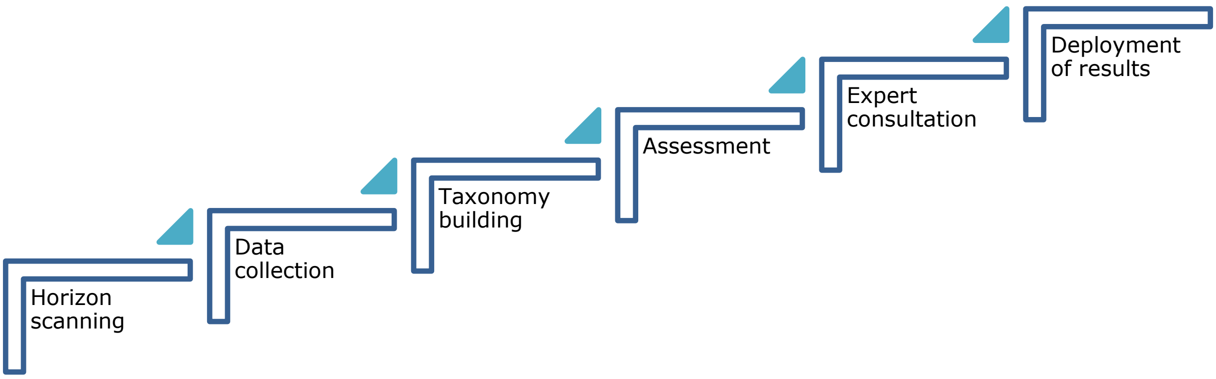
— Taxonomy building (key process)

— Assessment (key process)

— Expert consultation

— Deployment of results (visualisation and reporting)

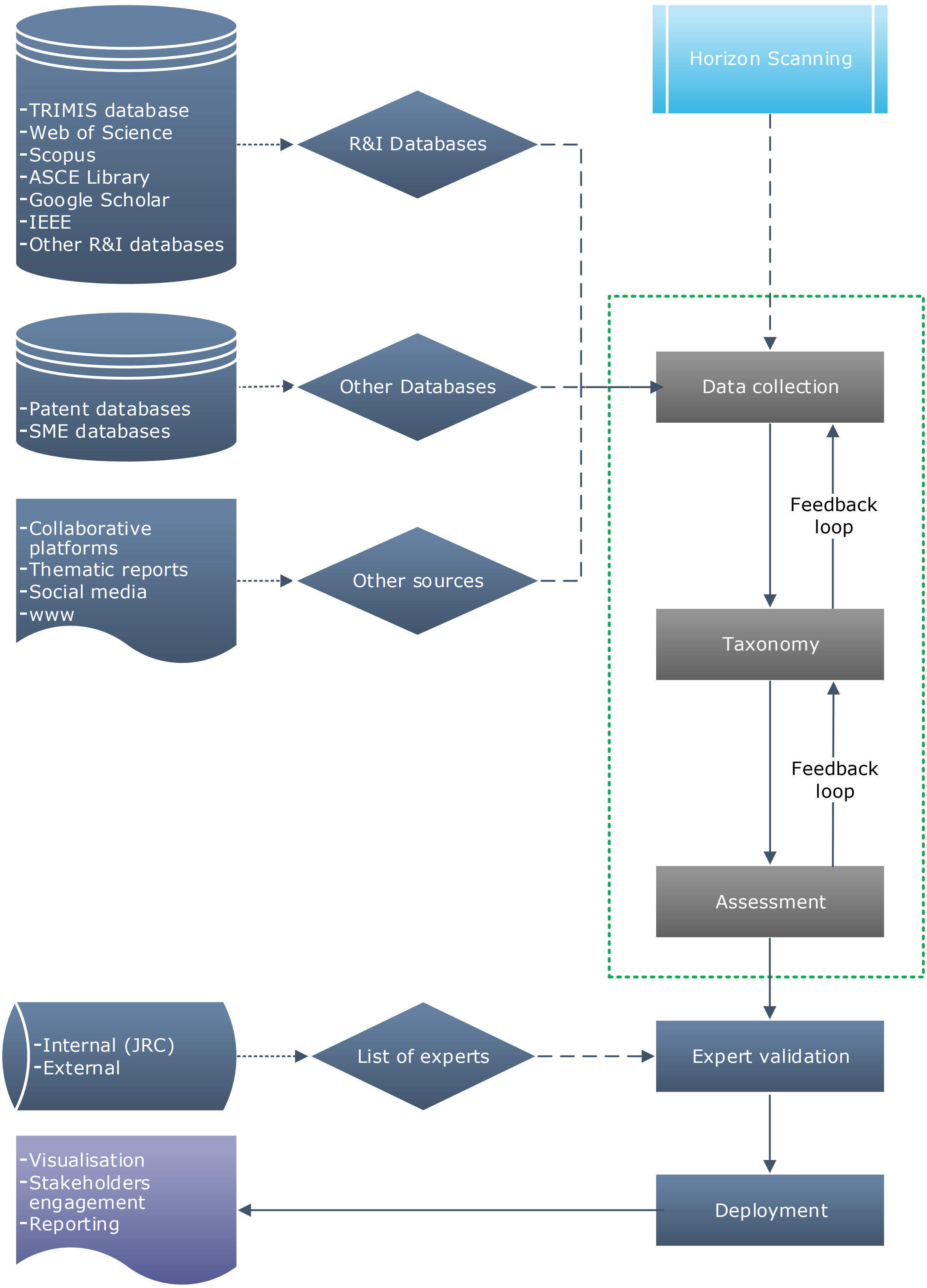
Figure 2. Activities for creating a NETT in transport inventory



This chapter provides the methodological steps for the realisation of the above activities, providing also the indication for sources of data and information and other details.

The flowchart of Figure 3 provides a more strict interpretation of the entire process.

Figure 3. NETT in transport: methodological assessment



3.1 Horizon scanning

Horizon scanning forms an integral part of the TRIMIS methodology, fostering an anticipatory culture, through the systematic examination of signals (potential threats, opportunities and early signs of future developments) in various sources including science literature and the media. These signals are on the margin of current practice but may have a strong impact in the future.

Since 2016, a pilot project of horizon scanning takes place internally at JRC, focusing initially on two topics: Energy and Climate change, and, Migration and Security. Horizon scanning for transport R&I is a cornerstone of TRIMIS and is tackled in a separate report.

A dedicated Horizon scanning methodology for TRIMIS is currently being finalised.

3.2 Data collection

This process includes several steps that secure the as-complete-as possible collection of data for the taxonomy. The taxonomy of NETT in transport will be build, spanning the entire transport sector, including connections with its interdependencies (e.g. energy, economy, construction).

3.2.1 Data sources definition

The identification of R&I data sources that contain data relevant to transport is the next step in the methodology. Both traditional sources (e.g. databases) and Big Data sources (e.g. the World Wide Web - www) will be considered. Principal sources of data are:

— R&I Databases (mostly structured text). In particular the TRIMIS database[11] (Tsakalidis et al. 2018c), The TRID[12] database, the Scopus[13] database, the ScienceDirect[14] database, the ASCE library[15], IEEE[16] and Google Scholar[17].

— Collaborative platforms (mostly unstructured text). These include Mendeley[18], Academia[19] and ResearchGate[20].

— Other Databases and sources (structured and unstructured text). Patent databases, specifically the European Patent Office (EPO) PATSTAT[21], www portals, SME (Small-and medium-sized enterprise) databases, thematic reports, social media.

A complete list of data sources will be identified, including information regarding data extraction (automatic/manual), relevant data fields (if applicable) and extraction procedure (workflow or automatic query). It will be regularly reviewed and updated also on the basis of statistics from the findings.

1. The TRIMIS database will be a source of information for NETT in transport. Since the database at the present state contains mostly European projects and programs, for which a lag time exists between the inception and the dissemination of deliverables, it can be expected that the contribution in newer technologies will be limited. However, directions of possible outcomes will be obtainable from the project objectives. In addition, programmes from outside the EU may give a hint on new technology developments.

[11] https://data.europa.eu/euodp/data/dataset/jrc-trimis-projects
[12] https://trid.trb.org
[13] https://www.scopus.com
[14] https://www.sciencedirect.com
[15] https://ascelibrary.org
[16] https://ieeexplore.ieee.org/Xplore
[17] https://scholar.google.com
[18] https://www.mendeley.com
[19] http://academia.edu
[20] https://www.researchgate.net
[21] https://www.epo.org

2. The Scopus and the ScienceDirect databases are reference resources for scientific research. Scopus is the largest abstract and citation database of peer-reviewed literature, while the ScienceDirect database covers over 14 million publications from over 3,800 journals and more than 35,000 books from Elsevier. Although not without drawbacks, they will form the principal pool of information for the inventory. The principal issues that need to be addressed are linked to the absence of many conference papers from the Scopus database that could have an impact on the assessment. In fact, initial ideas and proofs of concepts are usually presented in conferences, before their full development in journal papers. The extension including other sources (e.g. ResearchGate) that include conference papers and preprints will assist to overcome this limitation.

An effort will be made in the first phase of the TRIMIS project to implement the JRC software Tools for Innovation and Monitoring[22] (TIM) for the Scopus database search.

The input from patent databases could prove insufficient for building an inventory of NETT since there is a time lag of up to 4 years between filing for a patent and the actual granting. Nevertheless, innovation practices can be obtained from SME databases (e.g. the Venture Source database[23], the Amadeus Database[24], Eurostat[25]).

3.2.2 Data extraction

This step expands and organises the findings, in order to define manual and automatic search methods and patterns. An automatic process based on text mining (information extraction) is set. Technically, the automatic data extraction will follow a standard Extract, Transform, Load (ETL) process lifecycle, using a Structured Query Language (SQL). The experience gained in the TRIMIS team for data extraction from the CORDIS database will be exploited. Also, this process runs in parallel with an expansion of the TRIMIS database which aims to include additional sources of data.

In this step, fields in the database are set. A set of practical steps are reported below.

3.2.2.1 Synonyms and semantically similar words

When a technology or trend is starting to appear, terms are less consolidated. Likewise, technologies are often confused with brand names. A list of synonyms is built and stored in a database application, together with words that may refer to the same technology. For an example see Annex 2.

3.2.2.2 Terminological dissonance, polysemy and ambiguity

Dissonance can appear both in the same domain but also in an interdisciplinary context. An example of the second is the word "transport" which has different meanings in engineering and other fields (e.g. anatomy). In fact, many words and phrases can have multiple meanings depending on the context in which they appear (polysemy). A classic example is the word ATM, which has different meanings in finance, biology (two definitions), technology, and medicine. Also, American English and British English terms often differ.

Even though the taxonomy has not yet been defined at this stage, a automated process for a temporary clustering of terms (that is, collect terms that are similar regardless of the node in the taxonomy) is implemented to overcome the problem (e.g. "vehicle design" and "aerodynamic vehicle design"). At this stage, also term alias issues are addressed.

[22] http://www.timanalytics.eu
[23] https://www.dowjones.com/products/pevc
[24] https://www.bvdinfo.com/en-us/our-products/company-information/international-products/amadeus
[25] http://ec.europa.eu/eurostat/data/database

3.2.2.3 Search field definition and research area

An important step is the definition of the search fields in the data sources, especially when establishing an automatic link.

The definition is performed on a case by case basis, after a thorough examination of the specific source, and will be performed in different levels using the International Standard Text Code[26] (ISTC). Table 1 provides an example for the ScienceDirect database.

Table 1. ScienceDirect database search field

Level	Field
1	Title, keywords, abstract
2	Full text

3.3 NETT taxonomy

Building of the taxonomy is the second part of the cyclic process and includes an implicit interaction with the previous step (data collection). The taxonomic modelling follows the flow of Figure 4 and is developed in three sequential steps, comprising: the identification of domain elements, the definition of the taxonomy dimensions and the definition of the taxonomy attributes.

Figure 4. Methodologic steps of the taxonomy domain building

The use of methods and techniques from the semantic web such as the Simple Knowledge Organization System[27] (SKOS) will provide additional aid in this initial step. The reader is referred to Bailey (1994) for fundamental aspects of taxonomy building.

3.3.1 Taxonomy domain identification

The developed taxonomy has the purpose of including all possible transport technologies and applications, including horizontal enablers, and will be developed in several levels, including an implicit "Level 0" (i.e. the entire transport sector). The taxonomy will be developed in a database application, using appropriate tags and using a hybrid top-down and bottom-up process (Figure 5) following the concurrent data gathering (Section 3.2), the continuous Horizon Scanning (Section 3.1) and expert judgement.

The concurrent database development will allow crosschecking instantly the relevance to different aspects. In the first phase of implementation, the taxonomy will follow a strict model, in the form of a hierarchical network diagram, in the sense provided in the original paper by Simon (1962).

[26] http://www.istc-international.org
[27] https://www.w3.org/2004/02/skos

Figure 5. Taxonomy building hybrid process

In a second phase, additional representations will be considered (e.g. network type) that will allow highlighting the interconnections between technologies and other transport aspects. This will also allow to better address siblinghood between terms, e.g. terms that have a certain level of common characteristics.

3.3.2 Taxonomy domain dimensions

The taxonomy is developed on various dimensions, the principal one being spatial, which includes different levels of detail (i.e. scales). The number of scales can be either fixed or dynamic.

This subdivision allows to organise hierarchically the elements and to compare, cross check or perform statistical analysis on elements of the same level.

In the initial database building, two levels are considered: "technology themes" and "technologies". The data populating these two levels can be "shifted" higher or lower in the taxonomy, building the four levels identified below (see also Kashyap et al. 2005 for taxonomy construction).

Mega-scale. This is the broadest class and includes major areas of the transport sector or complete transport sub-systems. Examples in this category are the transport "mega trends", e.g. autonomous vehicles, electric vehicles, high-speed vacuum tube transport, mobility as a service.

Macro-scale. This class comprises main elements of sub-systems. Examples may include a single autonomous vehicle, a single electric vehicle, a single transport infrastructure etc. Elements of this class shape a single element of the higher scale.

Meso-scale. This class includes the principal elements of a macro-scale element. For an electric vehicle for example, meso-scale elements include the propulsion system (engine), the electric system, the gear system, etc.

Micro-scale. This is the lowest level class and includes individual elements that constitute a micro-scale subsystem. Using again an electric vehicle as an example, a micro scale element can be the battery, which is a component of the electric system.

On top of the above, "concentrations" on the taxonomy that go beyond the specified levels can be considered.

Figure 6 depicts the concept in a matrix format. From left to right, the scales represent the different levels of the taxonomy. For each scale (columns in the figure), the different elements or components are organised in a non-hierarchical manner. Each element at a lower scale is linked to its parent element at a scale above (horizontal organisation). As stated before, the taxonomy elements can be both tangible and intangible, depending also on the scale.

An additional attributes will be considered for the taxonomy. In Figure 6 for example, "time" is also shown. This attribute can be useful for comparing the evolution and for depicting trends (forward thinking) and lessons learned (backward learning). It can be also customised to rank selected chronological time instances (e.g. time of presentation, time of maturity, time of withdrawal). These instances will be linked to each element individually, but for assessment purposes, a time-frame can be established. Since the taxonomy will be organised in a matrix form, the linking to an appropriate database format will be straightforward, something that will help integration with existing transport databases or innovation and technical development tools. This will lead to the possibility of linking different levels of the taxonomy with R&I (both public and private) using available R&I data.

Figure 6. Spatial dimension of the taxonomy with time-based layers

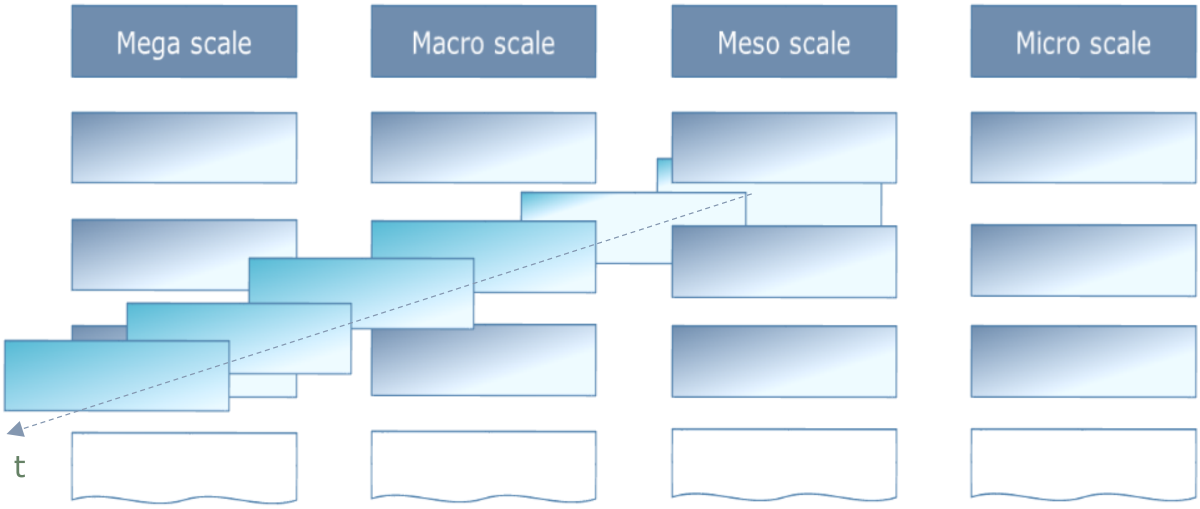


Table 2 provides a preliminary format for the database.

Table 2. NETT database format

Information	Field name	Source	Mandatory
PK	tech_ID	TRIMIS	y
	tech_name	TRIMIS	y
	Taxonomy level 1	TRIMIS	y
	Taxonomy level 2	TRIMIS	y
	Taxonomy level 3	TRIMIS	y
	Taxonomy level other	TRIMIS	y
	…	…	…
	Patent Group	CPC/TRIMIS	n
	Transport spatial	TRIMIS	y
	CAT	TRIMIS	y
	ALT	TRIMIS	y
	TRE	TRIMIS	y
	VDM	TRIMIS	y
	NTM	TRIMIS	y
	SMO	TRIMIS	y
	INF	TRIMIS	y
	Other	TRIMIS	y

3.3.3 Taxonomy domain attributes

The taxonomy is completed with the definition and selection of a set of attributes for each element. Attributes include both performance measures and additional descriptions, and may include:

- Readiness levels, e.g. TRL. Depending on each individual element, other appropriate indicators can be considered (system or integration readiness levels, manufacturing readiness levels, market readiness levels).
- Share of technologies in fields with high patent activity or SME involvement.
- Technology hype. This can be defined and measured in different ways, even though, its quantification is not straightforward.
- Socio-economic and geographic aspects, e.g. relevance to specific areas and regions, including production and manufacturing aspects.
- Association with transport modes, policies, STRIA roadmaps.

Additional key performance indicators can be developed and associated to each element of the taxonomy. Furthermore, the taxonomy will also prove useful for future studies, for example the identification of elements and parts for risk analyses (Haimes, 2008).

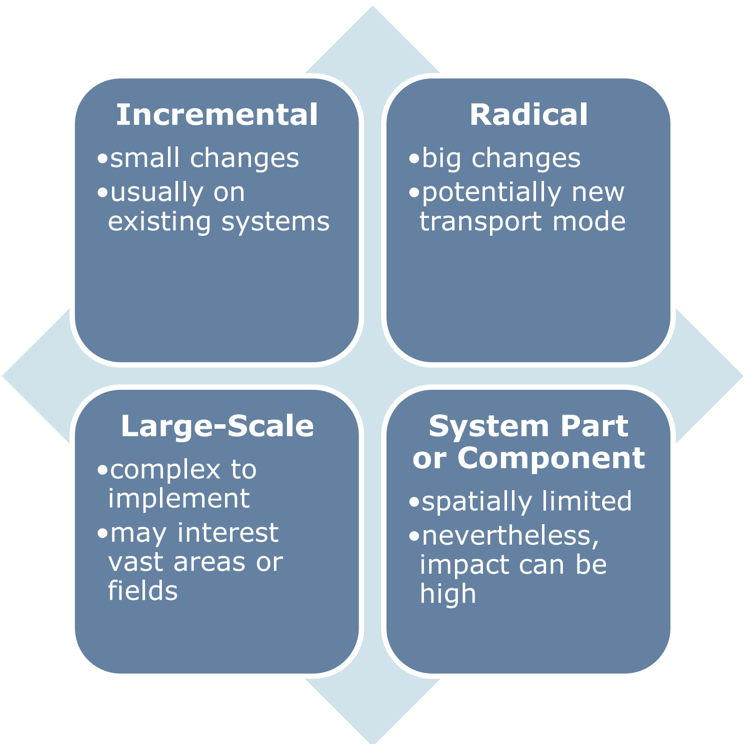
3.4 NETT assessment

The taxonomy serves as the starting point for the assessment of NETT.

3.4.1 Technology and trends categorisation

New and emerging technologies and trends need to be organised and allocated to different categories (Figure 7).

Figure 7. Different scales of NETT in transport magnitude and extent of changes



Two principal categories can be considered at a top level:

— New or innovative transport modes, large-scale technologies, or disruptive trends.

— New or innovative technology with influence on existing transport practice.

For example, an entire new mode of transport (e.g. a vacuum train) will fall into the first category, while, a new battery technology for electric cars will fall into the second category.

A technology can provide incremental changes or be radical and ground-breaking. In the above example, a vacuum train has the potential to be radical, while for a new battery technology, further considerations are needed (e.g. looking at the efficiency and comparing it current practice).

Subsequently, an assessment must take place to further assess the future effect of the technology or trend in terms of potential impact.

3.4.2 Technology and trends classification

It is important to perform a classification of new and emerging technologies and trends focusing on their maturity level and their readiness for implementation. For some technologies, this is possible merely by looking at their TRL.

Regarding the choice of the indicators, these come from corroborated literature and industry practice, and their selection will take place with criteria the availability of data or easiness of calculation. They will be followed by a validation phase in order to test their appropriateness. Candidate indicators include TRL eventually leading to System Readiness Levels (Sauser et al., 2006), Manufacturing Readiness Level (MRL) and technology operation and functional performance metrics (Koh and Magee, 2006).

Even though, the a-priori consideration of a technology or trend as "new and emerging" is based on a low TRL level and an unquantified hype level, the possibility to adopt a quantitative measure of "hype" as an indicator will be considered, using for example bibliometric analysis on scientific publication and patent applications (Campani and Vaglio, 2015) and internet traffic (Jun, 2012).

Regarding the actual implementation, it is assumed that the values for each performance indicator are provided or calculated at any point of time, for both technologies and trends and their constituting parts (lower hierarchies in the taxonomy).

The opportunity to develop composite indicators will be considered in a later phase, building on the knowhow gained in the recent years by the JRC Competence Centre on Composite Indicators and Scoreboards (COIN)[28].

3.4.3 Technology and trends assessment

Different methods with different levels of detail are used for the assessment of different technology categories. For system parts or components, simple assessment based on set KPIs or other indices (e.g. efficiency indices) is adequate. For large-scale technologies, technology acceptance models or surveys are more appropriate.

Using a hierarchic taxonomy for each technology, it will be possible to adjust in real time the performance in relation to components or parts belonging to a lower level in the taxonomy. In the same way, it will be possible to obtain a scoring limited by other attributes in the taxonomy (e.g. geographic availability of components or parts) and, after a calibration, perform comparative analysis for different scenarios corresponding to changes in the attributes of specific components.

In the assessment of R&I it is important to consider readiness levels as KPIs in order to foresee the time of introduction of a new technology. However, for some sectors, it is imperative to also consider socio-economic criteria (e.g. their potential impact and rate of social acceptance). The assessment does not need to be based exclusively on strict socio-economic models but it can be performed using other theories e.g. the Theory of Planned Behaviour by Ajzen (1991, 1985). It is also possible to model the effect of a new transport technology or trend on the basis of current practices and Technology Acceptance Models (see for example Venkatesh et al. (2003), with criteria based on:

[28] https://ec.europa.eu/jrc/en/coin

a. Potential impact (from marginal to mode shift)
b. Social acceptance

The assessment method is tailored to the specific level and the dependencies from lower levels are reflected and can be compared to either static thresholds or temporal comparisons. For example, a low readiness level in a component of a system may prove to be a bottleneck for the entire system.

The assessment will be linked to socio-economic aspects to show trends and opportunities, using geographical filtering (at member state level), building on knowhow gained in different sectors, e.g. the SETIS project (Fiorini et al., 2016; Wiesenthal et al., 2015; Wiesenthal et al., 2012), and will be linked to the Socio-economic assessment carried out within TRIMIS (Grosso et al. 2018).

3.5 Expert consultation

The last step for developing the inventory of NETT will be the consultation with experts in different sectors of transport and other horizontal or transversal sectors. It is foreseen an annual workshop for this purpose. Experts will be chosen in such a way to cover all seven STRIA roadmaps and all modes of transport.

For the annual workshops, a list of experts on the fields will be prepared. The creation of such network will be facilitated by:

— The experience built by the TRIMIS team in different horizontal sectors and enablers of the transport sector (e.g. cybersecurity, energy, digital economy).
— The active contribution of the TRIMIS team to large-scale JRC cross-sector activities, namely the forthcoming in 2019:
    - The "Future of transport and mobility" Flagship report.
    - The transport chapter of the report on the "State-of-Play of Digital Transformation in Selected Policy Areas".
    - The "Future of Cities" Flagship report.
    - The "Resilience" Flagship report.
— The building and maintaining of a transport stakeholders network within the TRIMIS project, which is being developed and will be constantly updated.

The possibility to consult with the experts in the list in additional occasions is also foreseeable.

3.6 Visualisation and reporting

The results of the assessment will be disseminated both statically (in a final report) and dynamically (in the form of infographics in the TRIMIS website). The representation will follow the logic of a phylogenetic tree (Letunic and Bork, 2016), focusing on specific scales of the taxonomy.

Figure 8 provides an indicative example for mega scale transport elements in the form of a truncated radial graph. The specific case was prepared using the Newick[29] tree notation, imported as a text file in the Interactive Tree of Life (iTol)[30], a web-based tool for the display, manipulation and annotation of phylogenetic trees.

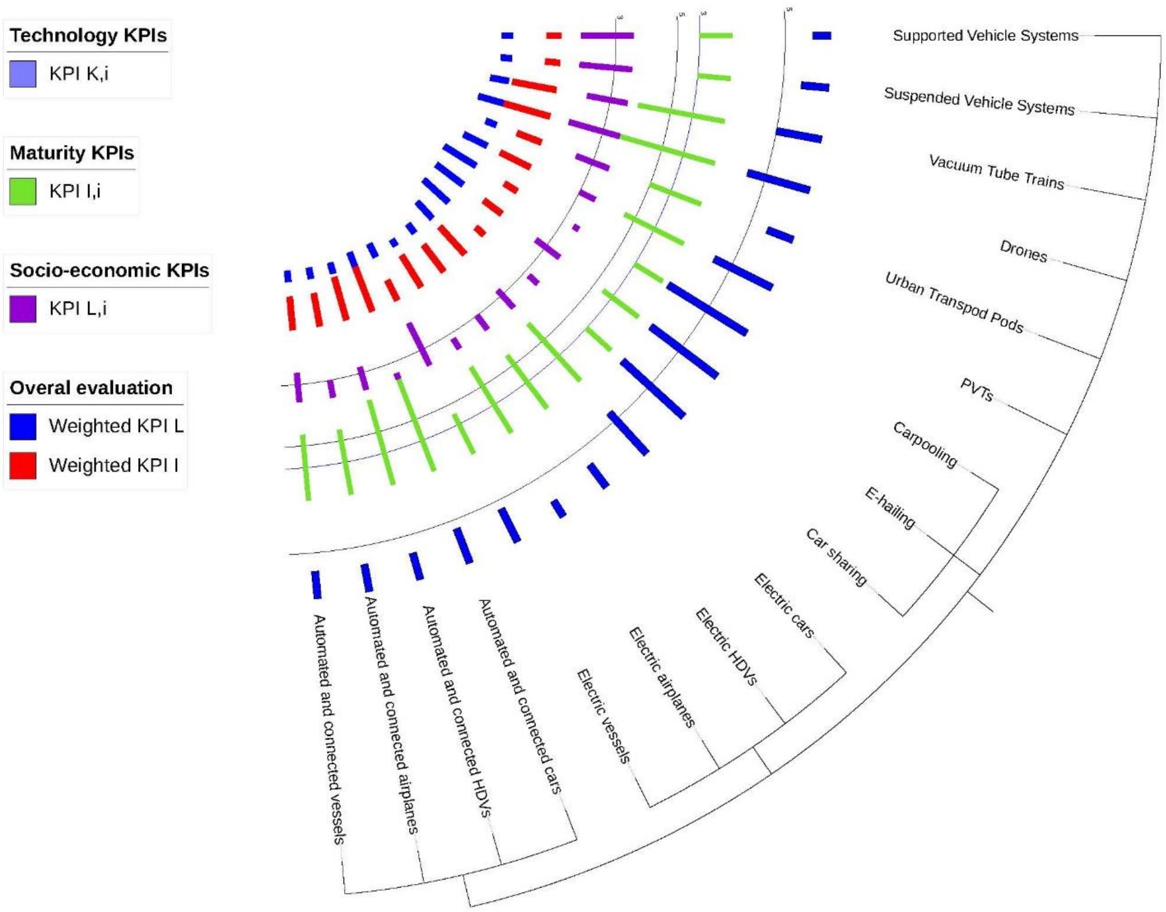
Such representation allows presenting in the outer part of the circular section the different elements of the taxonomy, while the element attributes provide information in a qualitative or quantitative manner. The elements can be filtered according to temporal, geographical, socio-economic or other criteria.

[29] http://evolution.genetics.washington.edu/phylip/newick_doc.html
[30] https://itol.embl.de

Element attributes can be normalised, weighted and summed-up for visualisation and assessment purposes. The intersecting lines indicate threshold values for the different KPIs, which can be grouped in different categories.

Additional representations can be implemented, showing lower and higher levels of the taxonomy and different attributes.

Figure 8. Transport technologies visualisation



Other dedicated tools for the representation of outcomes will be considered, together with the opportunity to create a web-based tool in the TRIMIS website, concurrently with the IT development of the TRIMIS portal.

4. Conclusions

This report has outlined the TRIMIS methodology for the Modelling and Assessment of New and Emerging Technologies and Trends (NETT) in the transport sector which includes the following key steps:

— definition of the data sources;
— development of a methodology for the data extraction;
— building of a taxonomy and a concurrent database;
— assessment, expert validation and deployment of the key results.

This report tries to address two principal challenges:

a. The complexity of the transport sector, especially in recent times of possible disruptions emerging from the digital transformation of the society.
b. The practical implementation of the methodology that will lead to an as much as comprehensive assessment of NETT in transport.

For the first, the report tries to identify principal collaboration inside the JRC and the TRIMIS team, considering that such assessment goes well beyond algorithms and data collection, and it must be the outcome of a more complex social process.

For the second, the methodology identifies principal points for each step, and details their implementation.

This report could therefore contribute towards the improvement of the analytical capabilities of TRIMIS and the policy relevance of STRIA.

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List of abbreviations and definitions

ALT	Low-emission alternative energy for transport
ASCE	American Society of Civil Engineers
CAT	Cooperative, connected and automated transport
CLIOS	Complex, Large-scale, Interconnected, Open, Socio-technical
COIN	Competence Centre on Composite Indicators and Scoreboards
CORDIS	Community Research and Development Information Service
CPC	Cooperative Patent Classification
DG MOVE	Directorate-General for Mobility and Transport
DG RTD	Directorate-General for Research and Innovation
EC	European Commission
EIS	European Innovation Scoreboard
EPO	European Patent Office
ETL	Extract, Transform, Load
EU	European Union
FET	Future and Emerging Technologies
IEEE	Institute of Electrical and Electronics Engineers
INF	Infrastructure
IP	Intellectual Property
ISTC	International Standard Text Code
iTol	interactive Tree of Life
ITS	Intelligent Transport Systems
JRC	Joint Research Centre
KET	Key Enabling Technology
KPI	Key Performance Indicator
LCEO	Low Carbon Energy Observatory
MRL	Manufacturing Readiness Level
NETT	New and Emerging Technologies and Trends
NTM	Network and traffic management systems
PATSTAT	Worldwide Patent Statistical Database
PK	Primary Key
R&I	Research and Innovation
RIO	Research and Innovation Observatory
SETIS	Strategic Energy Technologies Information System
SKOS	Simple Knowledge Organization System
SME	Small- and Medium-sized Enterprise
SMO	Smart mobility and services
SQL	Structured Query Language

STRIA	Strategic Transport Research and Innovation Agenda
TIM	Tools for Innovation Monitoring
TRE	Transport electrification
TRID	Transport Research International Documentation
TRIMIS	Transport Research and Innovation Monitoring and Information System
TRL	Technology Readiness Level
VDM	Vehicle design and manufacturing
WG	Working Group

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Annexes

Annex 1. Principal TRIMIS/JRC references for the NETT inventory

STRIA Roadmap	TRIMIS*	JRC [Unit/project acronym]^
Cooperative, connected and automated transport	TRIMIS team leader: Konstantinos Gkoumas, CA	C.4 C-ART C.4 C2ARTxSociety C.4 C2ART-Impact E.3 C-ITS
Transport electrification	TRIMIS team leader: Anastasios Tsakalidis, CA	C.4 AFI C.1 FiveVB C.1 LiBforSecUse
Vehicle design and manufacturing;	TRIMIS team leader: Alejandro Ortega Hortelano, CA	C.4 SMART C.1 CarE-Service
Low-emission alternative energy for transport	TRIMIS team leader: Alejandro Ortega Hortelano, CA	C.2 ALFA C.2 AAF
Network and traffic management systems	TRIMIS team leader: Mitchell van Balen, CA	C.4 VEST-App
Smart mobility and services	TRIMIS team leader: Anastasios Tsakalidis, CA	-
Infrastructure	TRIMIS team leader: Konstantinos Gkoumas, CA	C.4 INTEROP-STORE
Other		C.4 SIMOD C.4 RideChain E.5 AVSEC C.6 TSEA C.6 BDT

*as of November 2018
^non inclusive list, based on the JRC Work Programme 2018-2019[31]
CA: Contract Agent

[31] https://ec.europa.eu/jrc/sites/jrcsh/files/detailed_wp_2018_19.pdf

Annex 2: Example of synonyms and brand names for technology terms

Term	Synonym	Brand name
Tube transport	Hyperloop	Virgin Hyperloop One Hyperloop Transportation Technologies TransPod DGWHyperloop Arrivo Hardt Global Mobility Hyper Chariot Zeleros

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