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D4.2 Gap Analysis

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List of abbreviations

ANP	Analytic Network Process
ATC	Air Traffic Control
AV	Autonomous Vehicle
BEV	Battery Electric Vehicles
EC	European Commission
EV	Electric Vehicles
eVTOL	Electric Vertical Take-Off and Landing
FaaS	Freight as a Service
FCEV	Fuel Cell Electric Vehicles
HEV	Hybrid Electric Vehicles
HSR	High-speed rail
H2020	Horizon 2020 EU Research and Innovation Program
IMO	International Maritime Organization
MaaS	Mobility as a Service
PATS	Personal Airborne Transportation Systems
TaaS	Transport as a Service
TC(s)F	Transport Concept(s) of the Future
WP	Work Package

Executive summary

The main objective of D4.2 "Gap Analysis" is analysis and assessment of the realization of the defined transport concepts of the future – TCsF (D2.2). We have analyzed the advantages of each TCF and the obstacles that could appear on the path of their realization. The idea behind this deliverable is to contribute to the definition of the transport research priorities by determining a list of priority gaps or aspects that have not been addressed enough in the transport literature and practice so far.

For the given key TCsF, our goal was to determine a list of breakthroughs and obstacles based on: deliverable 2.2; review of previous transport related projects (both passenger and freight transport); academic literature; reports from business sector and consultancy firms; relevant websites, synopsis tool and databases.

By crossing the breakthroughs and obstacles for each TCF, we have identified existing research gaps and therefore made adequate proposals for their possible overcoming. It is noticeable that, in some cases, the same or similar gaps can be seen for different TCsF. Therefore, the same type of analysis could be applied in order to identify steps to be taken in order to eliminate such research gaps.

The priority list of gaps (Table 1) is obtained by taking into account priority order of TCsF, given in D3.2. This priority order is based on the opinions of experts and applied ANP method for both passenger and freight transport sectors.

Table 1. List of priority gaps

RANK	*PASSENGER*	*FREIGHT*
1.	**TC8 High-speed rail**	**TC1 Automation – Passenger and Freight Transport**
	• Changes in environmental, human health, resource, and climate change impacts • Costs and challenges facing the HSR	• Security, Cyber security • Social justice and equity • Repositioning • Increased congestion and pollution • Revenue for city • City infrastructure • Safety • Technology maturity • Infrastructure • Infrastructure (in metro) • Functional safety • IT security • System integration • Changes in the ports • Regulatory Framework • Insurance
2.	**TC5 Personal air transportation – "flying cars", "flying taxis"**	**TC6 Delivery Drones**
	• Cost and accessibility • Safety • Affects other sectors • Air traffic control and	• Requires investment • Drone insurance • Drone financing • Flying drone bill of rights

RANK	PASSENGER	FREIGHT
	infrastructure • Regulation	• Order staging • Designated delivery spots • Classification system for drone and cargo • Regulation • Licensing (Vehicle, Pilot, Operator) • Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots • Conditional awareness • Safety • Shipping big-ticket items • Override kill switch • Docking systems
3.	**TC1 Automation – Passenger and Freight Transport**	**TC2 Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS**
	• Security, Cyber security • Social justice and equity • Repositioning • Increased congestion and pollution • Revenue for city • City Infrastructure • Safety • Technology maturity • Infrastructure • Infrastructure (in metro) • Functional safety • IT security • System integration • Changes in the ports • Regulatory Framework • Insurance	• MaaS can still face strong competition from existing travel applications • Policy Framework for Implementation of MaaS • Travel demand modelling for MaaS
4.	**TC3 Electrification – Passenger and Freight Transport**	**TC10 Freight consolidation hubs, Freight Distribution Centres**
	• Electric parking spaces • Uncomfortable and slow charging • Limited range • Space required for storing electricity (battery) in the vehicle • Accessibility and awareness • Higher initial cost • Power solutions • Management and standardization competencies	• Organizational and contractual problems often limit effectiveness. • Increase in delivery costs • Potentially high set up costs (and sometimes high operating costs)
5.	**TC9 Hyperloops**	**TC3 Electrification – Passenger and Freight Transport**
	• Deadly Collisions • Construction cost and Environmental impact • An easy terrorist target	• Electric parking spaces • Uncomfortable and slow charging • Limited range • Space required for storing electricity

RANK	*PASSENGER*	*FREIGHT*
	• New management challenges	(battery) in the vehicle • Accessibility and awareness • Higher initial cost • Power solutions • Management and standardization competencies
6.	**TC4 Seamless transport chains**	**TC4 Seamless transport chains**
	• Efficient management systems • Coordination and collaboration Regulations • Technology acceptance	• Efficient management systems • Coordination and collaboration Regulations • Technology acceptance
7.	**TC7 Smart use of travel time**	**TC11 Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines**
	Obstacles of TC1	• Technology acceptance • Intermodal transfer with existing modes • Costs and funding
8.	**TC2 Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS**	
	• MaaS can still face strong competition from existing travel applications • Policy Framework for Implementation of MaaS • Travel demand modelling for MaaS	

Identification and selection of priority topics for the future transport research should also be based on determined list of gaps that can be noticed from the sketch of the future transport system.

1 Introduction

The overall objective of the INTEND project is to deliver an elaborated study of the research needs and priorities in the transport sector utilising a systematic data collection method. One of the main elements of the INTEND project is the review of pertinent literature (EU and international research projects including strategic research agendas, studies or roadmaps) in order to identify future technologies for each transport mode (road, aviation, rail, maritime) as well as infrastructure and transport systems which will be treated horizontally. The INTEND project also reviewed past futurology projects and recent futurology studies in order to present future mobility concepts. To ensure validity of the results, the Analytical Network Process was used to determine the prioritized elements in all clusters (technological advances, megatrends and political imperatives) for successful implementation and realization of key transport concepts of the future. Finally, INTEND has developed a transport agenda that would pave the way to an innovative and competitive European Transport sector. The project is driven by three main objectives:

- to define the transport research landscape;
- to define the megatrends and their impact on research needs;
- to identify the main transport research needs and priorities.

In order to enable a wide range of stakeholders to gain access to the results, INTEND has developed an online platform, INTEND Synopsis tool, which constitutes a dynamic knowledge base repository on the major developments in the transport sector. This has provided a visualisation of the INTEND's main outcomes. The basis for the platform was Transport Synopsis Tool which has already been developed under the project RACE2050 coordinated by TUB. The repository will be updated and integrated into the INTEND website to provide a comprehensive picture of all forward looking studies focusing on technological developments, megatrends and policies.

1.1 The INTEND work structure

Figure 1 depicts the work flow of the INTEND project and the relationship between the process of identification of key megatrends affecting both passenger and freight transportation systems of WP3 with the rest of the WPs.

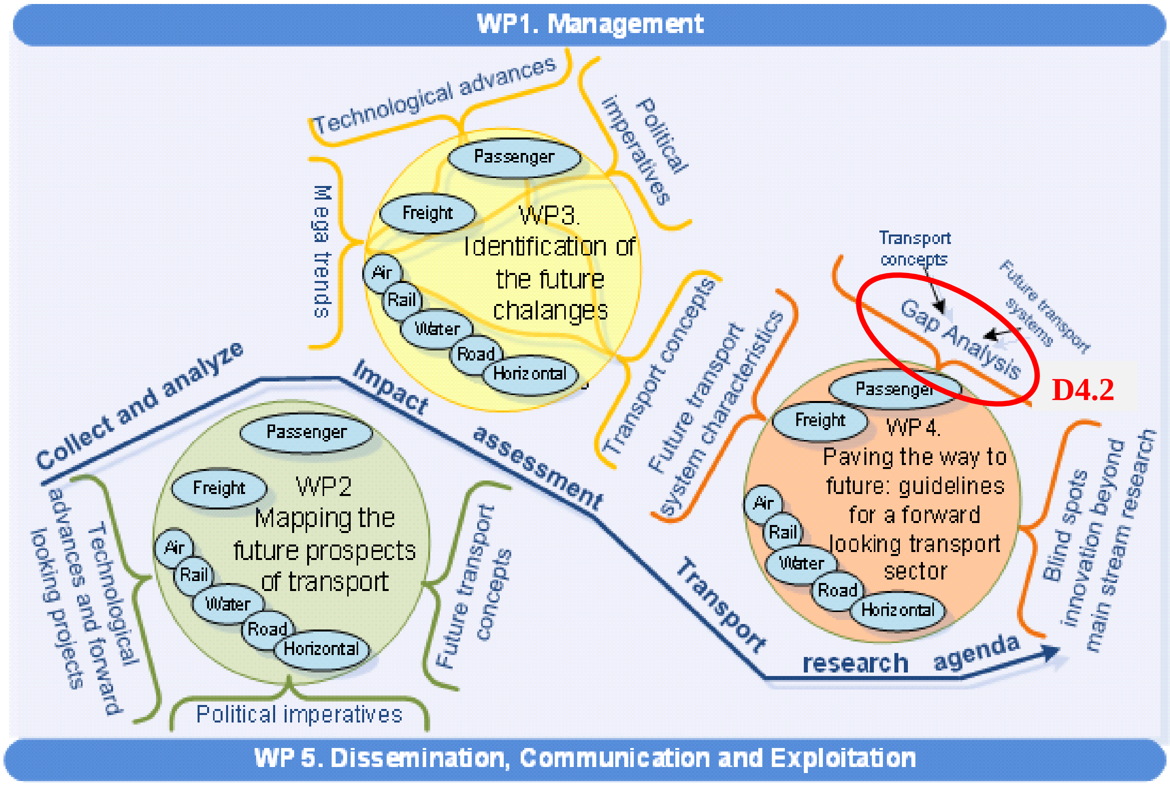


Figure 1. Workflow in INTEND and relations of task 4.2 with other WPs

1.2 Task 4.2: GAP analysis

The aim of this task was to find out the gaps between technological advances in the transport sector and development prospects of the transport and mobility systems influenced by megatrends. The GAP analysis was based on the utilization of the following information:

- the transport technological advances, mobility concepts and research systems trends from Task 2.1;
- identified political imperatives in Task 2.3;
- determined and validated megatrends (WP3), which impact the realization of key transport concepts of the future from Task 2.2.

By applying the results from WP2 and WP3, we have defined streams of needed future researches in the fields of transport technologies, mobility concepts and research systems, etc., required to achieve the political goals (imperatives) that are to be associated with shared and long-term vision about the future of transport. We have laid out explicit priorities about what technologies to develop and megatrends to research by taking into account breakthroughs and obstacles related to transport concepts of the future, identified in Task 2.2. In addition, by taking into account impact assessments from Task 3.2, we have determined technological advances and megatrends which will have the most significant impact on overcoming the challenges and reaching the defined future transport system. The approach has led to extraction and definition of research fields whose progress will primarily contribute to the improvement of the future transport systems.

1.3 Deliverable D 4.2 in the frame of INTEND work structure

INTEND's methodology for definition of future transport research priorities has also been based around the GAP analysis. Starting from the results of WP2 and WP3, we have analyzed the research gaps that will constitute an important input for the development of the **transport research agend**a in the form of a **blueprint** on transport research needs, priorities and opportunities (Task 4.3). Role of gaps identification in the INTEND work structure can be seen from Figure 2.

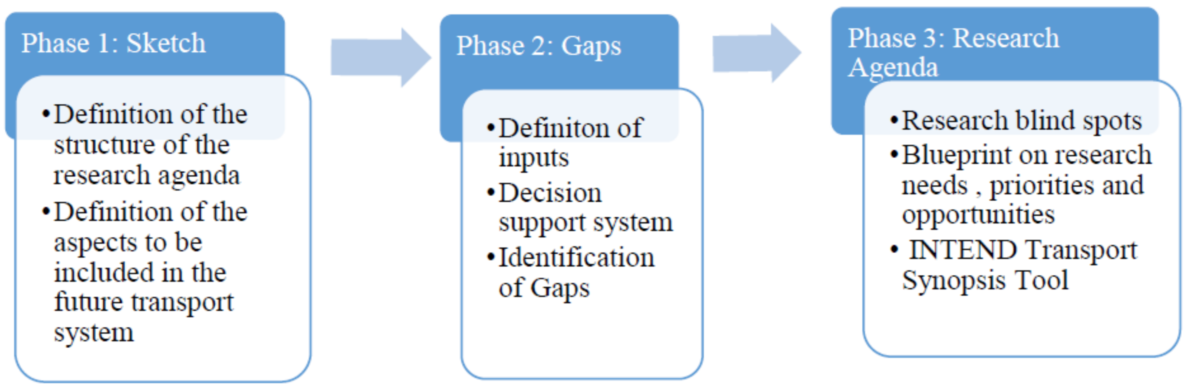


Figure 2. Role of GAP analysis in the frame of INTEND work structure

2 Transport concept of the future - breakthroughs and obstacles – GAP analysis

2.1 Methodology

The main objective of D4.2 "Gap Analysis" is analysis and assessment of the realization of the defined transport concepts of the future – TCsF (D2.2). We have analyzed the advantages of each TCF and the obstacles that appear on the path of their realization. The idea behind this deliverable is to contribute to the definition of the transport research priorities by defining a list of priority gaps or aspects that have not been addressed enough in the transport literature and practice so far.

The starting point for this report are outcomes of D2.2, where key TCsF were outlined. For the given key TCsF, our goal is to determine a list of breakthroughs and obstacles based on:

- ✓ D2.2 outcomes;
- ✓ review of previous transport related projects (both passenger and freight transport);
- ✓ academic literature;
- ✓ reports from business sector and consultancy firms;
- ✓ relevant websites, synopsis tool and databases.

By crossing the breakthroughs and obstacles for each TCF, we have identified existing research gaps and therefore made adequate proposals for their possible overcoming. Our methodology also contains an analysis of existence of the all identified gaps in the defined sketch of the transport system of the future – D4.1.

Expected outcomes of this Gap analysis is to define a priority list of topics for future transport research based on a defined list of gaps that are present in the sketch of the future transport system.

This section of the deliverable contains an individual analysis of the proposed TCF and for each of them the breakthroughs and obstacles are presented.

2.2 Automation – Passenger and Freight Transport (autonomous cars, trucks, aircrafts, trains, vessels)

Report D2.2 describe TCF "Automation – Passenger and Freight Transport (autonomous cars, trucks, aircrafts, trains, vessels)" as follows:

"*Autonomous – driverless vehicles operating with no need for any human intervention; autonomous cars; autonomous trucks, platooning technology for heavy duty vehicles, autonomous networks of long-haul trucks; autonomous passenger aircrafts; automated trains for passenger and freight transport; autonomous ferries and vessels for passenger and freight transport, automation – platooning of vessels / ferries".*

Based on the available literature, it is possible to identify some specific characteristics of the breakthroughs and obstacles related to this TCF (Automation – Passenger and Freight Transport). Our approach has also allowed the identification of various breakthroughs and obstacles in various transport modes. These are:

- Road transport – (Table 1 – breakthroughs and Table 2 – obstacles);
- Air transport – (Table 3 – breakthroughs and Table 4 – obstacles);
- Rail transport – (Table 5 – breakthroughs and Table 6 – obstacles);
- Water transport – (Table 7 – breakthroughs and Table 8 – obstacles).

Road transport

Table 1. Breakthroughs of TCF Automation – Passenger and Freight Transport – Road transport

	TCF: Automation – Passenger and Freight Transport – *Road transport*	**Description**
Breakthroughs	Increased safety	Eliminate all human causes of crashes
	Better use of travel time	Passenger can read or check email or do something else useful
	More efficient	Efficient-road use and decreased congestion
	Energy savings	Efficient traffic flow (and thus less sporadic acceleration and braking) and parking and automated ridesharing
	Decreases in polluting emissions	Automation of cars can reduce passenger car emissions by making driving more efficient, enabling shifting from ownership of vehicles and changing the size, weight and efficiency of vehicles.
	Provision of mobility services to people currently unable to drive	People who do not have driving license or people with disability
	Reduction in the need for parking space	A reduction in the need for parking space and the disappearance of congestion due to vehicles searching for parking space
	High cost of Automated Vehicles (AVs) may accelerate the move to shared mobility	Personal autonomous vehicles results in high costs which has the effect on shared autonomous vehicles
	Roadway infrastructure could be managed dynamically	Autonomous driving technologies has created a critical need for adaptation in transport infrastructure, control systems and management strategies to improve mobility and accessibility in urban areas.
	Reduce the need for pedestrian areas	Because AVs would give highest priority to pedestrians in terms of safety, AV reduce the need for pedestrian areas, thereby increasing door-to-door mobility for mobility impaired people.
	Predictable travel times	In a fully automated system, travel times will become perfectly predictable (or estimates will be instantaneously adjusted in case of incidents), reducing the waiting time at intermodal interchanges, and thus promoting intermodal transport.

Table 2. Obstacles of TCF Automation – Passenger and Freight Transport - Road transport

	TCF: Automation – Passenger and Freight Transport - *Road transport*	Description
Obstacle	Increased congestion and pollution	Increased congestion and pollution caused by travel by those currently unable to drive, such as young people without driving license, the physically impaired, and elderly people (Franckx, 2015). Le Vine et al., 2016, examined the impact of the dynamics of driving autonomous vehicles on congestion in traffic. Autonomous vehicles which offer a comfortable ride similar to slowing down and acceleration of rail, create more traffic congestion than a man behind the wheel. Only the vehicles with drivers and autonomous vehicles were included in the study. There were no trucks, buses, or pedestrians.
	It is not clear to what extent autonomous cars will really lead to shorter headways	One should not compare the theoretical safety distance between AVs with the theoretical safety distance between vehicles driven by humans as a lot of people drive closer to the preceding car than is justified on safety grounds (Franckx, 2015).
	A shift away - from public transit	due to the lower cost of time spent in a car (Franckx, 2015)
	Longer trips (especially commutes)	Opportunity cost of the time spent in traffic decreases; longer commutes will lead to further urban sprawl, and to buildings with a larger environmental footprint (Franckx, 2015)
	Repositioning	After having dropped their passenger, the AVs will now have to drive to places where parking is available (or cheaper), or to catch other users (which could be other family members, or, in the case of shared cars, third parties); this “repositioning” could have an important impact on traffic flows (Franckx, 2015).
	Security	Automated vehicles could be used for terrorist attacks (as a bomb for instance) without any physical risk and with much lower risks of detection for the terrorist. Moreover, automated vehicles could be hacked for malicious purposes (Franckx, 2015).
	Traffic Management	Very quick availability of autonomous vehicles can lead to an increase in the number of personnel on the road, which would prevent the efficiency of public transport (GovTech, 2017).
	Infrastructure	Often, AVs require a clear striming stripe, storage locations for data collected during guidance, and a robust network of climbing if they are working on electricity (GovTech, 2017).
	Revenue	AVs will not go to red light, they will not accelerate to the highway over the permitted border or park outside the permitted parking space. This, however, will affect the city budget. In some cities, traffic fines make a significant percentage of the city's budget. Cities will need to generate new revenue streams to counter the loss of funds (GovTech, 2017).
	Liability Insurance	One of the most sensitive areas for autonomous vehicles is the issue of liability and insurance. How will insurance companies handle fenders while the driver reads and does not pay attention to the road? In addition, who will do the "driver" who has the ultimate "control"?(GovTech, 2017)
	Police and Emergency Response	The issue that arises in relation to AV is the issue of law enforcement. It's not hard to imagine that AV is being usedused narcotics transport (GovTech, 2017)
	Social Justice and Equity	There is a risk that AV would benefit more from the rich and create a higher burden for low-income people. These without AV can be in a

	TCF: Automation – Passenger and Freight Transport - *Road transport*	Description
		disadvantageous position when it comes to employment, because they can work with AV and respond to e-mail while travelling.
	Creating (and maintaining) maps for self-driving cars is difficult work	Google self-driving cars work by relying on a combination of detailed pre-made maps, as well as sensors that "see" the obstacles on the road in real time. Both systems are crucial and work in tandem. Before Google can test the auto-driving of fully automated vehicles, in any new city or city, employees first hand-drive vehicles all over the street and build a detailed 3-D map of the area. The car uses the map as a reference, then deploys its sensors to look at other vehicles, pedestrians, and all new objects that are not on the map, such as unexpected signs or constructions. Currently, Google has made only detailed 3-D maps for a relatively limited number of testing areas, such as Mountain View. For cars that will be driving alone, Google would have to build and maintain detailed maps across the country and keep them constantly updated. As more and more autonomous cars are on the way, they will constantly meet new objects and obstacles that can be passed on to the mapping team and update other cars. However, this is incredibly scary and potentially expensive. Autonomous technology can progress more quickly if all companies that test such vehicles, share information that their sensors collects. Otherwise, it seems that some car companies do not think that Google's precise mapping is the way to go. Tesla hopes to make buses that rely more on image processing and sensors (Plumer, 2016). Other companies like HERE maps are building High Definition(HD) maps for AVs that rely on HD localization, lane and road models.
	Driving requires many complex social interactions — which are still tough for robots	Driving is an intense social process that often involves complicated interactions with other drivers, bikers and pedestrians. In many of these situations, people rely on intelligence and common sense, while robots still have a very small disadvantage. Much of the test Google has done over the years has been the "training" of car software to identify the different situations that appear on the roads. When it comes to the most difficult situations, companies can introduce a compromise solution: autonomous vehicles controlled by a man when the computer is not sure what to do. Google's cars should be completely free of drivers, but more traditional car companies such as BMV or Audi work on autonomous vehicles that can cross between computers and drivers, depending on the situation. The huge lack of another approach, as many analysts have noticed, is that joint control can potentially make cars for driving cars much more dangerous. (Plumer, 2016)
	Bad weather makes everything trickier	The fact is that time is still a big challenge for the buses that drive. Like our eyes, car sensors do not work so well in fog, rain or snow. Moreover, companies are currently testing cars at locations with benign climatic conditions (Plumer, 2016).
	We may have to design regulations before we know how safe self-driving cars really are	Another big obstacle for autonomous vehicles is not technical - it is political. Before autonomous vehicles can be on the roads, regulators will have to repatriate them for use. There are also special legal issues, such as how these cars will be insured and who will be responsible - driver or manufacturer - in the event of a fall (Plumer,

	TCF: Automation – Passenger and Freight Transport - *Road transport*	Description
		2016). Regulators could adopt alternative testing procedures - such as modeling or simulation, or even pilot programs in volunteer cities. Currently, even testing of autonomous vehicles may require special permit to be taken from the manufacturer from the authorities.
	Cyber security will likely be an issue — though a surmountable one	"How do we ensure that these cars cannot be hacked? How vehicles become smarter and connected, there are more ways to get in and disturb what they do." This should not be impossible to fix. Software companies have long been facing this problem (Plumer, 2016).

Available literature also suggests some of the ways or approaches to overcome the obstacles listed for this TCF (Automation – Passenger and Freight Transport - Road transport). Possible approaches should be directed in the area of:

- ***Infrastructure*** – The opening of a dialogue is recommended in order to define the priorities of public investment in infrastructure. Public information can help officials understand whether it is necessary to expand existing infrastructure or to establish new opportunities for AVs*.*
- ***Revenue*** **–** Some reports suggests that city develops a mileage tax or an AV registration tax*.*
- ***Liability insurance*** – Literature recommends utilization of opportunities for partnership with AV companies to facilitate smooth introduction to AVs*.*
- ***Police and emergency response*** **–** As a quick solution, available literature proposes a development of specific procedures for interaction training between police and emergency services with AVs. As a long-term solution, cooperation between agents with manufacturers is being considered to create "killers" to disable AVs suspected of carrying illegal cargo*.*
- ***Bad weather makes everything trickier*** – We imagine we are going to find places where the weather is good, where the roads are easy to drive — the technology might come there first. Then, once we have confidence with that, we will move to more challenging locations*.*
- ***Cyber security will likely be an issue – though a surmountable one*** – It is likely to require a change in the culture in the automotive industry, which has traditionally not much being concerned with the issues of cyber security.

Air transport

Table 3. Breakthroughs of TCF Automation – Passenger and Freight Transport – Air transport

	TCF: Automation – Passenger and Freight Transport - *Air transport*	Description
Breakthroughs	Low noise	
	Energy efficiency	The use of passenger drones for short distance travel and unmanned passenger aircrafts could also reduce energy efficiency (Voege, 2016). ATC Automation allows the trajectories to be predefined and to

	TCF: Automation – Passenger and Freight Transport - *Air transport*	Description
		make adjustments at a greater distance from the airport, so the final descent can be smooth and energy efficient. (Spinardi, 2015) A sophisticated ATC can also allow the plane to fly at an altitude that would be better in terms of efficient fuel consumption, but would, on the other hand, affect comfort and safety.
	Low engine power	In particular, enabling aircraft to utilise idle thrust descents, with low engine power, is a key challenge for ATC because of the complexity and time pressure of many different types of aircraft converging on a limited landing space at an airport (Spinardi, 2015).

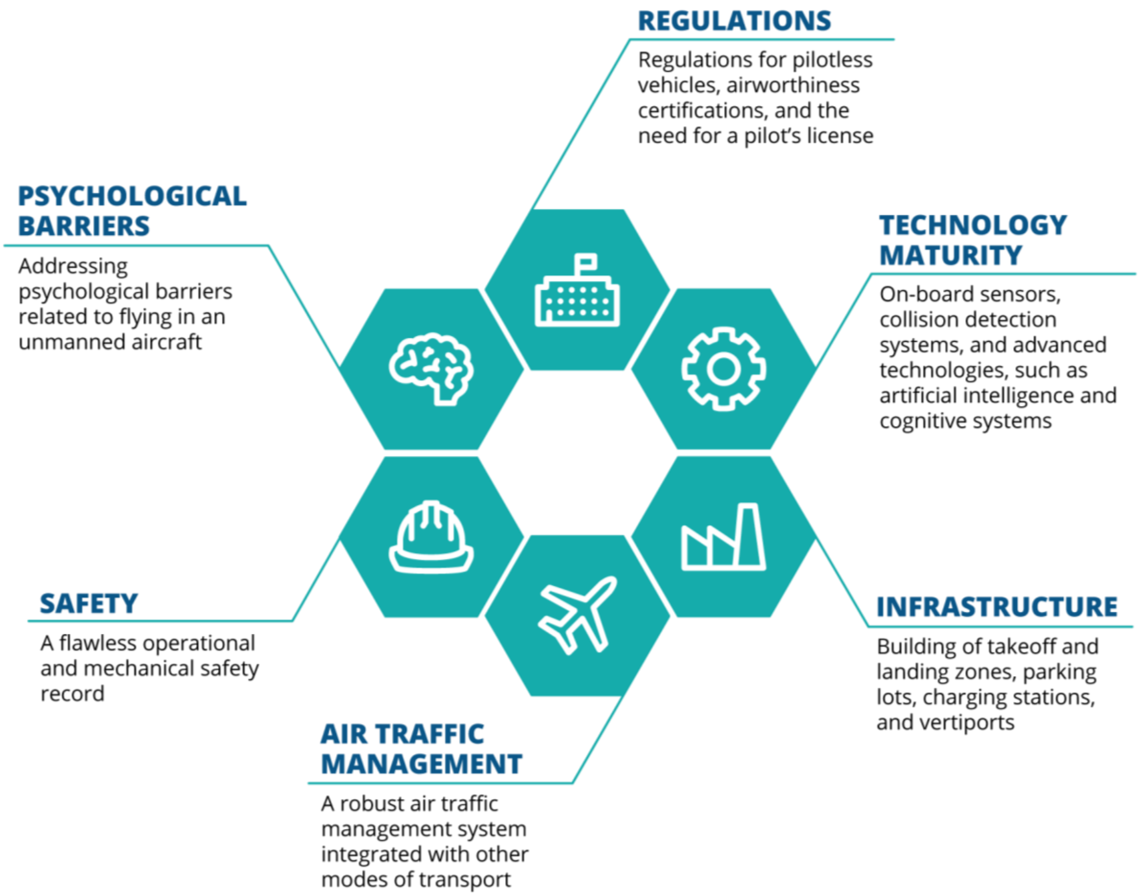
Some authors notice the lack of an established, cohesive air-traffic management network (Margaritoff, 2018). Flying taxis are transporting human beings, not parcels, which adds a complicated layer of safety, insurance, and potential adoption fears on behalf of users.

Table 4. Obstacles of TCF Automation – Passenger and Freight Transport - Air transport

	TCF: Automation – Passenger and Freight Transport - Air transport	Description
Obstacles	Risk perceptions	Barriers to change can include risk perceptions that cannot be easily calculated through costs or benefits. Trust in ATC performance cannot be generated exclusively through a budget (Spinardi, 2015).
	Safety	Obstacles to the advancement of automation depend on basic safety concerns (a key problem due to potential loss of life and poor publicity that may be the result of a collision of aircraft) – Spinardi, 2015. For the adoption of passenger drones and flying cars (especially fully autonomous), operators of these vehicles should show a safety record covering both mechanical integrity and safe operations. As has been shown in autonomous cars, any accidents can have considerable attention and can slow down the adoption of such a concept (Lineberger et al., 2018).
	Necessary "heterogeneous engineering"	In the case of the ATC, further advances in the field of automation will also require "heterogeneous engineering", which combines technical development with efforts to overcome significant political and organizational barriers.
Obstacles for drones	Regulations	Transport related regulatory agencies must comply with requirements for pilots and autonomous passenger drones: Is a pilot's license required? What airspace can they occupy? What are the vehicle airworthiness requirements? There is some progress, since some manufacturers have begun discussing certification opportunities. Believes that in the beginning it is important that these vehicles begin to work and then work on their autonomous assistance and then fully automate them. It is also necessary to regulate the use of airspace (lower elevations at higher altitudes) in view of the exponential growth of pilots and autonomous vehicles using airspace (Lineberger et al., 2018).
	Technology maturity	Although GPS technology exists and is used in autonomous cars, it should be improved to provide remote sensing and recognition

	TCF: Automation – Passenger and Freight Transport - Air transport	Description
		needed to deal with the multi-way and fast convergence associated with the autonomous flight. These vehicles would require advanced technologies, such as artificial intelligence, to allow advanced detection and avoidance capabilities. Machine learning can be essential since operations move from piloted to autonomous: the vehicle should learn from pilots on the basis of over a thousand working hours to become completely autonomous over time. Energy management is crucial: to have enough energy to transport passengers or cargo, to maintain a safety margin and reload for the next flight. Although the technology of using batteries as a source rapidly improves, in order to increase the capacity of passengers and cargo and extend the range of passenger drones, it is necessary to further improve or to find alternatives (Lineberger et al., 2018).
	Infrastructure	In terms of infrastructure, it is necessary to provide the appropriate landing and landing zone, as well as the charging stations for the battery. A broad network requires new infrastructure or the conversion of existing infrastructure (such as helipads, roofs of large public buildings and unused land). In order to provide a unified traffic management system, additional infrastructure along the predefined flight corridors should be installed to help rapidly communicate data and geolocation. All these changes in infrastructure would require cooperation with commercial actors and local urban planning bodies (Lineberger et al., 2018).
	Air traffic management	In order to achieve a stable air traffic management system that would guarantee the safe and efficient operation of passenger aircraft and flying cars, industry leaders are likely to reach agreement on a reliable traffic management framework that integrates with other modes of transport, especially in urban areas. There is already progress in the United States, as Uber and NASA have recently signed an agreement on the traffic area for traffic management of autonomous vehicles that will fly at low altitude (Lineberger et al., 2018).
	Psychological barriers	People need to overcome the psychological barriers they may have associated with the idea of flying in unmanned airplanes, since these vehicles are likely to be autonomous in the end. Psychological barriers can be overcome if manufacturers and regulatory authorities ensure that these vehicles are safe as airplanes and vehicles have documented safety records (Lineberger et al., 2018).

Challenges to taking flight *- (Lineberger et al., 2018) Despite technological advances and many potential applications for these planes, there are various challenges to consider in terms of regulations, certificates, infrastructure and air traffic management (Figure 1). The key could be* ***close cooperation between regulators and stakeholders in the private sector in the ecosystem of extended mobility.***



Source: Lineberger et al. (2018)

Figure 3. Challenges to taking flight

Table 5. Breakthroughs of TCF Automation – Passenger and Freight Transport - Rail transport

	TCF: Automation – Passenger and Freight Transport - *Rail transport*	**Description**
Breakthroughs	Capacity	Contributes to the increase of the transportation capacity on existing lines (Shift2Rail, 2015).
	Costs and energy efficiency	Reduces the operating costs and improves energy efficiency (Shift2Rail, 2015).
	Fully automated rail freight system	Contribute towards the vision of a fully automated rail freight system (Shift2Rail, 2015).

Table 6. Obstacles of TCF Automation – Passenger and Freight Transport – Rail transport

	TCF: Automation – Passenger and Freight Transport - *Rail transport*	**Description**
Obstacles	Infrastructure (in metro)	Modification or replacement of vehicle fleet and signaling system and additional complexity can increase costs in comparison with other signaling and control systems. Closing an existing system over a longer conversion period is likely to be difficult and costly, as existing metro lines often represent vital links in the urban transport network. In order to ensure high levels of security, a greater degree of physical segregation from the environment will be required than for trains in which a driver can react to extraordinary or unexpected events such as collapse, burning trees or damage to the infrastructure. It is necessary to improve the system of communication and tracking for passengers throughout the system in order to provide functions that would otherwise be performed by a staff member. This also applies to remote monitoring and correction (where possible) of equipment faults by the remote control center. The equipment requires a high degree of reliability and availability to ensure the safety of passengers. Such systems would require **additional capital and maintenance costs** (Powell, 2016).
	Public attitudes and staff opposition	Public attitudes towards operator without driver are divided. Some passengers are concerned about the safety of trains that are automatically controlled and without the direct supervision of people. Public awareness of successfully installed subway stations, along with general trends in increased technology acceptance, will contribute that less and less passengers are opponents of trains without drivers. There was a significant opposition to the increase in automation by the unions, usually because of the possibility of losing a job, although security concerns are often cited as a reason (Powell, 2016).
	System integration	Smart systems need to communicate across rail services, transport modes and infrastructure (Bosch, 2017).
	Software development	Higher investment to satisfy increased customer needs and to ensure valid real-time data analysis (Bosch, 2017).
	Functional safety	Higher system complexity increases potential error rates and demands new functional safety approaches (Bosch, 2017).
	Sensor implementation	Identify optimal combination of various sensors (e.g. cameras, radar, infrared) to ensure seamless communication through all weather conditions (Bosch, 2017).
	IT security	More digitised and interconnected systems are exposed to numerous hazards and vulnerabilities (Bosch, 2017).

Table 7. Breakthroughs of TCF Automation – Passenger and Freight Transport – Waterborne sector

	TCF: Automation – Passenger and Freight Transport - *Waterborne sector*	**Description**
Breakthroughs	Advanced in modern ships	Detecting radars, automated warnings for crossing traffic as well as autopilots and track pilots, usage of satellite positioning systems (Voege, 2016).
	Safety and energy efficiency	Further automation in the waterborne sector is expected to assist in the adoption of Shipping 4.0 into deep sea, coastal and inland shipping thus in an effort to improve safety and energy efficiency either through full automation or shore-based control (Voege, 2016).

Table 8. Obstacles of TCF Automation – Passenger and Freight Transport – Waterborne sector

	TCF: Automation – Passenger and Freight Transport - *Waterborne sector*	**Description**
Obstacles	Ship systems	The main obstacle to open innovation in the field of automation of ships and autonomy is that ship systems are characterized by relatively low integration between different manufacturers' systems and significant difficulties in adding functionality to third parties. It is necessary to develop admissibility criteria for the operation of different types of autonomous vessels. This includes technical and operational risks, as well as social acceptance. Missing criteria, both design and approval will be difficult and expensive because there are no common standard (EU, 2018).
	Changes in the ports	Increased ships' automation will require some changes in the ports, e.g. for maintenance of ships, as well as for increased automation in both approaches and landing. (EU, 2018).
	Regulatory Framework	So far, the legislation governing autonomous ships is totally unclear. The main concern is about the provisions on the number of crew members and safety, as well as the construction standards. IMO International rules should be amended to include vessels with special characteristics that will allow them to sail with less or no crew on board. The same situation is with regard to the safety of the ship, where minimum standards regarding the conditions of vessels and equipment should be applied. Building and maintenance standards that classification societies also provide should be materially supplemented, and these societies will require people with expertise in autonomous technologies. A boat sailing in the open sea faces many risks associated with weather, other hurdles, or even risking being threatened by a third party (e.g. pirates). So, such an autonomous ship should be very intelligent to be able to control any potential risk (Jokioinen, 2017).
	Insurance	Existing insurance includes war risks, piracy risks, cargo insurance. However, premiums may vary depending on the level of actual risks in the navigation of these vessels (Jokioinen, 2017).
	Cyber Security	The new risk that can arise using remote navigation is a cyber security. In this way, a new type of piracy can be developed. The systems should be developed in such a way that they will exclude unauthorized access but also give the shore master overriding authority over any unauthorized instruction (Jokioinen, 2017).

2.3 Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS

D2.2 "Report on key transport concepts of the future" describes the transport concept "Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS" as follows:

"Shared ownership models, on-demand mobility; proliferation of car/ride/ fleet-sharing and ride-hailing; novel sharing concepts; Mobility as a Service – MaaS, Freight as a Service – FaaS, Logistics as a Service – LaaS".

Similar as with automation, we will identify some specific characteristics of the breakthroughs and obstacles collected from the literature and related to this *TC*. Our approach enabled us to single out of 10 breakthroughs (Table 9) and 5 obstacles (Table 10).

Table 9. Breakthroughs of TCF Shared mobility, on-demand mobility and MaaS

	TCF: Shared mobility, on-demand mobility, MaaS	**Description**
Breakthroughs	Integration of transport modes	The goal of the MaaS program is to encourage the use of public transport services, by linking multimodal transport and enabling users to facilitate their own intermodal travel with their choice. Following modes of transport can also be included: public transport, taxi, car sharing, driving sharing, bicycle sharing, car rental, bus service on request. Predicting the service outside the urban border, will include buses and trains on the long-distance, flights and ferries (Jittrapirom et al., 2017).
	Tariff option	MaaS platform offers users two types of tariffs: "mobility package" and "pay-as-you-go". The package offers options of different modes of transport and includes a certain amount of km / minute / points that can be used in return for a month's payment (Jittrapirom et al., 2017).
	One platform	MaaS relies on a digital platform (a mobile application or web site) that users use to access the necessary travel services: travel planning, booking, ticket issuance, payment and real-time information. Users are provided with accessibility and other useful services (weather forecasting, synchronization with calendar of personal activities, trip history report, invoicing and feedback) (Jittrapirom et al., 2017).
	Multiple actors	MaaS ecosystem is based on the interaction between different groups of actors through the digital platform: mobility claimants (e.g. private customers or business clients), transport provider (e.g. public or private) and platform owners (e.g. third party, PT provider, authority). Other actors can also work together to enable operation and improve efficiency: local government, clearing, telecommunications and data management companies (Jittrapirom et al., 2017).
	Use of technologies	Combining various technologies in order to enable the functioning of MaaS: devices, such as mobile computers and smartphones; reliable mobile internet network (WiFi, 3G, 4G, 5G, LTE); GPS; e-ticketing and e-payment system; database management system and integrated infrastructure technologies such as IoT (Jittrapirom et al., 2017).
	Demand orientation	MaaS is a user-centric paradigm. It strives to offer the best transport solution for multi-modal travel planning from a customer's

		perspective (Jittrapirom et al., 2017).
	Registration requirement	The end user accesses the platform for accessing available services. An account can be valid for an individual or, in certain cases, even a household. In addition to facilitating the use of services, the subscription also enables the personalization of the service (Jittrapirom et al., 2017).
	Personalisation	Personalization ensures end users' requirements and more effective satisfaction, taking into account the uniqueness of each customer. The system provides the user with specific recommendations and customized solutions based on his profile, expressed preferences and past behaviors (e.g. travel history). In addition, users can link their profiles to social networks with their MaaS account. (Jittrapirom et al., 2017)
	Customisation	Customization allows end-users to change the service offered according to their desires. This feature can increase the attractiveness of Maas among passengers as well as loyalty of customers. They can compile their mobility package with varying levels of use of certain modes of transport in order to better achieve their desired travel experience. (Jittrapirom et al., 2017)
	Discussion of MaaS's Roles in Future Mobility	At present, MaaS targets young customers who use smartphones for information and payment. Contrary to current target customers, predictions are that Maas will benefit more from older travelers than younger ones. A large percentage of older people use smartphones and will continue to use them for travel needs. One solution for accessing and paying for all kinds of transport modes would be an excellent solution for older travelers. Research has also shown that older travelers have longer trips than younger ones (Li & Voege, 2017).

Table 10. Obstacles of TCF Shared mobility, on-demand mobility and MaaS

	TCF: Shared mobility, on-demand mobility, MaaS	**Description**
Obstacles	Travel demand modelling for MaaS	It is necessary to think critically about how to expand existing models based on activities and models of elections in order to better capture the overall nature of travel behavior and the decision-making process related to MaaS (Jittrapirom et al., 2017).
	Supply-Side Modelling	The main challenge is the optimization of the fleet. It is necessary to take into account the integrated supply network as a step that is needed to bring them further under the ecosystem of Maas. The effect of autonomous vehicles is another aspect to consider and which will ease the efforts for relocation (Jittrapirom et al., 2017).
	The benefits may be limited	If the MaaS service only targets local consumers, the benefits may be limited. Dropping users from using well-known travel applications and switching to one application is a challenge for MaaS service providers. It can be said that the user's perspective towards MaaS is not well studied and understandable (Li & Voege, 2017).
	MaaS can still face strong competition from existing travel applications	Even if Maas would aim at a pan-European or global market, MaaS can still face strong competition from existing travel applications that have already offered global services. Maas service will have to work with existing providers. It remains unclear whether such providers are willing to integrate their platforms with MaaS (Li & Voege, 2017).
	Policy Framework for Implementation of MaaS	Implementation of MaaS in the city can face financial challenges. If Maas had a profit from his monthly subscriptions, this does not necessarily mean that the sale of tickets for public transport was

		realized. Government policy will have to define the MaaS business model in terms of public transport services. Many employers offer free passes for public transport for their employees when traveling by public transport. Often employees can get a tax reduction for travel expenses. If an employee chooses Maas instead of public transport, an employee may not be able to receive the same subsidy or tax cuts. So, only when local governments identified MaaS as a type of sustainable transport system with the same state subsidy policy or tax cuts, MaaS can be applied in a city where subsidies and taxes are offered for those traveling by public transport (Li & Voege, 2017).

2.4 Electrification – Passenger and Freight Transport (electric cars, trucks, aircrafts, trains, vessels)

D2.2 "Report on key transport concepts of the future" describes the TCF "Electrification – Passenger and Freight Transport" as follows:

"Electromobility; electric bicycles; electric cars, battery electric vehicles – BEVs, fuel cell electric vehicles – FCEVs, hybrid electric vehicles – HEVs, plug - in hybrids, full hybrids; electric trucks; electric aircrafts; hybrid and electrified ferries and vessels; electric and hydrogen powered trains for passenger transport; charging infrastructure for EVs".

Similarly, it is possible to identify some specific characteristics of the breakthroughs and obstacles collected from the literature for this *TCF* for various transport modes, i.e.:

- *Road transport* – 3 breakthrough and 7 obstacles (Table 11 and Table 12);
- *Waterborne transport* – 6 breakthrough and 3 obstacles (Table 13 and Table 14);
- *Air transport* – 1 and 3 obstacles (Table 15 and Table 16);
- *Rail transport* - 1 breakthrough **(**Table 17).

Table 11. Breakthroughs of TCF Electrification – Passenger and Freight Transport – Road transport

	TCF: Electrification – Passenger and Freight Transport – *Road transport*	**Description**
Breakthroughs	Electricity Energy (efficient and utilize)	Electricity can directly utilize energy from renewable sources available for transport. When connected to an electrical network, electric vehicle batteries can stabilize the network and balance supply and demand that facilitates the integration of renewable sources (EC, 2017) using smart grids
	Improving local and regional air quality	As the actual EU electricity power mix presents an increased use of renewable energy sources, the benefit in terms of total CO2 emissions is already very important in the EU (ERTRAC, 2017).
	Benefit for shareholders and owners of EVs	For shareholders- they can increase returns and represent a new source of growth and investment and for owners of EVs- they realize savings in fuel costs, improving the efficiency of vehicles (Ryan and Lavin, 2015).

Table 12. Obstacles of TCF Electrification – Passenger and Freight Transport – Road transport

	TCF: Electrification – Passenger and Freight Transport – *Road transport*	**Description**
Obstacles	Electric parking spaces	In large cities, the use of electric vehicles would result in the need for millions of electric parking spaces, which is a real challenge for implementation. Implementation of the EV fleet would also require changes in infrastructure, to allow significantly higher power supplies to chargers than is currently available (García-Olivares et al., 2018).
	High costs	Standardization, manufacturability and high cost of lithium-ion batteries represent the biggest obstacles to further development and application of electric vehicles. So far, a number of studies and projects dealing with post-Li-ion batteries have been made, through which greater energy densities are achieved with lower costs. However, such systems can not be found in manufacturing. In other words, if we want the autonomy of electric vehicles to be at the level of conventional cars, which is one of the most important tasks in this research field, it is necessary to explore the possibilities of applying new chemistries such as Si-based anodes, high voltage electrolyte and cathodes or in the longer term Li-S and Li-Air systems, which can be charged at high power (ERTRAC, 2017).
	Uncomfortable and slow charging	Convenient and reliable re-charging is one of the most important aspects to increase user acceptance of electric vehicles, but is most often neglected. One clear challenge is to provide appropriate charging capabilities to urban dwellers that often have to rely on overnight street parking and limited garage spaces in high-density populated city areas. These users will have to rely on quick-charge capabilities or charging during the day at work. Additionally, there is the possibility to promote this means of charging with incentives due to the potential usage in vehicle-to-grid applications (ERTRAC, 2017).
	Limited range	Increasing range capability of electric vehicles remains a high priority in order to increase user acceptance and win the broad mainstream market especially in comparison to conventional vehicles and current existing usage models of these vehicles. It is important to keep in mind, however, that increasing driving range supplied by the electro-chemical energy stored in the battery can only be achieved directly by increasing the size of the battery. Increasing the size of the battery increases the “installed” energy storage capability at an increased cost and increased size and weight (ERTRAC, 2017).
	Availability of chargers	The availability of chargers and the costs of upgrading the electrical infrastructure from the network to the charger can be a barrier (SCE, 2017).
	Accessibility and awareness	Other incentives such as access to the driver and parking access are high value, low-cost incentives for adoption. Local competencies must also play a role, ensuring that the local location and the license for a new EV service are quickly terminated (SCE, 2017).
	Space required for storing electricity (battery) in the vehicle	These problems can be solved by supplying electricity directly to the cables while the vehicle is active. Losses are limited to the conventional distribution of electricity and the power of electronics on the vehicle, and the exceptional efficiency of the electrical machine can be used at full scale. This advantage in the efficiency

		of the system, turns into significant benefits in operating costs (eHighway, 2017).
	Rare earth materials for batteries and motors	Future wider penetration could be hindered by lack of rare earth materials for electric motors and batteries that are used in the manufacturing of EVs, which are controlled by countries such as China. Investments will need to be made to find permanent magnet free motors.

Table 13. Breakthroughs of TCF Electrification – Passenger and Freight Transport – Waterborne transport

	TCF: Electrification – Passenger and Freight Transport - *Waterborne transport*	**Description**
Breakthroughs	Flexibility of ship design	Construction with cables connecting key components instead of complex gearboxes and axles (EC, 2017)
	Flexibility of the ship's operation	Choice of the main drivers that supply the drive shaft, as well as the need for power on board (EC, 2017)
	Silencing the noise on the boat	Important for passenger ships, and also for warships (EC, 2017)
	Improved efficiency of fuel consumption	Constant maintenance of diesel engines in the power range that provides good fuel consumption (EC, 2017)
	Effectively operated with On/Off technology	Hybrid drives enable batteries to work with diesel engines, so others can be effectively operated with On/Off technology (EC, 2017)
	Powering the ship	Ships on batteries may use containers for powering the ship at a speed and range that determines the amount of batteries required (EC, 2017)

Table 14. Obstacles of TC Electrification – Passenger and Freight Transport – Waterborne transport

	TC3: Electrification – Passenger and Freight Transport - *Waterborne transport*	**Description**
Obstacles	Power solutions	Due to the diversity of ships and sailing (some boats spend a week at sea and only a few days in the port), the power solutions for one type of ship are not suitable for another ship (EC, 2017).
	Higher initial cost	The main disadvantages of all electric drives are the higher initial cost compared to the propulsion systems based on internal combustion engines, the increase in losses in the conversion of energy from fuel to propulsion, the greater the volume of the system due to the large number of component parts, and the issue of energy density in vessels with batteries (EC, 2017).

	Adequate charging infrastructure	An adequate charging infrastructure represents another barrier. Electrified ships would require very high charging currents to provide an adequate turnaround time. The safety of the battery systems must be ensured in terms of heating, fire and explosion risk (EC, 2017).

The appropriate approach to electrification in the water transport could potentially be:

- *separate the transport sector into market segments by analyzing the types and roles of ships;*
- *identify the range of electrical technologies that can be used by ships that contribute to emission reductions; and*
- *establish other benefits of electrical technologies related to improved vessel control and increased reliability.*

Table 15. Breakthroughs of TC Electrification – Passenger and Freight Transport – Air transport

	TC3: Electrification – Passenger and Freight Transport – *Air transport*	**Description**
Breakthroughs	Reduction in CO_2 emissions	A significant reduction in CO_2 emissions can be achieved by improving existing technologies (better aerodynamics, jet engine efficiency, air traffic management or the use of biofuels). However, these improvements will reach the limit, so large-scale electrification systems will be part of the solution to achieve the overall target of reducing exhaust emissions. The electrification of floor coverings and movements that have already begun at many airports should be increased (EC, 2017).

Table 16. Obstacles of TC Electrification – Passenger and Freight Transport – Air transport

	TC3: Electrification – Passenger and Freight Transport - *Air transport*	**Description**
Obstacles	High costs of light aircraft	The emerging challenges for the development of leading-edge technology for large-scale commercial airplanes need to be aligned with key principles: cheaper development demonstration technology (ground testing, validation, flight testing) light aircraft capabilities under certain operational conditions (speed, range, load capacity, extremely high efficiency, low carbon emissions, low operating costs) – EC, 2017.
	Management and standardization competencies	At present, there is no established access to standards, however, in order to make the supply chain efficient, specific standards, including the definition of components need to be defined (e.g. an electric motor considered to be a drive engine) – (EC, 2017).
	Training of workers	In the short term, the evolution towards electrification of aeronautical transport also requires training for many workers involved in this field and the acquisition of specific certificates for handling electrical equipment (EC, 2017).

Moreover, it is necessary to solve the lack of infrastructure at airports, and certification, security and insurance should be part of the equation of application.

***Management and standardization competencies**: Regulations and certificates must be adapted to costs / taxes / price handling (for example, when setting tax rates, it is necessary to consider cost analysis and all factors).*

Table 17. Breakthroughs of TC Electrification – Passenger and Freight Transport - Rail transport

	TC3: Electrification – Passenger and Freight Transport – *Rail transport*	**Description**
Breakthroughs	Energy savings	Rail is expected to achieve further energy savings thanks to lighter materials in vehicles and wider use of energy recuperation devices (e.g. regenerative braking or energy storage technologies). Electrified rail is already using a significant share of renewable energies and further increasing their use. According to the International Energy Agency, 40% of the electricity mix used by railways in Europe is low-carbon, which originates with an average of around 20% from renewable sources.

Some of the on-going trends in the field of electrification in rail transport are the following:

- *there are **no technical obstacles to further electrification**;*
- *new vehicle concepts for non-electrified railway lines are being developed (manufacturers of rail vehicles are testing emission-free trains equipped with fuel cell drives);*
- *hybrid diesel-electric locomotives are able to operate in emission-free mode;*
- *in urban areas there is no alternative to electrification;*
- *the European rail supply industry has declared energy efficiency as one of the key topics to be addressed by the Shift2Rail Joint Undertaking;*
- *cost for upgrading and electrifying the existing rail infrastructure and the expected carbon reduction need to be considered on a case by case basis (EU funding support where necessary – EC, 2017);*
- *the **challenge is optimizing the energy management of the system***.

2.5 Seamless transport chains

Report D2.2 contains the definition of the TCF "Seamless transport chains" as follows:

"Seamless transport chains for both passenger and freight transport; seamless national and international travel for passengers; seamless logistics; seamless multimodal freight transport services; integration of all transport modes – multimodality, intermodality; seamless transport chains as a result of MaaS."

Some of the general characteristics of this TCF are the following:

- genuine seamlessness is vital for the smooth transport of people, raw materials and products and thus is **central to economic growth** (ITR, International Transport Forum);
- **seamless services save time, money and the environment**;
- some authors consider seamless transport within the framework of MaaS (that is why there is overlapping of the advantages and obstacles on the way of the rationalization of these two TCsF).

Our analysis of the various literature sources has enabled us to identify 3 breakthroughs (Table 18) and 8 obstacles (Table 19) related to this *TCF* (*Seamless transport chains*).

Table 18. Breakthroughs of TCF Seamless transport chains

	TCF: Seamless transport chains	Description
Breakthroughs	Energy efficiency	increase of energy efficiency (by using renewable energy and electrification) – SETRIS, 2017
	Reduced emissions	progress in reducing CO_2 and other pollutants (SETRIS, 2017)
	Integration	Achieve seamless integration of network and traffic, including cross-border co-modal transport operations that ensure unhindered transport and security for Europe (SETRIS, 2017). Perkins (2012), sets out a hierarchy of key areas for integration as follows: • integration of public transport information; • physical integration of public transport services; • integration of public transport fares and ticketing; • integration of infrastructure provision, management and pricing for public and private transport; • integration of passenger and freight transport; • integration of (transport) authorities; • integration between transport measures and land use planning policies; • integration between general transport policies and the transport policies of the education, healthcare and social services sectors; • integration between transport policies and policies for the environment and for socio-economic development.

Table 19. Obstacles to the realization of TCF Seamless transport chains

	TC4: Seamless transport chains	Description
Obstacles	Coordination and collaboration modes	Need for intermediation and coordination to overcome the power imbalance and to reduce searching and transaction costs, and to avoid moral hazard and opportunism. • gain sharing: the presence of conflict in co-modal initiatives is also connected to the perception of the unfair share of gain; fair gain sharing is a proxy for horizontal collaboration. • information sharing and visibility: shippers and carriers do not collaborate horizontally because of competition law, fear of losing competitive advantage, and a lack of cross network visibility, among others. • risk allocation: the existing literature allocates the risk related to co-modality (unused capacity, disruptions, delays, etc.) to the carrier which is usually in charge of the consolidation of different flows from its clients (CO^3, 2012).
	Adequate structure and the coherence system	Adequate structure and definition of the coherence system linking long distances (main nodes) and the last mile (city junctions) by reviewing the urban distribution of goods to the final consumer (Perkins, 2012).
	Development of transhipment technology	Development of transhipment technology (automation) and operations between transport modes and between modes and storage/hubs (Perkins, 2012)
	Efficient management systems	Introducing more efficient management systems and cross-port operations in consolidation/distribution nodes close to cities; preserving the added value of long journeys (Perkins, 2012);
	Fast and low cost	Allowing fast and low cost handling of loads in loading and unloading

	handling of loads	operations within the mode of transport or for any type of vehicle (Perkins, 2012)
	Work in the cross-border network	Work in the cross-border network will support multimodal transport.
	Electronics and business models	Process electronics and business models are important areas of intervention necessary for the realization of the European synchronous system (Perkins, 2012).
	Too many regulations	Too many regulations hinder innovation. Different standards, regulations and procedures in member states prevent impeccable cross-border transport operations, as well as synchronic transport when logistics chains involve several countries (Perkins, 2012)

2.6 Personal air transportation – "flying cars", "flying taxis"

INTEND report D2.2 ("Report on key transport concepts of the future") describes the TCF (Personal air transportation – "flying cars", "flying taxis")s follow:

"Urban air mobility; small personal aerial vehicles manually piloted, remotely piloted or fully autonomous; "Passenger Drones", "Flying Cars", "Flying Taxies"."

By analyzing relevant and available literature, we have identified 4 breakthroughs (Table 20) and 6 obstacles (Table 21) related to this *TC Personal air transportation – "flying cars", "flying taxis"*.

Table 20. Breakthroughs of TCF Personal air transportation – "flying cars", "flying taxis"

	TC5: Personal air transportation – "flying cars", "flying taxis"	**Description**
Breakthroughs	Avoid congestion on road	Saves time (depending – can often fly direct rather than follow roads, vehicle will probably be faster than cars, etc.) – Shelton, 2017. The flying car is a good solution to prevent traffic jams (Rajashekara et al 2016).
	Improvement of the standard of living	Flying cars will significantly enhance personal transportation, revolutionize the transportation industry, and improve the standard of living in many parts of the world. It is also very helpful for the police and military for fast rescues or rapid action (Rajashekara et al 2016).
	Reduced infrastructure development	• reduces infrastructure development (i.e., building roads and bridges) and saves a number of trees from being cut, thus helping to improve the environment; • building of fewer airports, thus reducing the number of air-traffic-control problems; • a new class of industries related to flying-car components will develop electrical, mechanical, electronics; signals, controls, communications; and many other related disciplines (Rajashekara et al 2016).
	Reduced emissions, fuel use, and capital cost	Personnel air transportation, as TCF, could replace helicopters and provide versatile operation with reduced emissions, fuel use, and capital cost (Rajashekara et al 2016). These vehicles are highly energy efficient, with reduced or zero emissions; and can be substantially quieter than a traditional helicopter (Lineberger et al., 2018).

Table 21. Obstacles of TCF Personal air transportation – “flying cars”, “flying taxis”

	TCF: Personal air transportation – “flying cars”, “flying taxis”	**Description**
Obstacles	Air traffic control and infrastructure	There are numerous practical challenges in the direction of creating a regulatory management system: small drones are more susceptible to changes in time; the need for a dynamic mapping system that is updated in real time; connection for tracking; constant tracking of drones in flight; and even interoperability, including devices that do not fly. Also, the lack of available free space and the difficulty of accessing up-and-down infrastructure (for landing and taking off and flight safety) are significant obstacles, and the construction and design a vast network of vertiports is a major urban planning job in itself *(*Dewost, 2018).
Obstacles	High costs	Flying costs are more than driving, and the same goes for drones. It is estimated that average driving costs are 12 times higher for flying vehicles than those left on the ground (Dewost, 2018; Krauth, 2018).
Obstacles	Safety and security	Private planes may be the closest device to mobility in air traffic, and are much more dangerous than cars. The biggest obstacle seriously delaying the great development of air traffic in urban areas is perhaps security, reflecting highly mediated discussions about autonomous accidents in the vehicle. One survey found that more than half of the Americans surveyed said that their main concern was the safety of autonomous flying cars (Dewost, 2018; Krauth, 2018).
Obstacles	Charging infrasttucture	At the moment, battery life is the biggest obstacle for unmanned aircraft manufacturers seeking to increase flight time. Traveling roads will need a charging infrastructure. Wireless charging promises (Blair, 2017).
Obstacles	Need for drone-friendly regulations	Existing rules, updated by the FAA in August 2016, insist that drones must be in the line of sight and must always be controlled live by the operator. Rules suffocates new innovations (at least in the U.S.). Other countries were welcomed by autonomous drones with open arms. For example, Delft agreed to implement the first fully autonomous network of unmanned aerial vehicles, complete with docking stations and drone rentals. New Zealand has been selected as the first commercial service for the delivery of drones in the world due to friendly regulations in the country (Blair, 2017). Necessary co-operation of city-transport operators on demand with regulators to understand and respond to key regulatory issues (airspace management, fully autonomous adoption path, licensing and certification, and air traffic management). Air Traffic Management Providers should consider working with their national airspace management regulators (such as the FAA in the United States) to participate in early pilot programs, formulating regulatory and standards, and adapting hardware and software to meet major quantity, low altitude and fully automated unique air traffic management systems in the future. (Lineberger et al., 2018)

Companies engaged in personal air transportation will run into two main barriers in their business (Blair, 2017):

***Charging** – Cities could determine freeways for the drones and limit the laser charge of these airstrips. Filling energy in flying would drastically expand flights and flights daily, as they should never be lowered for filling.*

Regulation – *The United States could return by testing passenger craft with emergency services. In cases of cardiac action, for example, victims need treatment within six minutes for a survival chance. For people who live in New York, where the average emergency time in 2015 was over 12 minutes, why not allocate paramedics and defibrillators in an unmanned flight? Why do not you risk to save people who do not have a chance? Such trials can reduce regulatory resistance to autonomous drones.*

2.7 Delivery Drones

D2.2 "Report on key transport concepts of the future" describes the TCF "Delivery Drones" as follow:

"Urban airspace utilization for goods deliveries; delivery drones as a part of the supply chain."

In addition, literature review allowed for the identification of 7 breakthrough (Table 22) and 34 obstacles (Table 23) related to this TCF.

Table 22. Breakthroughs of TCF Delivery Drones

	TCF: Delivery Drones	**Description**
Breakthroughs	Cost effective	Drone delivery will only happen if it saves money for retailers. The so-called "last mile" delivery problem makes up more than a quarter of the total cost of present delivery (Kobie, 2018).
	Delivering products	Obviously, delivery drones are mainly used for delivering commodities or objects. These are programmed devices that deliver drone from their headquarters to a designated area. The most visible delivery drones are copter drones from retail shops. Large delivery drones are operated in transport companies with bulk materials to transfer (GrinDrone, 2017).
	Improves time management	Delivery drones allow human counterparts to focus on other important delivery procedures. This is because this device delivers faster due to its accurate locating program. Delivery drones has lesser error margin when locating the exact targeted area (GrinDrone, 2017).
	Conserves energy	Delivery drones helps workers to conserve effort while delivering commodities. The mechanical device increases workforce activity to accomplish more tasks. Exhaustion risk is minimized because there are devices that can replace human activities (GrinDrone, 2017).
	Saves time	Delivery drone makes an additional manpower to any institution that it serves. It carries objects and transports them to other locations through a remote controlled system. Workers will have more time to attend other important delivery operations at the workplace (GrinDrone, 2017).
	Increase safety	Drones prevents accidents because they are physically delivering the commodity to consumers. Human delivery personnel are often exposed to hazardous environments. When using drones, delivery personnel will no longer have to risk their lives from accidents (GrinDrone, 2017).
	High accuracy rate	Delivery drones are more efficient when delivering products to the right recipient. They have a higher accuracy rate on delivering materials to the right recipient than a human. Incidents of wrong recipients can significantly lessen (GrinDrone, 2017).

Table 23. Obstacles of TCF Delivery Drones

	TCF: Delivery Drones	Description
Obstacles	Regulation	The second big challenge is regulation, and as ever the law trails innovation (Kobie, 2018).
	Safety	Safety is very important particularly in case of the drone fall from the sky, either by mechanical error or by the devious hacker (Kobie, 2018). Health and safety - injuries because of collisions; contamination with dangerous loads (Nentwich & Hórvath, 2018).
	Order staging	In unmanned flights, the existing space allocation process will have to be redesigned to support drones, and employees will have to be trained for these new processes (Mehra, 2015).
	Weight limit	Since drones support only orders below a certain weight, the seller will have to divide the order on multiple shipment. This will increase the cost of delivery and will have to be somehow compensated or transferred to the consumer (Mehra, 2015; Nentwich & Hórvath, 2018).
	Drop ship vendors	Many retailers use drop ship vendors. These vendors will have to invest in drones to support faster delivery, to remain competitive, or retailers will have to look for other options (Mehra, 2015).
	Distance limit	Drones can only travel at a certain distance (Mehra, 2015).
	Requires investment	The introduction of drones as part of the delivery process requires greater investment. The impression is that the investment will be more burdensome for smaller traders - or use third-party services that utilize drones (Mehra, 2015).
	Shipping big-ticket items	The drones will become the target of thieves as they fly several hundred meters from the ground. Retailers will have to consider this before using drones to send big-ticket items (Mehra, 2015).
	Uninterrupted service	Drones are machines that canhave catastrophic failures. In the event that this happens, sellers will probably have to send another drone to deliver an order. They will also have to determine how to collect broken drone (Mehra, 2015).
	Designated delivery spots	Drones will need designated places for package delivery (Frey, 2015). So, flight is the easy part. Dropping off the package is the problem. Some authors address the issue by creating special landing zones (Kobie, 2018; Nentwich & Hórvath, 2018).
	Durability	Manufacturing drones durable enough to make 100 deliveries between scheduled maintenance and 10000 flights over their lifetime will be an absolute necessity (Frey, 2015).
	Conditional awareness	Drones will invariable fly into unusual situations, and whether it's swarms of bees, bird attacks, lightening strikes, or signal jammers, they will need to alert operators of problems as soon as they arise (Frey, 2015).
	Black boxes	Much like today's commercial aircrafts, whenever a drone crashes, some sort of signaling device will be needed to allow for follow-up investigation and cleanup (Frey, 2015).
	Maintenance plans	Higher end delivery drones will need a consistent schedule for prop replacement, motor alignment, sensor checks, controller board cleaning, etc (Frey, 2015).
	Override kill switch	Wireless signals are far from perfect. If a signal is lost, hacked, or hijacked, the drone must either return home or be removed from danger (Frey, 2015).
	Classification system for drone and cargo	Drones are being created in thousands of different shapes and sizes with thousands of different capabilities. A comprehensive classification system will be needed to properly manage and regulate this industry (Frey, 2015). Cargo classification systems applied to ground-based shipping will need

		to be revised for the more volatile conditions associated with remote controlled airborne vehicles (Frey, 2015).
	Drone insurance	Drones, drone cargo, and drone businesses will soon become the largest new market for insurance companies (Frey, 2015).
	Licensing (Vehicle, Pilot, Operator)	Every drone that falls within certain classification guidelines will need to be licensed and insured. (Frey, 2015; Nentwich & Hórvath, 2018). Those who fly drones will need to be tested and licensed in a less rigorous but similar way that airplane pilots are tested today (Frey, 2015). People who load and unload cargo onto flying drones will also need to be licensed (Frey, 2015).
	Weather contingency plans	Every drone will have to deal with extreme weather at one time or another. Any condition ranging from wind, to rain, snow, hail, extreme heat or extreme cold, will need a contingency plan for both the retrieval and safe delivery of the cargo. (Frey, 2015) A customer who decides for faster delivery using drones, will need his orders to be delivered, regardless of weather conditions. The drones are not ideal for bad weather, such as snow, city, rain, and big winds, which could affect the delivery delay to the customer. (Mehra, 2015)
	Rules (privacy, security, drone spam rules, noise guidelines)	Privacy means different things to different people, but flying drones with cameras, scanners, and sensors give nefarious people far more capabilities than ever before. Privacy rules will need to be established sooner than later (Frey, 2015). Once a famous person’s delivery address becomes known, they run the risk of receiving unwanted packages, solicitations, threats, and even things like chemical attacks (Frey, 2015). Much like junk mail and spam email, flying drones open up the possibility of receiving everything from annoying products samples to mean-spirited pranks. Rules for “drone hate crimes” and “drone bullying” will soon follow (Frey, 2015). The larger the drone and the greater the distance it has to cover, the larger the engine it will need to operate. Since electric drones only cover short distances, some form of petrochemical fuel will be needed, and these vehicles will be noisy. Rather than waiting for 10,000 communities to imposed their own one-off noise ordinances, it would be better for the industry to be proactive in this area (Frey, 2015).
	Automated here-to-there delivery	Drone delivery only becomes a mass-market affordable option when human operators are removed from the equation (Frey, 2015).
	Grasp and release mechanisms	People who set a package out front, wanting to send it across town, will require a pickup drone capable of automated grasp and release (Frey, 2015).
	Aerodynamic packaging	Packages attached to the bottom of a drone will need to be far more aerodynamic than the rectangular boxes most commonly delivered today (Frey, 2015).
	Fly-drive capabilities	Because of trees, porticos, awnings, and overhangs, drones may need the ability to land on open space and drive to the appropriate delivery spot (Frey, 2015).

	Systems (Collision avoidance, Crowded skies navigation system, Drone operating system)	With the potential of flying into everything from power lines, to trees, windmills, Christmas decorations, and other UAVs, a comprehensive collision avoidance system will be necessary (Frey, 2015). At some point in the future there may be as many as 10,000 drones flying over a city in a given day. Not only will they need to avoid flying into buildings, trees, and commercial aircraft, they will need to avoid other drones as well (Frey, 2015). An operating system is the most important software that runs on a computer because it defines how it functions. Since drones have a different role and purpose, they will require an entirely different kind of operating system (Frey, 2015).
	Shot from the sky recourse	Many disturbed individuals will view drones as a "form of target practice." Drone owners and operators will need recourse for these situations (Frey, 2015).
	Political and consumer awarenes	Paranoia is already rampant when it comes to all the bad things people can do with drones. For this reason its imperative that politicians be given special attention so they can understand the cost-benefit ratio associated with any of their decisions (Frey, 2015).
	Education for the drone police, for drone lobbyists, for drone maintenance and repair, education & certification for drone pilots	Police will not only employ drones to assist in managing public safety, they will also use drones to monitor other drones. Drones are far more versatile and faster to deploy than virtually all other options officers have at their disposal (Frey, 2015). Drones will become one of the most highly regulated industries of all times. It is not too soon to start educating the influencers (Frey, 2015). With all their different configurations, styles, and function, drone pilots will require far different training than airline pilots do. Currently there are very few simulation programs available for practice (Frey, 2015). People who service and fix drones will be in hot demand in the near future (Frey, 2015).
	Drone financing	As the need for instrumentation and safety equipment increases, delivery drones will become far more expensive. As a result, drone financing will become a hot new area of business in the near future (Frey, 2015).
	Flying drone bill of rights	Do people have the right to "keep and bear drones?" (Frey, 2015)
	Docking systems	People will eventually not want packages delivered onto their driveways. For example, any pizza left on a driveway becomes an open invitation for cats, dogs, and other stray animals. A better option would be to have some sort of docking system that would allow the drone to land and deliver the package into a secure area (Frey, 2015).
	Better battery tech	Battery technology has not progressed nearly fast enough for the drone industry. Even gas-powered drones will likely need batteries to fly through "quiet zones" such as hospitals, nursing homes, and environmentally sensitive areas (Frey, 2015; Nentwich & Hórvath, 2018).
	Airbag crash protectors	Accidents will happen and on occasion, drones will indeed fall out of the sky. To prevent large drones with heavy or dangerous payload from causing serious damage to people and property on the ground, some form of rapidly inflating airbag will be needed (Frey, 2015).
	Invisible fences	There will be many no-fly zones around the world and these zones will need the equivalent of an "invisible fence" to keep intruders out (Frey, 2015).

Kobie, N., (2018) – Amazon filed a patent for the use of street lamps for drone delivery stations. DHL's Parcelopter delivers packets in a "smart locker" and send the recipient the unlock code. In this way, the service by DHL's drones does not provide service to your door, but they could be

built into the top of apartment buildings one day – or even use your smart car for delivery. Regulation actually holding back airborne deliveries, not technology.

Mehra, G., (2015) – Distance limit – Limited distance can affect traders to load drones, together with ordered products, in delivery trucks and use them for delivery only if they are within a certain radius for customer delivery.

2.8 Smart use of travel time

INTEND deliverable D2.2 defines TCF "Smart use of travel time" as follow:

"Use of travel time made available because of vehicle automation; travel time as a usable timeslot for a wide range of activities."

The same report (D2.2) recognizes that the smart use of travel time, as a transport concept of the future, is a direct consequence of the autonomous driving. Accordingly, many of the obstacles that are present in autonomous driving and have been processed in Chapter 2.2 are also relevant for the transport concept "Smart use of travel time" and will not be considered again.

2.9 High-speed rail

INTEND report D2.2 defines "High-speed rail" as transport concept of the future as follows:

"High-speed train technologies; high-speed rail for passenger transport."

Based on the literature review, we were able to identify 3 breakthroughs (Table 24) and 4 groups of obstacles (Table 25) which are mostly relevant for this TCF.

Table 24**.** Breakthroughs of TCF High-speed rail

	TCF: High-speed rail	**Description**
Breakthroughs	Attractive alternative to aviation	High-speed rail, especially for medium and even long-distance passenger travel
	High-speed rail as a cheaper, greener and more sustainable transport alternative	High speed rail is not an economic development tool by itself, but it can activate economic development potential in numerous ways: saving time and money; expanding labor markets for employers and expanding employment opportunities for labor force; enhancing "clusters" of economic activity across regions; and creating a focal point for future development including potentially transformative benefits to cities and towns (Metcalf et al., 2010).
	Need for a complete European high-speed rail network	

Table 25. Obstacles of TCF High-speed rail

	TCF: High-speed rail	Description
Obstacles	Technical obstacles	• Enable stability and comfort of passengers (while the train is running at high speed); • maintain the ability to stop safely; • avoid a sharp increase in (train) operating costs and (track) maintenance costs; • avoid an increase in noise and vibration to areas adjacent to the line (Givoni, 2006); • potentially higher energy costs than some competing modes; • higher noise externalities. (Levinson, 2012)
	Changes in environmental, human health, resource, and climate change impacts	• spatial incompatibility between HSR and other long-distance modes that is often ignored; • siloed interest in particular environmental impacts; • dearth of data on future vehicle and energy sources; • poor understanding of secondary impacts, particularly in land use (Chester and Ryerson, 2014).
	Problems of the impact of rail development	• the investment itself may be the main source of growth (construction can have short-term benefits in the region; for example, road projects can be more beneficial for poor regions, assuming that local workforce and locally produced inputs are used for their utilization, rather than rail projects that are technologically advanced); • the effectiveness of infrastructure depends on the quality of the whole network (there will be no major benefits from improving local infrastructure if the network as a whole does not improve); • access to networks is critical (for companies and individuals in the region, a critical factor will be how easy it is to access this network; in this way, for example, the existence and location of high speed rail stations is an essential factor in improving access to the entire region) – Vickerman (1997).
	Costs and challenges facing the HSR	• Total per mile costs of providing rail service increases significantly with increases in travel speed, but ridership also increases with faster speeds, albeit less dramatically. Hence, there is a “sweet spot” where ridership and costs are optimized. This sweet spot also varies from corridor to corridor. • The feasibility and benefits of higher and high speed rail investments depend primarily on ridership. Therefore, it is important to focus initially on connecting major mega-regions with proven demand. • Certain metropolitan regions are more conducive to high speed rail by virtue of existing land use patterns and complementary public transportation service (Metcalf et al., 2010).

2.10 Hyperloops

INTEND report D2.2 recognizes "Hyperloops" as another transport concept of the future. It was described as follow:

"The Hyperloop concept entails levitating small capsules traveling along a low-pressure tube. Thanks to air resistance and friction elimination, the pods are capable of traveling long distances in times comparable to air travel."

We have also identified some specific characteristics of the breakthroughs (Table 26) and obstacles (Table 27), collected from the literature and related to this *TCF Hyperloops*.

Table 26. Breakthroughs of TCF Hyperloops

	TCF: Hyperloops	Description
Breakthroughs	Very fast	The technology offers speed of transportation which is twice that of aircraft. The Hyperloop, a mode of transportation that shoots pods filled with people through vaccum sealed tubes, reaches speeds of more than 500 miles per hour. That will take commuters from San Francisco to LA, or vice versa, in just 30 minutes (Muoio, 2015).
	Low power consumption	Electricity can be generated with less-polluting means such as nuclear reactors, windmills, and solar panels. This might help prevent many of the disasters in the first place by limiting or reducing the possibility of global warming (Nietzsche, 2017).
	Cheaper for travelers	Low cost transportation system on long run.
	Immune to bad weather	Since the Hyperloop operates inside a tube, it is protected from the weather. Wind, rain, snow, and even catastrophes like hurricanes might not affect the system. It will keep operating under horrendous conditions when planes cannot fly, and roads are blocked (Nietzsche, 2017).
	Increased frequency	Hyperloop capsule will come every 30 seconds (Muoio, 2015).

Table 27. Obstacles of TCF Hyperloops

	TCF: Hyperloops	Description
Obstacles	Construction cost	Land acquisition and building/tunnelling rights (Krauth, 2018).
	Construction material	**Radial thermal expansion** of the steel tubes under direct sunlight will result in pipeline distortions between joints (over a 100 km pipeline, the longitudinal thermal expansion could be as much as 50m, meaning that a huge number of flexible joints would have to be in place – it's a maintenance nightmare). There are questions about **whether the steel is strong enough to withstand normal atmospheric pressure when it's internal pressure is so drastically reduced** (atmospheric forces acting on the outside of the structure would be around 10 tonnes per square metre). The **pipeline would also have to take the vibrational and centrifugal forces of the pods** – thought to weigh between 10 and 15 tonnes fully loaded – travelling at close to the speed of sound. The **steel pipelines wall thickness will almost certainly need to be greater than the current test pipelines of just 20 mm** (Cunningham, 2017).
	Pressure	Essentially, the weight will accumulate about **10,000 kg per meter squared** (if the tube became punctured, external air would tear into the tube, shredding it apart as it violently rushes in to fill the void (Interesting Engineering, 2017).
	Spontaneous decompression	If a tube is punctured for any reason, the outside air forcefully enters the tube while trying to equalize the pressure gradient. In the case of Hyperloop, the air would enter the tube with 15 PSI (!) equivalent to one atmosphere or 10,000 kg per square meter. The pressure would open the tube as a can. There would be separation of the capsules standing in the way, and the results would almost certainly have been lethal (Interesting Engineering, 2017).

	Deadly collisions	Capsule capable of sustaining force in the event of decompression should be extremely difficult given the nature of the design. The capsule must be strong enough to withstand atmospheric pressure inside the cabin, but it must remain light enough to not destroy or compromise the tube while traveling. Assuming it does not immediately destroy itself in pieces in the event of decompression, the capsules will accelerate the path until they collide with each other with deadly force (Interesting Engineering, 2017).
	Acceleration of the capsule	**In seconds, the capsule would accelerate to over 100 km/h.** Thus far, no breaking systems have been proposed to prevent the capsules from accidentally accelerating due to spontaneous decompression. Decompression would not only ruin the system, but it would likely be fatal to all the passengers. Unfortunately, a wide range of events could cause a perforation in the tube (Interesting Engineering, 2017).
	The multi-ton capsules intended to carry passengers also pose as liabilities themselves	The hyperloop tube would have to withstand constant force and vibration, because each capsule travels through pipes hundreds of miles per hour. The capsules would affect the structural integrity of the tube. With regular maintenance and proper functioning of the pipe, this would not be a problem. However, if the engineers did not catch a faulty hose (and will be thousands of tubes), this could lead to spontaneous decompression (Interesting Engineering, 2017).
	Too much air creates significant problems	How the capsule travels hundreds of kilometers per hour, and the turbine rotates tens of times faster than that, the air pocket would be more like a wall. If the capsule encountered an air pocket, the difference in pressure would create such a violent stroke that the turbine blades would become currently damaged. The turbine would become unbalanced, but it would still continue to rotate at astronomical speeds. (Interesting Engineering, 2017).
	An easy terrorist target – safety standards and security	People are more concerned than ever about the threats of a terrorist attack. Designing hundreds of kilometers of tube transporting hundreds of people at the same time brings the real possibility of a terrorist attack (Interesting Engineering, 2017; Krauth, 2018).
	New management challenges	The dispatch system must meet the increased requirements for speed and reliability. It should provide simultaneous activation and execution of command sequences in the presence of a large number of different dispersed objects (Dudnikov, 2017).

2.11 Freight consolidation hubs, Freight Distribution Centres

INTEND report D2.2 recognizes "Freight consolidation hubs, Freight Distribution Centres" as one of the most promising transport concepts of the future. This TCF was defined in the following way:

"(Peri)-urban freight consolidation hubs; freight hubs located close to urban agglomerations, for goods consolidation between long distance hauls and short-distance inner-city transport; Freight distribution centres (freight villages); multimodal settlements that provide access to different

modes of transport as well as several inter-modal infrastructure facilities, for transport-oriented companies, logistics service providers, etc."

Literature review has allowed for identification of 8 breakthroughs (Table 28) and 9 obstacles (Table 29) relevant for this TCF. Browne, et al., (2005) gave a systematized list of positive issues about UCCs (Urban Freight Consolidation Centres**)** shown in table 28.

Table 28. Breakthroughs of TCF Freight consolidation hubs, Freight Distribution Centres

	TCF: Freight consolidation hubs, Freight Distribution Centres with description
Breakthroughs	Environmental and social benefits resulting from more efficient and less intrusive transport operations within urban areas
	Possible facilitate a switch from push to pull logistics through better control and visibility of the supply chain
	Better inventory control, product availability and customer service
	Potential to link in with wider policy and regulatory initiatives
	Theoretical cost benefits from contracting out “last mile”
	Public relations benefits for participants
	Potential to allow better use of resources at delivery locations
	Specific transport advantages opportunity for carrying out value-added activities

Table 29. Obstacles of TCF Freight consolidation hubs, Freight Distribution Centres

	TC10: Freight consolidation hubs, Freight Distribution Centres with description
Obstacles	Potentially high set up costs (and sometimes high operating costs) - Browne, et al., 2005. Logistical zones in the area of the port have some disadvantages, especially because they involve higher land costs with potentially more restrictive labor regulations if they are under the jurisdiction of port workers (Rodrigue, 2017).
	Much urban freight is already consolidated at the intra-company level or by parcels carriers, so limited benefits (or even negative consequences) are possible for trying to channel these flows through a consolidation centre. The potential scope for UCCs may therefore be limited (Browne, et al., 2005).
	Difficult for a single centre to be able to handle the wide range of goods moving in and out of an urban area, for example due to different handling and storage requirements (Browne, et al., 2005).
	Most studies report an increase in delivery costs due to an additional stage in supply chain which imposes a cost (and often a time) penalty, though this clearly depends on how well the centre is integrated into the supply chain and the extent to which all costs and benefits are considered (Browne, et al., 2005).
	Single consolidation centre for an urban area is unlikely to be attractive for many suppliers’ flows due to the degree of diversion required from normal route (and may therefore negate transport savings for onward distribution) Browne, et al., (2005).
	Lack of enforcement of regulations for vehicles not included in the consolidation scheme (Browne, et al., 2005).
	Organizational and contractual problems often limit effectiveness (Browne, et al., 2005).
	Potential to create monopolistic situations, thus eliminating competition and perhaps leading to legal issues (Browne, et al., 2005).
	Loss of the direct interface between suppliers and customers (Browne, et al., 2005).

2.12 Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

"Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines", as another transport concept of the future, was explained the INTEND report D2.2. It was defined as follow:

"Hyperloops, Cargo Tubes, Underground Freight Pipelines (e.g. "CargoCaps")".

For this TCF, we identified 5 breakthroughs (Table 30) and 6 obstacles (Table 31) from the relevant literature.

Table 30. Breakthroughs of TCF Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

	TCF: Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines	**Description**
Breakthroughs	Improvement in safety and security	Road freight crime is a current problem that has an impact on production, as well as traders who will encourage any mode of transport that will reduce the risk of theft. When embedded in the underground, pipelines offer an improvement in the safety of people and the safety of goods (Egbunike and Potter, 2011). Pipelines are safe, accident-free and environmental friendly (Barnawal, 2018). Ecological safety and the possibility to fully automate the movement will reduce the trucks on highways, resulting in reduced accidents, traffic jams, air pollution, noise and damage to bridges (Shibani et al., 2016).
	Improved reliability	The possibility of reducing congestion on city highways will be provided through improved reliability and enable better movement of cargo. The pipelines have electronic and computerized control, and the movement is undisturbed in underground infrastructure. Delivery time is better predicted and goods are adequately monitored (Egbunike and Potter, 2011). Pipelines can be laid through difficult terrains as well as under water (Barnawal, 2018).
	Environmental benefits	With the increased focus on climate change, there is a need to fully assess the environmental benefits of capsule pipelines. It is assumed that due to the use of electric energy, there will be little or no emissions from the use of freight pipe-lines given an increasing focus on using nuclear and renewable sources of electricit (Egbunike and Potter, 2011). It involves very low energy consumption (Barnawal, 2018).
	Delivery times	Logistic operators want to complete delivery within 24 hours. Freight pipelines are invisible and unobtrusive, yet efficient and reliable, and therefore it is possible that the goods can be delivered at any time within the 24-hour frame (Egbunike and Potter, 2011). They are ideally suited to transport the liquids and gases (Barnawal, 2018).
	Transport Costs	Due to the complete automation of this system, there may be a reduction in human costs, as well as driver costs. The use of advanced planning

		techniques also reduces unused infrastructure capacity. Given that the pipeline for the transport of goods can be part of the intermodal transport stream, these savings will have to exceed the additional costs of manipulation for transfer to / from the pipeline (Egbunike and Potter, 2011).

Table 31. Obstacles of TCF Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

	TCF: Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines	**Description**
Obstacles	Technology acceptance	One of the challenges is the acceptance of the technology as a viable alternative to conventional transport modes. It is not envisaged that this technology will completely replace other forms of transport but work in tandem with them to best optimize the transportation network (Egbunike and Potter, 2011).
	Intermodal transfer with existing modes	Pipelines will have to be connected to other types of transport and that the design boundary of such a system must include this interface. Efficiency and flawless transfer of goods in data exchange facilities, as well as an increase in the number of items for handling products, are of concern (Egbunike and Potter, 2011). There are special disadvantages of the pneumatic tube mail system, which are the inability to carry special delivery parcels due to the size of the carriers (Shibani et al., 2016).
	Support for adoption	Lack of interest by policy makers can be considered a major obstacle. Industry will also have to be convinced, especially if it probably provides most of the funds for such schemes (Egbunike and Potter, 2011).
	Costs and funding	Related to the acceptance issue is financing. Investment costs can be considered as factors that influence the underground infrastructure planning. Obtaining a financial asset will only be possible if the technology proves itself. Operating costs will then depend on maintaining a constant flow of products through the pipeline (Egbunike and Potter, 2011). The cargo transportation prices are rising each year. There are high cost of creating and maintaining the vacuum tube and the tracking pipeline itself (Shibani et al., 2016).
	Design and construction	Certain design issues are challenges associated with the acceptance of the pipeline for the capsules. Due to the fact that this infrastructure is capital intensive, but also underground, any change in infrastructure planning will be expensive and time-consuming. A shortage in freight pipelines is that modal transport must overcome altitude differences between the tunnel and the surface. This will contribute to total costs. Today, in many developed areas, tunnel networks exist both for utility services and underground passenger transport. Consequently, the construction of new tunnels can be challenging (Egbunike&Potter, 2011).
	Competition	There is a question of competition for the established modes of transport. In particular, the networks that are needed for traditional modalities are often already provided, and for this reason significant initial costs have already been generated. The challenge for transport pipelines is to offer a solution that can complement these models (Egbunike and Potter, 2011).

3 Crossing breakthroughs and obstacles of TCF

In accordance with the proposed methodology, for each of the TCF, we have defined the breakthroughs, that is, the advantages it brings to and which contribute to the easier functioning of the human being and affect the protection of the environment. Contrary to the progress, the obstacles encountered in the implementation of TCF were also investigated. Their detailed review is given in the previous chapter. Crossings of breakthroughs and obstacles for each TCF enabled us to identify the obvious research gaps which are considered to have the greatest impact on the realization of the TCF. Results of these crossing activities are given in Tables 32 – 46.

Table 32. Breakthroughs and obstacles of TCF Automation – Passenger and Freight Transport – Road transport

TCF Automation – Passenger and Freight Transport - Road transport		**Breakthroughs**										
		Increased safety	Better use of travel time	More efficient	Energy savings	Decreases in polluting emissions	Provision of mobility services to people currently unable to drive	Reduction in the need for parking space	The high cost of AVs may accelerate the move to shared mobility	Roadway infrastructure could be managed dynamically	Reduce the need for pedestrian areas	Predictable travel times
Obstacles	Increased congestion and pollution					X		X				
	A shift away - from public transit											
	Longer trips (especially commutes)											
	Repositioning				X							
	Security	X					X					
	Traffic management											
	City Infrastructure									X		
	Revenue								X			
	Liability insurance											
	Police and emergency response											
	Social justice and equity		X									
	Creating (and maintaining) maps for self-driving cars is difficult work											

	Driving requires many complex social interactions — which are still tough for robots											
	Bad weather makes everything trickier											
	Regulations											
	Cyber security	X										

Table 33. Breakthroughs and obstacles of TCF Automation – Passenger and Freight Transport – Air transport

TCF Automation – Passenger and Freight Transport - Air transport		**Breakthroughs**		
		Low noise	Energy efficiency	Low engine power
Obstacles	Risk perceptions			
	Safety		X	
	Necessary "heterogeneous engineering"			
	Regulations			
	Technology maturity		X	X
	Infrastructure			X
	Air traffic management			
	Psychological barriers			

Table 34. Breakthroughs and obstacles of TCF Automation – Passenger and Freight Transport - Rail transport

TCF Automation – Passenger and Freight Transport - Rail transport		**Breakthroughs**		
		Capacity	Costs and energy efficiency	Fully automated rail freight
Obstacles	Infrastructure (in metro)	X		
	Public attitudes and staff opposition			
	System integration			X
	Software development			
	Functional safety		X	
	Sensor implementation			
	IT security		X	

Table 35. Breakthroughs and obstacles of TCF Automation – Passenger and Freight Transport – Waterborne sector

TCF Automation – Passenger and Freight Transport - Waterborne sector		Breakthroughs: Advanced in modern ships	Breakthroughs: Safety and energy efficiency
Obstacles	Ship systems		
	Changes in the ports	X	
	Regulatory Framework		X
	Insurance		X
	Cyber Security		X

Table 36. Breakthroughs and obstacles of TCF Shared mobility, on-demand mobility, MaaS

TCF Shared mobility, on-demand mobility, MaaS		Breakthroughs: Integration of transport modes	Tariff option	One platform	Multiple actors	Use of technologies	Demand orientation	Registration requirement	Personalization	Customization	Discussion of MaaS Roles in Future Mobility
Obstacles	Travel demand modelling for MaaS						X				
	Supply-Side Modelling										
	The benefits may be limited										
	MaaS can still face strong competition from existing travel applications	X									
	Policy Framework for Implementation of MaaS				X	X					

Table 37. Breakthroughs and obstacles of TCF Electrification – Passenger and Freight Transport – Road transport

TCF Electrification – Passenger and Freight Transport - Road transport		Breakthroughs: Electricity Energy (efficient and utilize)	Improving local and regional air quality	Benefit for shareholders and owners of EVs
Obstacles	Electric parking spaces	X		
	High costs			
	Uncomfortable and slow charging	X		
	Limited range	X		
	Availability			
	Accessibility and awareness		X	
	Space required for storing electricity (battery) in the vehicle	X		
	Rare earth materials for batteries and motors			

Table 38. Breakthroughs and obstacles of TCF Electrification – Passenger and Freight Transport - Waterborne transport

TCF Electrification – Passenger and Freight Transport - Waterborne transport		**Breakthroughs**					
		Flexibility of ship design	Flexibility of the ship's operation	Silencing the noise on the boat	Improved efficiency of fuel consumption	Effectively operated with On/Off technology	Powering the ship
Obstacles	Power solutions						X
	Higher initial cost				X		
	Adequate charging infrastructure						

Table 39. Breakthroughs and obstacles of TCF Electrification – Passenger and Freight Transport – Air transport

TCF Electrification – Passenger and Freight Transport - Air transport		**Breakthroughs**
		Reduction in CO_2 emissions
Obstacles	Emerging challenges for the development of leading-edge need to be aligned with key principles	
	Management and standardization competencies	X
	Training workers	

Table 40. Breakthroughs and obstacles of TCF Seamless transport chains

TCF Seamless transport chains		**Breakthroughs**		
		Energy efficiency	Reduced emissions	Integration
Obstacles	Coordination and collaboration			X
	Adequate structure and the coherence system			
	Development of transhipment technology			
	Efficient management systems	X		
	Fast and low cost handling of loads			
	Work in the cross-border network			
	Electronics and business models			
	Regulations			X

Table 41. Breakthroughs and obstacles of TC Personal air transportation – “flying cars”, “flying taxis”

TC Personal air transportation – “flying cars”, “flying taxis”		**Breakthroughs**			
		Avoid congestion on road	Enhance personal transportation, revolutionize the transportation industry, and improve the standard of living	Infrastructure	Reduced emissions, fuel use, and capital cost
Obstacles	Air traffic control and infrastructure			X	
	Cost and accessibility	X			X
	Safety		X		
	Charging				
	Regulation			X	
	Affects other sectors		X		

Table 42. Breakthroughs and obstacles of TCF Delivery Drones

TCF Delivery Drones		**Breakthroughs**						
		Cost effective	Deliver Products	Improves Time Managem ent	Conserve s Energy	Saves Time	Promote Safety	Accuracy
Obstacles	Regulation			X				
	Safety						X	
	Order staging		X					
	Weight limit							
	Drop ship vendors							
	Distance limit							
	Requires investment	X						
	Shipping big-ticket items						X	
	Uninterrupted service							
	Designated delivery spots		X					
	Durability							
	Conditional awareness					X		
	Black boxes							
	Maintenance plans							
	Override kill switch						X	
	Classification system for drone and cargo		X					
	Drone insurance	X						
	Licensing (Vehicle, Pilot, Operator)			X				
	Weather contingency plans							
	Rules (Privacy, Security, Drone spam rules, Noise guidelines)							
	Automated here-to-there delivery							

	Grasp and release mechanisms							
	Aerodynamic packaging							
	Fly-drive capabilities							
	Systems (Collision avoidance, Crowded skies navigation system, Drone operating system)							
	Shot from the sky recourse							
	Political and consumer awareness							
	Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots			X				
	Drone financing	X						
	Flying drone bill of rights	X						
	Docking systems							X
	Better battery tech							
	Airbag crash protectors							
	Invisible fences							

Table 43. Breakthroughs and obstacles of TCF High-speed rail

TCF High-speed rail		**Breakthroughs**		
		Attractive alternative to aviation	High-speed rail as a cheaper, greener and more sustainable transport alternative	Need for a complete European high-speed rail network
Obstacles	Technical obstacles			
	Changes in environmental, human health, resource, and climate change impacts		X	
	Problems of the impact of rail development			
	Costs and challenges facing the HSR		X	

Table 44. Breakthroughs and obstacles of TCF Hyperloops

TCF Hyperloops		**Breakthroughs**				
		Very fast	Power	Cheaper for travelers	Weather	The Hyperloop will arrive more frequently
Obstacles	Construction cost			X		
	Construction material					
	Pressure					
	Spontaneous Decompression					
	Deadly Collisions	X				
	Acceleration of the capsule					

	The multi-ton capsules intended to carry passengers also pose as liabilities themselves.					
	Too much air creates significant problems					
	Safety standards and security			X		
	New management challenges					X

Table 45. Breakthroughs and obstacles of TCF Freight consolidation hubs, Freight Distribution Centres

TCF Freight consolidation hubs, Freight Distribution Centres		**Breakthroughs**							
		Environmental and social benefits resulting from more efficient and less intrusive transport	Possible facilitate a switch from push to pull logistics through better control and visibility of the supply	Better inventory control, product availability and customer service	Potential to link in with wider policy and regulatory initiatives	Theoretical cost benefits from contracting out “last	Public relations benefits for participants	Potential to allow better use of resources at	Specific transport advantages opportunity for carrying out value-
Obstacles	Potentially high set up costs (and sometimes high operating costs)					X			
	Logistical zones in the area of the port have some disadvantages, especially because they involve higher land costs with potentially more restrictive labor regulations if they are under the jurisdiction of port workers								
	Much urban freight is already consolidated at the intra-company level or by parcels carriers, so limited benefits for trying to channel these flows through a consolidation centre. The potential scope for UCCs may therefore be limited.								
	Difficult for a single centre to be able to handle the wide range of goods moving in and out of an urban area, for example due to different handling and storage requirements								
	Most studies report an increase in delivery costs due to an additional stage in supply chain which imposes a cost (and often a time) penalty, though this clearly depends on how well the centre is integrated into the supply chain and the extent to which all costs and benefits are considered.		X						
	Single consolidation centre for an urban area is unlikely to be attractive for many suppliers’ flows due to the degree of diversion								

	required from normal route								
	Lack of enforcement of regulations for vehicles not included in the consolidation scheme								
	Organizational and contractual problems often limit effectiveness	X							
	Potential to create monopolistic situations, thus eliminating competition and perhaps leading to legal issues								
	Loss of the direct interface between suppliers and customers								

Table 46. Breakthroughs and obstacles of TC Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines

TC Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines		**Breakthroughs**				
		Safety and security	Reliability	Environmen t	Delivery times	Transport Costs
Ostacles	Technology acceptance	X				
	Intermodal transfer with existing modes		X			
	Support for adoption					
	Costs and funding					X
	Design and construction					
	Competition					

4 Summary of Transport Research Gaps

After crossing and over-viewing all breakthroughs and obstacle that are present on the realization path for each of the TCF, we can identify all transport-related research gaps. Table 47 gives a summary of all determined gaps.

Table 47. List of transport-related research gaps

TCsF		Breakthroughs	Gaps
TCF: Automation – Passenger and Freight Transport	**Road transport**	Increased safety; Provision of mobility services to people currently unable to drive	**1.Security, Cyber security**
		Better use of travel time	**2.Social justice and equity**
		Energy savings	**3.Repositioning**
		Decreases in polluting emissions; Reduction in the need for parking space	**4.Increased congestion and pollution**
		The high cost of AVs may accelerate the move to shared mobility	**5.Revenue for city**
		Roadway infrastructure could be managed dynamically	**6.City Infrastructure**
	Air transport	Energy efficiency	**7.Safety**
			8.Technology maturity
		Low engine power	**9.Infrastructure**
	Rail transport	Capacity	**10.Infrastructure (in metro)**
		Costs and energy efficiency	**11.Functional safety**
			12.IT security
		Fully automated rail freight system	**13.System integration**
	Waterborne sector	Advanced in modern ships	**14.Changes in the ports**
		Safety and energy efficiency	**15.Regulatory Framework**
			16.Insurance
TCF: Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS	**MaaS**	Integration of transport	**17.MaaS can still face strong competition from existing travel applications**
		Multiple actors	**18.Policy Framework for Implementation of MaaS**
		Use of technologies	
		Demand orientation	**19.Travel demand modelling for MaaS**
TCF:	**Road**	Electricity Energy (efficient	**20.Electric parking spaces**

TCsF		Breakthroughs	Gaps
			21.Uncomfortable and slow charging
			22.Limited range
			23.Space required for storing electricity (battery) in the vehicle
		Improving local and regional air quality	**24.Accessibility and awareness**
	Waterborne sector	Improved efficiency of fuel consumption	**25.Higher initial cost**
		Powering the ship	**26.Power solutions**
	Air transport	Reduction in CO_2 emissions	**27.Management and standardization competencies**
TCF: Seamless transport chains		Energy efficiency	**28.Efficient management systems**
		Integration	**29.Coordination and collaboration**
			30.Regulations
TCF: Personal air transportation - "flying cars", "flying taxis"		Avoid congestion on road; Reduced emissions, fuel use, and capital cost	**31.Cost and accessibility**
		Enhance personal transportation, revolutionize the transportation industry, and improve the standard of living	**32.Safety**
			33.Affects other sectors
		Infrastructure	**34.Air traffic control and infrastructure**
			35.Regulation
TCF: Delivery Drones		Cost effective	**36.Requires investment**
			37.Drone insurance
			38.Drone financing
			39.Flying drone bill of rights
		Deliver Products	**40.Order staging**
			41.Designated delivery spots
			42.Classification system for drone and cargo
		Improves Time Management	**43.Regulation**
			44.Licensing (Vehicle, Pilot, Operator)
			45.Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots
		Saves Time	**46.Conditional awareness**
		Promote Safety	**47.Safety**
			48.Shipping big-ticket items
			49.Override kill switch
		Accuracy	**50.Docking systems**
TCF: High-speed rail		High-speed rail as a cheaper, greener and more	**51.Changes in environmental, human health, resource, and**

TCsF	Breakthroughs	Gaps
	sustainable transport alternative	**climate change impacts**
		52.Costs and challenges facing the HSR
TCF: Hyperloops	Very fast	**53.Deadly Collisions**
	Cheaper for travelers	**54.Construction cost and Environmental impact**
		55.An easy terrorist target
	The Hyperloop will arrive more frequently	**56.New management challenges**
TCF: Freight consolidation hubs, Freight Distribution Centres	Environmental and social benefits	**57.Organizational and contractual problems often limit effectiveness.**
	Possible facilitate a switch from push to pull logistics through better control and visibility of the supply chain"	**58.Increase in delivery costs**
	Theoretical cost benefits from contracting out "last mile	**59.Potentially high set up costs (and sometimes high operating costs)**
TCF: Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines	Safety and security	**60.Technology acceptance**
	Reliability	**61.Intermodal transfer with existing modes**
	Transport Costs	**62.Costs and funding**

As it can be seen from the Table 47, we have identified 62 gaps in transport researches in total. Clarification of identified gaps, i.e. an explanation of obstacles that should be overcome so as the TCF would function and come to life, is given in Table 48.

Table 48. Description of identified transport research gaps

Gaps
1.Security, Cyber security Automated vehicles could be used for terrorist attacks (as ar bomb for instance) without any physical risk and with much lower risks of detection for the terrorist. Moreover, automated vehicles could be hacked for malicious purposes. (Franckx, 2015) "Another question is cyber security", "How do you ensure that these cars cannot be hacked? How vehicles become smarter and connected, there are more ways to get in and disturb what they do." This should not be impossible to fix. Software companies have long been facing this problem. (Plumer, 2016) The new risk that can arise using remote navigation is a cyber security. In this way, a new type of piracy can be developed. Therefore, the systems should be developed in such a way that they will exclude unauthorized access but also give the shore master overriding authority over any unauthorized instruction. Furthermore, a new insurance cover may be required which will cover such type of risks. (Jokioinen, 2017)
2.Social justice and equity There is a risk that AV would benefit more from the rich and create a higher burden for low-income people. These without AV can be in a disadvantageous position when it

Gaps
comes to employment, because they can work with AV and respond to e-mail while travelling. (GovTech, 2017)
3.Repositioning After having dropped their passenger, the AVs will now have to drive to places where parking is available (or cheaper), or to catch other users (which could be other family members, or, in the case of shared cars, third parties); this “repositioning” could have an important impact on traffic flows (Franckx, 2015).
4.Increased congestion and pollution Increased congestion and pollution caused by travel by those currently unable to drive, such as young people without driving license, the physically impaired, and elderly people. (Franckx, 2015) It is not clear to what extent autonomous cars will really lead to shorter headways -One should not compare the theoretical safety distance between AVs with the theoretical safety distance between vehicles driven by humans as a lot of people drive closer to the preceding car than is justified on safety grounds; (Franckx, 2015) Le Vine and at. 2016, examined the impact of the dynamics of driving autonomous vehicles on congestion in traffic. Autonomous vehicles which offer a comfortable ride similar to slowing down and acceleration on the rail, create more traffic congestion than a man behind the wheel. When driverless cars accelerated and decelerated in the style of light rail, the congestion deteriorated from 4 percent to 50 percent and the number of cars travelling through the intersection also fell between 4 percent and 21 percent. Going for high speed rail style of smoothness, those numbers got even worse: Delays increased from 36 percent to nearly 2,000 percent and intersection capacity fell between 18 percent and 53 percent. Only the vehicles with drivers and autonomous vehicles are included in simulation in study. There were no trucks, buses, or pedestrians
5.Revenue for city AVs will not go to red light, they will not accelerate to the highway over the permitted border or park outside the permitted parking space. This, however, will affect the city budget. In some cities, traffic fines make a significant percentage of the city's budget. Cities will need to generate new revenue streams to counter the loss of funds. (GovTech, 2017)
6.City Infrastructure Often, AVs require a clear striming stripe, storage locations for data collected during guidance, and a robust network of climbing if they are working on electricity. (GovTech, 2017)
7.Safety Obstacles to the advancement of automation depend on basic safety concerns (a key problem due to potential loss of life and poor publicity that may be the result of a collision of aircraft). (Spinardi, 2015) For the adoption of passenger drones and flying cars (especially fully autonomous), operators of these vehicles should show a safety record covering both mechanical integrity and safe operations. As has been shown in autonomous cars, any accidents can have considerable attention and can slow down the adoption of such a concept. (Lineberger et al., 2018)

Gaps
8.Technology maturity Although GPS technology exists and is used in autonomous cars, it should be improved to provide remote sensing and recognition needed to deal with the multi-way and fast convergence associated with the autonomous flight. These vehicles would require advanced technologies, such as artificial intelligence, to allow advanced detection and avoidance capabilities. Machine learning can be essential since operations move from piloted to autonomous: the vehicle should learn from pilots on the basis of over a thousand working hours to become completely autonomous over time. Energy management is crucial: to have enough energy to transport passengers or cargo, to maintain a safety margin and reload for the next flight. Although the technology of using batteries as a source rapidly improves, in order to increase the capacity of passengers and cargo and extend the range of passenger drones, it is necessary to further improve or to find alternatives. (Lineberger et al., 2018)
9.Infrastructure In terms of infrastructure, it is necessary to provide the appropriate landing and landing zone, as well as the charging stations for the battery. A broad network requires new infrastructure or the conversion of existing infrastructure (such as helipads, roofs of large public buildings and unused land). In order to provide a unified traffic management system, additional infrastructure along the predefined flight corridors should be installed to help rapidly communicate data and geolocation. All these changes in infrastructure would require cooperation with commercial actors and local urban planning bodies. (Lineberger et al., 2018)
10.Infrastructure (in metro) Modification or replacement of vehicle fleet and signaling system and additional complexity can increase costs in comparison with other signaling and control systems. Closing an existing system over a longer conversion period is likely to be difficult and costly, as existing metro lines often represent vital links in the urban transport network. In order to ensure high levels of security, a greater degree of physical segregation from the environment will be required than for trains in which a driver can react to extraordinary or unexpected events such as collapse, burning trees or damage to the infrastructure. This is not so significant for underground lines as it is important when converting a surface infrastructure that was not originally designed for such a high degree of isolation. A very high percentage of runs on which trains are currently running without a driver are underground or raised. By contrast, most of the metro is at the ground level, and it is likely that the peripheral line should be upgraded, as the crossing is a daily problem on the metro paths. It is necessary to improve the system of communication and tracking for passengers throughout the system in order to provide functions that would otherwise be performed by a staff member. This also applies to remote monitoring and correction (where possible) of equipment faults by the remote control center. The equipment requires a high degree of reliability and availability to ensure the safety of passengers. Such systems would represent **additional capital and maintenance costs**. (Powell, 2016)

Gaps
11.Functional safety Higher system complexity increases potential error rates and demands new functional safety approaches. (Bosch, 2017)
12.IT security More digitised and interconnected systems are exposed to numerous hazards and vulnerabilities. (Bosch, 2017)
13.System integration Smart systems need to communicate across rail services, transport modes and infrastructure. (Bosch, 2017)
14.Changes in the ports Increased automation of ships will require some changes in the ports, e.g. for maintenance of ships, as well as for increased automation in both approaches and landing. (EU, 2018)
15.Regulatory Framework So far, the legislation governing autonomous ships is totally unclear. The main concern concerns the provisions on the number of crew members and safety, as well as the construction standards. According to IMO International rules, all ships should be employed with a minimum number of crew members in order to be able to navigate. This rulebook should be amended to include vessels with special characteristics that will allow them to sail with less or no crew on board. The same situation is with regard to the safety of the ship, where minimum standards regarding the conditions of vessels and equipment should be applied. Building and maintenance standards that classification societies also provide should be materially supplemented, and these societies will require people with expertise in autonomous technologies. Safety in navigation and responsibility: it is probably the main concern of people who are still cautious about autonomous ships. A boat sailing in the open sea faces many risks associated with weather, other hurdles, or even risking being threatened by a third party (e.g. pirates). So, such an autonomous ship should be very intelligent to be able to control any potential risk. (Jokioinen, 2017)
16.Insurance Existing insurance (..., war risks, piracy risks, cargo insurance...) should be available. However, premiums may vary depending on the level of actual risks in the navigation of these vessels. (Jokioinen, 2017)
17.MaaS can still face strong competition from existing travel applications Even if Maas would aim at a pan-European or global market, MaaS can still face strong competition from existing travel applications that have already offered global services. Maas service will have to work with existing providers. It remains unclear whether such providers are willing to integrate their platforms with MaaS. (Li & Voege, 2017)
18.Policy Framework for Implementation of MaaS Implementation of MaaS in the city can face financial challenges. Many cities subsidize public transport services. If Maas had a profit from his monthly subscriptions, this does not necessarily mean that the sale of tickets for public transport was realized. Government policy will have to define the MaaS business model in terms of public transport services. Many employers offer free passes for public transport for their employees when traveling by public transport. Often employees can get a tax reduction

Gaps
for travel expenses. If an employee chooses Maas instead of public transport, an employee may not be able to receive the same subsidy or tax cuts. So, only when local governments identified MaaS as a type of sustainable transport system with the same state subsidy policy or tax cuts, MaaS can be applied in a city where subsidies and taxes are offered for those traveling by public transport. (Li & Voege, 2017)
19.Travel demand modelling for MaaS Providing innovative services such as MaaS requires the continuation of ongoing modeling of demand based on activities, given the more dynamic context of modern lifestyles, social impact, ICT, responses to travel recommendation systems, attitudes and subjective considerations, and an increasing degree of uncertainty. It is necessary to think critically about how to expand existing models based on activities and models of elections in order to better capture the overall nature of travel behavior and the decision-making process related to MaaS. (Jittrapirom et al., 2017)
20.Electric parking spaces In large cities, the use of electric vehicles would result in the need for millions of electric parking spaces, which is a real challenge for implementation. Implementation of the EV fleet would also require changes in infrastructure, to allow significantly higher power supplies to chargers than is currently available. (García-Olivares et al., 2018)
21.Uncomfortable and slow charging Convenient and reliable re-charging has already been identified as one of the most important aspects to increase user acceptance of electric vehicles, but is most often neglected. One clear challenge is to provide appropriate charging capabilities to urban dwellers that often have to rely on overnight street parking and limited garage spaces in high-density populated city areas. Municipalities aim long-term to reduce the number of vehicles in cities and are reluctant to electrify a high number of parking spaces with bulky or unsightly charging stations that often do not fit easily in the townscape. These users will have to rely on quick-charge capabilities or charging during the day at work. Additionally, there is the possibility to promote this means of charging with incentives due to the potential usage in vehicle-to-grid applications. (ERTRAC, 2017)
22.Limited range Increasing range capability of electric vehicles remains a high priority, as previously mentioned, inorder to increase user acceptance and win the broad mainstream market especially in comparison to conventional vehicles and current existing usage models of these vehicles. It is important to keep in mind, however, that increasing driving range supplied by the electro-chemical energy stored in the battery can only be achieved directly by increasing the size of the battery. Increasing the size of the battery increases the “installed” energy storage capability at an increased cost and increased size and weight. (ERTRAC, 2017)
23.Space required for storing electricity (battery) in the vehicle These problems can be solved by supplying electricity directly to the cables while the vehicle is active. Losses are limited to the conventional distribution of electricity and the power of electronics on the vehicle, and the exceptional efficiency of the electrical machine can be used at full scale. This advantage in the efficiency of the system, turns

Gaps
into significant benefits in operating costs. (eHighway, 2017)
24.Accessibility and awareness Other incentives such as access to the driver and parking access are high value, low-cost incentives for adoption. Local competencies must also play a role, ensuring that the local location and the license for a new EV service are quickly terminated. (SCE, 2017)
25.Higher initial cost The main disadvantages of all electric drives are the higher initial cost compared to the propulsion systems based on internal combustion engines, the increase in losses in the conversion of energy from fuel to propulsion, the greater the volume of the system due to the large number of component parts, and the issue of energy density in vessels with batteries. (EC, 2017)
26.Power solutions Due to the diversity of ships and sailing (some boats spend a week at sea and only a few days in the port, while other vessels are regular vessels), the power solutions for one type of ship are not suitable for another ship. (EC, 2017)
27.Management and standardization competencies At present, there is no established access to standards, however, in order to make the supply chain efficient, specific standards, including the definition of components (e.g. an electric motor considered to be a drive engine?). (EC, 2017)
28.Efficient management systems Introducing more efficient management systems and cross-port operations in consolidation/distribution nodes close to cities, preserving the added value of long journeys; (Perkins, 2012)
29.Coordination and collaboration Need for intermediation and coordination to overcome the power imbalance and to reduce searching and transaction costs, and to avoid moral hazard and opportunism. •Fair gain sharing: the presence of conflict in co-modal initiatives is also connected to the perception of the unfair share of gain. Fair gain sharing is a proxy for horizontal collaboration. •Information sharing and visibility: shippers and carriers do not collaborate horizontally because of competition law, fear of losing competitive advantage, and a lack of cross network visibility, among others. •Risk allocation: The existing literature allocates the risk related to co-modality (unused capacity, disruptions, delays, etc.) to the carrier which is usually in charge of the consolidation of different flows from its clients. (CO^3, 2012)
30.Regulations Too many regulations that hinder innovation. Different standards, regulations and procedures in member states prevent impeccable cross-border transport operations, as well as synchronic transport when logistics chains involve several countries. (Perkins, 2012)
31.Cost and accessibility Flying costs are more than driving, and the same goes for drones. It is estimated that average driving costs are 12 times higher for flying vehicles than those left on the ground. As far as personal planes are concerned, their price remains surprising. *(*Dewost, 2018); (Krauth, 2018)

Gaps
32.Safety Private planes may be the closest device to mobility in air traffic, and are much more dangerous than cars. The biggest obstacle seriously delaying the great development of air traffic in urban areas is perhaps security, reflecting highly mediated discussions about autonomous accidents in the vehicle. The survey found that more than half of the Americans surveyed said that their main concern was the safety of autonomous flying cars. *(*Dewost, 2018); (Krauth, 2018)
33.Affects other sectors • Necessary co-operation of city-transport operators on demand with regulators to understand and respond to key regulatory issues (airspace management, fully autonomous adoption path, licensing and certification, and air traffic management). • Education of urban planners in terms of infrastructure conditions that are necessary in urban areas for operations with passenger drones to begin to involve them in urban planning processes in local communities. • Manufacturers should consider improving their concepts, working with regulators, and cooperating with urban transport operators on demand, in order to establish a market for their aircraft. In addition, manufacturers should begin to plan reduced production and subsequent aircraft support. • Drone technology providers should consider cooperation with drone manufacturers in order to fully understand their needs and integrate technological software, sensors, materials, engines and energy management into vehicles. Air Traffic Management Providers should consider working with their national airspace management regulators (such as the FAA in the United States) to participate in early pilot programs, formulating regulatory and standard standards, and adapting hardware and software to meet major quantity, low altitude and fully automated unique air traffic management systems in the future (Lineberger et al., 2018).
34.Air traffic control and infrastructure There are numerous practical challenges in the direction of creating a regulatory management system: small drones are more susceptible to changes in time; the need for a dynamic mapping system that is updated in real time; connection for tracking constant tracking of drones in flight; and even interoperability, including devices that do not fly. Also, the lack of available free space and the difficulty of accessing up-and-down infrastructure (for landing and landing and flight safety) are significant obstacles, and the construction and design a vast network of vertiports is a major urban planning job in itself *(*Dewost, 2018).
35.Regulation The existing rules, updated by the FAA in August 2016, insist that drones must be in the line of sight and must always be controlled live by the operator. Rules suffocates new innovations (at least in the U.S.). Other countries were welcomed by autonomous drones with open arms. For example, Delft agreed to implement the first fully autonomous network of unmanned aerial vehicles, complete with docking stations and drone rentals. New Zealand has been selected as the first commercial service for the delivery of drones in the world due to friendly regulations in the country (Blair, 2017).
36.Requires investment The introduction of drones as part of the delivery process requires greater investment.

Gaps
The impression is that the investment will be more burdensome for smaller traders - or use third-party services that utilize drones (Mehra, 2015).
37.Drone insurance Drones, drone cargo, and drone businesses will soon become the largest new market for insurance companies (Frey, 2015).
38.Drone financing As the need for instrumentation and safety equipment mushrooms, delivery drones will become far more expensive. As a result, drone financing will become a hot new area of business in the near future (Frey, 2015).
39.Flying drone bill of rights Do people have the right to “keep and bear drones?” (Frey, 2015)
40.Order staging In unmanned flights, the existing allocation process will have to be redesigned to support drones, and employees will have to train for these new processes (Mehra, 2015).
41.Designated delivery spots Drones will need designated places for package delivery (Frey, 2015). So flight is the easy part. Dropping off the package is the problem. Others address the issue by creating special landing zones (Kobie, 2018),(Nentwich & Hórvath, 2018).
42.Classification system for drone and cargo Drones are being created in thousands of different shapes and sizes with thousands of different capabilities. A comprehensive classification system will be needed to properly manage and regulate this industry. Cargo classification systems applied to ground-based shipping will need to be revised for the more volatile conditions associated with remote controlled airborne vehicles (Frey, 2015).
43.Regulation The second big challenge is regulation, and as ever the law trails innovation (Kobie, , 2018)
44.Licensing (Vehicle, Pilot, Operator) Every drone that falls within certain classification guidelines will need to be licensed and insured (Frey, 2015); (Nentwich & Hórvath, 2018). People who load and unload cargo onto flying drones will also need to be licensed. Those who fly drones will need to be tested and licensed in a less rigorous but similar way that airplane pilots are tested today (Frey, 2015).
45.Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots People who service and fix drones will be in hot demand in the near future. Drones will become one of the most highly regulated industries of all times. It is not too soon to start educating the influencers. With all their different configurations, styles, and function, drone pilots will require far different training than airline pilots do. Currently there are very few simulation programs available for practice. Police will not only employ drones to assist in managing public safety, they will also use drones to monitor other drones. Drones are far more versatile and faster to deploy than virtually all other options officers have at their disposal (Frey, 2015).

Gaps
46.Conditional awareness Drones will invariable fly into unusual situations, and whether it's swarms of bees, bird attacks, lightening strikes, or signal jammers, they will need to alert operators of problems as soon as they arise (Frey, 2015).
47.Safety Safety is very important the question of the fall of the drone from the sky, either by mechanical error or by the devious hacker (Kobie, 2018). Health and safety - injuries because of collisions; contamination with dangerous loads (Nentwich & Hórvath, 2018).
48.Shipping big-ticket items The drones will become the target of thieves as they fly several hundred meters from the ground. Retailers will have to consider this before using drones to send big-ticket items(Mehra, 2015).
49.Override kill switch Wireless signals are far from perfect. If a signal is lost, hacked, or hijacked, the drone must either return home or be removed from danger (Frey, 2015).
50.Docking systems People will eventually not want packages delivered onto their driveways. For example, any pizza left on a driveway becomes an open invitation for cats, dogs, and other stray animals. A better option would be to have some sort of docking system that would allow the drone to land and deliver the package into a secure area (Frey, 2015).
51.Changes in environmental, human health, resource, and climate change impacts • spatial incompatibility between HSR and other long-distance modes that is often ignored, • an environmental review process that obviates modal alternatives, • siloed interest in particular environmental impacts, • dearth of data on future vehicle and energy sources, • poor understanding of secondary impacts, particularly in land use. (Chester and Ryerson, 2014)
52.Costs and challenges facing the HSR • Total per mile costs of providing rail service increase significantly with increases in travel speed, but ridership also increases with faster speeds, albeit less dramatically. Hence, there is a “sweet spot” where ridership and costs are optimized. This sweet spot also varies from corridor to corridor. • The feasibility and benefits of higher and high speed rail investments depend primarily on ridership. Therefore, it is important to focus initially on connecting major mega-regions with proven demand. • Certain metropolitan regions are more conducive to high speed rail by virtue of existing land use patterns and complementary public transportation service. It is important to provide rail service where people and economic activity are already concentrated, but it is also important to plan ahead for growing cities and regions (Metcalf et al., 2010)
53.Deadly Collisions Capsule capable of sustaining force in the event of decompression should be extremely

Gaps
difficult given the nature of the design. The capsule must be strong enough to withstand atmospheric pressure inside the cabin, but it must remain light enough to not destroy or compromise the tube while traveling. Assuming it does not immediately destroy itself in pieces in the event of decompression, the capsules will accelerate the path until they collide with each other with deadly force (Interesting Engineering, 2017).
54.Construction cost and Environmental impact Land acquisition and building/tunnelling rights (Krauth, 2018).
55. Safety standards and security People are more concerned than ever about the threats of a terrorist attack. Designing hundreds of kilometers of tube transported by hundreds of people at the same time brings the real possibility of a terrorist attack (Interesting Engineering, 2017), (Krauth, 2018)
56.New management challenges The dispatch system must meet the increased requirements for speed and reliability. It should provide simultaneous activation and execution of command sequences in the presence of a large number of different dispersed objects (Dudnikov, 2017).
57.Organizational and contractual problems often limit effectiveness
58.Increase in delivery costs Most studies report an increase in delivery costs due to an additional stage in supply chain which imposes a cost (and often a time) penalty, though this clearly depends on how well the centre is integrated into the supply chain and the extent to which all costs and benefits are considered (Browne, et al., 2005).
59.Potentially high set up costs (and sometimes high operating costs) Potentially high set up costs (and sometimes high operating costs) (Browne, et al., 2005) Logistical zones in the area of the port have some disadvantages, especially because they involve higher land costs with potentially more restrictive labor regulations if they are under the jurisdiction of port workers (Rodrigue, 2017).
60.Technology acceptance One of the challenges is the acceptance of the technology as a viable alternative to conventional transport modes. it is not envisaged that this technology will completely replace other forms of transport but work in tandem with them to best optimize the transportation network. While this optimization is necessary, certain challenges exist with the use of this technology (Egbunike and Potter, 2011).
61.Intermodal transfer with existing modes Pipelines will have to be connected to other types of transport and that the design boundary of such a system must include this interface. Efficiency and flawless transfer of goods in data exchange facilities, as well as an increase in the number of items for handling products, are of concern (Egbunike and Potter, 2011). There are special disadvantages of the pneumatic tube mail system which are the inability to carry special delivery parcels due to the size of the carriers and because of that can carry only five pounds of mails in each container (Shibani et al., 2016).
62.Costs and funding Related to the acceptance issue is financing. Investment costs can be considered factors that influence the underground infrastructure planning. When making the pipeline network a capsule, it is necessary that the network offers a long-term transport solution.

Gaps
However, obtaining a financial asset will only be possible if the technology proves itself. Operating costs will then depend on maintaining a constant flow of products through the pipeline (Egbunike and Potter, 2011). The cargo transportation prices are rising each year. The high cost of creating and maintaining the vacuum tube and the tracking pipeline itself (Shibani et al., 2016).

By over viewing the list of gaps, it is evident that some of the gaps are present in more TCsF. This is the case, for example, with Safety (TCF1, TCF5, TCF6,), Regulations (TCF1, TCF4, TCF5, TCF6) and Costs (TCF3, TCF5, TCF8, TCF9, TCF10, TCF11). Their grouping would provide a general picture on the guidelines for research needs, investment priorities and regulation necessities for removing obstacles. In this report, ranking of research gaps has been done by taking into account TCsF priority lists given in D3.2. Based on ranking of TCsF for passenger and freight transportation, Table 49 contains a list of prioritized research gaps.

Table 49. List of priority gaps

RANK	*PASSENGER*	*FREIGHT*
1.	**TC8 High-speed rail**	**TC1 Automation – Passenger and Freight Transport**
	• Changes in environmental, human health, resource, and climate change impacts • Costs and challenges facing the HSR	• Security, Cyber security • Social justice and equity • Repositioning • Increased congestion and pollution • Revenue for city • City infrastructure • Safety • Technology maturity • Infrastructure • Infrastructure (in metro) • Functional safety • IT security • System integration • Changes in the ports • Regulatory Framework • Insurance
2.	**TC5 Personal air transportation – “flying cars”, “flying taxis”**	**TC6 Delivery Drones**
	• Cost and accessibility • Safety • Affects other sectors • Air traffic control and infrastructure • Regulation	• Requires investment • Drone insurance • Drone financing • Flying drone bill of rights • Order staging • Designated delivery spots • Classification system for drone and cargo • Regulation • Licensing (Vehicle, Pilot, Operator) • Education for the drone police, for drone lobbyists, for drone maintenance and repair, Education & certification for drone pilots • Conditional awareness

RANK	*PASSENGER*	*FREIGHT*
		• Safety • Shipping big-ticket items • Override kill switch • Docking systems
3.	**TC1 Automation – Passenger and Freight Transport**	**TC2 Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS**
	• Security, Cyber security • Social justice and equity • Repositioning • Increased congestion and pollution • Revenue for city • City Infrastructure • Safety • Technology maturity • Infrastructure • Infrastructure (in metro) • Functional safety • IT security • System integration • Changes in the ports • Regulatory Framework • Insurance	• MaaS can still face strong competition from existing travel applications • Policy Framework for Implementation of MaaS • Travel demand modelling for MaaS
4.	**TC3 Electrification – Passenger and Freight Transport**	**TC10 Freight consolidation hubs, Freight Distribution Centres**
	• Electric parking spaces • Uncomfortable and slow charging • Limited range • Space required for storing electricity (battery) in the vehicle • Accessibility and awareness • Higher initial cost • Power solutions • Management and standardization competencies	• Organizational and contractual problems often limit effectiveness. • Increase in delivery costs • Potentially high set up costs (and sometimes high operating costs)
5.	**TC9 Hyperloops**	**TC3 Electrification – Passenger and Freight Transport**
	• Deadly Collisions • Construction cost and Environmental impact • An easy terrorist target • New management challenges	• Electric parking spaces • Uncomfortable and slow charging • Limited range • Space required for storing electricity (battery) in the vehicle • Accessibility and awareness • Higher initial cost • Power solutions • Management and standardization competencies
6.	**TC4 Seamless transport chains**	**TC4 Seamless transport chains**
	• Efficient management systems • Coordination and collaboration	• Efficient management systems • Coordination and collaboration

RANK	*PASSENGER*	*FREIGHT*
	Regulations • Technology acceptance	Regulations • Technology acceptance
7.	**TC7 Smart use of travel time**	**TC11 Superfast Ground and Underground Transportation, Cargo Tubes, Underground Freight Pipelines**
	Obstacles of TC1	• Technology acceptance • Intermodal transfer with existing modes • Costs and funding
8.	**TC2 Shared mobility, on-demand mobility, MaaS, TaaS, FaaS, LaaS**	
	• MaaS can still face strong competition from existing travel applications • Policy Framework for Implementation of MaaS • Travel demand modelling for MaaS	

5 Conclusions

This report gives an overview of prioritized research gaps in both passenger and freight transportation. It is based on the most important transport concepts of the future, described in the INTEND report D2.2. For each of these concepts, we have identified and elaborated relevant literature. It has enabled us to define a list of most important breakthroughs, but also obstacles that have potential to slow down or even prevent the development and implementation of suggested TCsF. By crossings of breakthroughs and obstacles, we were able to determine existing research gaps for both transportation sectors.

In addition, obtained list of gaps has been adjusted to the list of prioritized TCsF, given in the INTEND Report D3.2. This process has enabled us to also identify prioritized research areas (gaps) for further implementation of each TCF.

Concerning passenger transportation, TCF "High-speed rail" can be selected as the TCF with the highest priority (INTEND Report D3.2). Our analysis has clearly pointed out the research gaps that could be particularly important for future development of this TCF. These are:

- **Changes in environmental, human health, resource, and climate change impacts** (spatial incompatibility between HSR and other long-distance modes that is often ignored; an environmental review process that obviates modal alternatives; siloed interest in particular environmental impacts; dearth of data on future vehicle and energy sources; poor understanding of secondary impacts, particularly in land use).
- **Costs and challenges facing the HSR** (Total per mile costs of providing rail service increase significantly with increases in travel speed, but ridership also increases with faster speeds, albeit less dramatically. Hence, there is a "sweet spot" where ridership and costs are optimized. This sweet spot also varies from corridor to corridor. The feasibility and benefits of higher and high speed rail investments depend primarily on ridership. Therefore, it is important to focus initially on connecting major mega-regions with proven demand. Certain metropolitan regions are more conducive to high speed rail by virtue of existing land use patterns and complementary public transportation service. It is important to provide rail service where people and economic activity are already concentrated, but it is also important to plan ahead for growing cities and regions).

By following the same approach, we can identify the most important research areas for further development of TCF "Automation", as TCF with highest priority for freight transportation sector. These are:

- **Security, Cyber security** (Automated vehicles could be used for terrorist attacks (as ar bomb for instance) without any physical risk and with much lower risks of detection for the terrorist. Moreover, automated vehicles could be hacked for malicious purposes; "Another question is cyber security", "How do you ensure that these cars cannot be hacked? How vehicles become smarter and connected, there are more ways to get in and disturb what they do." This should not be impossible to fix. Software companies have long been facing this problem).
- **Social justice and equity** (There is a risk that AV would benefit more from the rich and create a higher burden for low-income people. These without AV can be in a disadvantageous position when it comes to employment, because they can work with AV and respond to e-mail while travelling).
- **Repositioning** (After having dropped their passenger, the AVs will now have to drive to places where parking is available (or cheaper), or to catch other users (which could be other family members, or, in the case of shared cars, third parties); this "repositioning" could have an important impact on traffic flows).

- **Increased congestion and pollution** (Increased congestion and pollution caused by travel by those currently unable to drive, such as young people without driving license, the physically impaired, and elderly people. It is not clear to what extent autonomous cars will really lead to shorter headways. One should not compare the theoretical safety distance between AVs with the theoretical safety distance between vehicles driven by humans as a lot of people drive closer to the preceding car than is justified on safety grounds).
- **Revenue for city** (AVs will not go to red light, they will not accelerate to the highway over the permitted border or park outside the permitted parking space. This, however, will affect the city budget. In some cities, traffic fines make a significant percentage of the city's budget. Cities will need to generate new revenue streams to counter the loss of funds).
- **City Infrastructure** (Often, AVs require a clear striving stripe, storage locations for data collected during guidance, and a robust network of climbing if they are working on electricity).
- **Safety** (Obstacles to the advancement of automation depend on basic safety concerns (a key problem due to potential loss of life and poor publicity that may be the result of a collision of aircraft). For the adoption of passenger drones and flying cars (especially fully autonomous), operators of these vehicles should show a safety record covering both mechanical integrity and safe operations. As has been shown in autonomous cars, any accidents can have considerable attention and can slow down the adoption of such a concept).
- **Technology maturity** (Although GPS technology exists and is used in autonomous cars, it should be improved to provide remote sensing and recognition needed to deal with the multi-way and fast convergence associated with the autonomous flight. These vehicles would require advanced technologies, such as artificial intelligence, to allow advanced detection and avoidance capabilities. Machine learning can be essential since operations move from piloted to autonomous: the vehicle should learn from pilots on the basis of over a thousand working hours to become completely autonomous over time. Energy management is crucial: to have enough energy to transport passengers or cargo, to maintain a safety margin and reload for the next flight. Although the technology of using batteries as a source rapidly improves, in order to increase the capacity of passengers and cargo and extend the range of passenger drones, it is necessary to further improve or to find alternatives).
- **Infrastructure** (In terms of infrastructure, it is necessary to provide the appropriate landing and landing zone, as well as the charging stations for the battery. A broad network requires new infrastructure or the conversion of existing infrastructure (such as helipads, roofs of large public buildings and unused land). In order to provide a unified traffic management system, additional infrastructure along the predefined flight corridors should be installed to help rapidly communicate data and geolocation. All these changes in infrastructure would require cooperation with commercial actors and local urban planning bodies).
- **Infrastructure – metro** (Modification or replacement of vehicle fleet and signaling system and additional complexity can increase costs in comparison with other signaling and control systems. Closing an existing system over a longer conversion period is likely to be difficult and costly, as existing metro lines often represent vital links in the urban transport network. In order to ensure high levels of security, a greater degree of physical segregation from the environment will be required than for trains in which a driver can react to extraordinary or unexpected events such as collapse, burning trees or damage

to the infrastructure. This is not so significant for underground lines as it is important when converting a surface infrastructure that was not originally designed for such a high degree of isolation. A very high percentage of runs on which trains are currently running without a driver are underground or raised. By contrast, most of the metro is at the ground level, and it is likely that the peripheral line should be upgraded, as the crossing is a daily problem on the metro paths. It is necessary to improve the system of communication and tracking for passengers throughout the system in order to provide functions that would otherwise be performed by a staff member. This also applies to remote monitoring and correction (where possible) of equipment faults by the remote control center. The equipment requires a high degree of reliability and availability to ensure the safety of passengers. Such systems would represent **additional capital and maintenance costs**).

- **Functional safety** (Higher system complexity increases potential error rates and demands new functional safety approaches).
- **IT security** (More digitised and interconnected systems are exposed to numerous hazards and vulnerabilities).
- **System integration** (Smart systems need to communicate across rail services, transport modes and infrastructure).
- **Changes in the ports** (Increased ships' automation will require some changes in the ports, e.g. for maintenance of ships, as well as for increased automation in both approaches and landing).
- **Regulatory Framework** (So far, the legislation governing autonomous ships is totally unclear. The main concern concerns the provisions on the number of crew members and safety, as well as the construction standards. According to IMO International rules, all ships should be employed with a minimum number of crew members in order to be able to navigate. This rulebook should be amended to include vessels with special characteristics that will allow them to sail with less or no crew on board. The same situation is with regard to the safety of the ship, where minimum standards regarding the conditions of vessels and equipment should be applied. Building and maintenance standards that classification societies also provide should be materially supplemented, and these societies will require people with expertise in autonomous technologies. Safety in navigation and responsibility: it is probably the main concern of people who are still cautious about autonomous ships. A boat sailing in the open sea faces many risks associated with weather, other hurdles, or even risking being threatened by a third party (e.g. pirates). So, such an autonomous ship should be very intelligent to be able to control any potential risk).
- **Insurance** (Existing insurance (..., war risks, piracy risks, cargo insurance...) should be available. However, premiums may vary depending on the level of actual risks in the navigation of automation vessels).

Through the same approach, we can identify research gaps that are particularly important for further development of each TCF. Therefore, our gap analysis enables overviewing of obstacles that can influence the implementation of TCsF. It clearly points out the importance of the selected gaps for structuring and definition of the future transport system.

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