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Transport and climate change:
Critical role of inland transport in accelerating climate change mitigation

Accelerating the inland transport sector`s climate change mitigation measures - lessons learned from the aviation and maritime sectors*

Note by the secretariat

I. Mandate

1. The ECE Inland Transport Committee (ITC), at its eighty-fourth session, in February 2022, welcomed document ECE/TRANS/2022/16 on the critical role of inland transport in accellerating climate change mitigation worldwide and on the overview of related activities by the Committee and its Working Parties.

2. In this regard, ITC expressed its resolve that its Working Parties should take further action to accelerate their work and impact for climate change mitigation and adaptation and to achieve that, invited them to submit to the by mid-October 2022 their ongoing contributions, future plans, and suggestions in support of climate change mitigation. ITC also requested the secretariat, in consultation with the Bureau, to prepare a comprehensive paper with these activities and action-oriented options for the Committee and Working Parties for consideration at the Committee`s eighty-fifth plenary session in February 2023.

3. In response to this request the WP.5 secretariat, in order to initiate a specific discussion at WP.5 which serves as a think tank for ITC, has compiled the current document which provides an overview of what the aviation and maritime transport sectors are doing in reducing their environmental footprint and identifies lessons learnt and possible next steps for the inland transport sector to increase its own efforts.

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4. WP.5 is invited to share its feedback on the proposals contained in the document and provide guidance on how it sees its own role and the role of ITC in further advancing the inland transport sector decarbonization agenda.

II. Introduction

A. Global environmental effects of transport sector

5. Transport plays a vital role in today's society and economy. However, transport is one of the key sources of environmental pressures around the world and contributes significantly to climate change, air pollution and noise. Generally, transport is known to have various environmental impacts. Transport emissions lead to climate change and air pollution, noise results in health risks and infrastructure developments have severe impacts on the ecosystems and the landscape. This includes emissions from both, passenger and freight transport [1].

1. Impact of aviation

6. Aviation refers to all forms of activities with regards to aircrafts that carry people along with goods. It is estimated that 4.56 billion people used some form of aviation pre Covid Pandemic in 2019. It is also estimated to have carried 221,496 million tons of freight between destinations [2]. Like all major forms of transport, aviation emits CO_2 through the usage of jet fuel and is considered a net positive driver towards climate change [3]. Modern innovations in both the technology and the fuel have significantly improved fuel consumption since the 1970's, however the total emission is predicted to keep rising for the foreseeable future. One of the key impacts of aviation on climate change is through aviation cloudiness. It is stated that 2.5per cent of all CO_2 emissions globally and 1.9 per cent of GHG come from aviation [3, 4]. Aviation emissions are not attributed or included in the emission for a country by default; domestic flights are included whereas international flights are not, instead, they are assigned a special designation. The logic behind this is sound, as most international flights travel over multiple countries and it would not be feasible to assign it to one specific country.

2. Impact of maritime transport

7. Huge volumes of global maritime transportation result in negative and unintended effects on the environment including marine environment. Environmental effects of maritime transport include: air pollution, GHG emissions, releases of cargo residues, and many others [5]. Ship emissions tend to have substantial environmental effects with international shipping voyages contributing significantly to air and water pollution, mainly due to the long journey lengths. Emission of GHG and volatile organic compounds from maritime transport can lead to enhanced surface ozone formation and methane oxidation, depleting the ozone. Emissions from bunker fuel burned by the international cargo and passenger fleet represent a significant contribution to the global anthropogenic emissions, and particularly, for Nitrogen Oxides (NOx) and Sulphur Oxides (SO_X) [6]. International shipping accounted for ~2per cent of global energy-related CO_2 emissions in 2020 and 3per cent of global greenhouse gas (GHG) emissions [7, 8, 9, 10].

3. Impact of inland transport

8. Inland transport refers to all transport activities that are performed on land and covers transport done by road, rail and inland waterways for the transfer of people and goods [11]. Road transportation is one of the main sources of atmospheric pollution in urbanised areas. Environmental issues start to arise in large cities mainly due to urbanism and mobility [12]. Road transport, mainly involving the use of cars, buses, trucks and vans, accounts for greater than 70per cent of the overall GHG emissions resulting from the transport sector in the EU, thus being the main source of environmental pollution. Also, road transportation is known to be the main contributor to local air pollution [13, 14, 15].

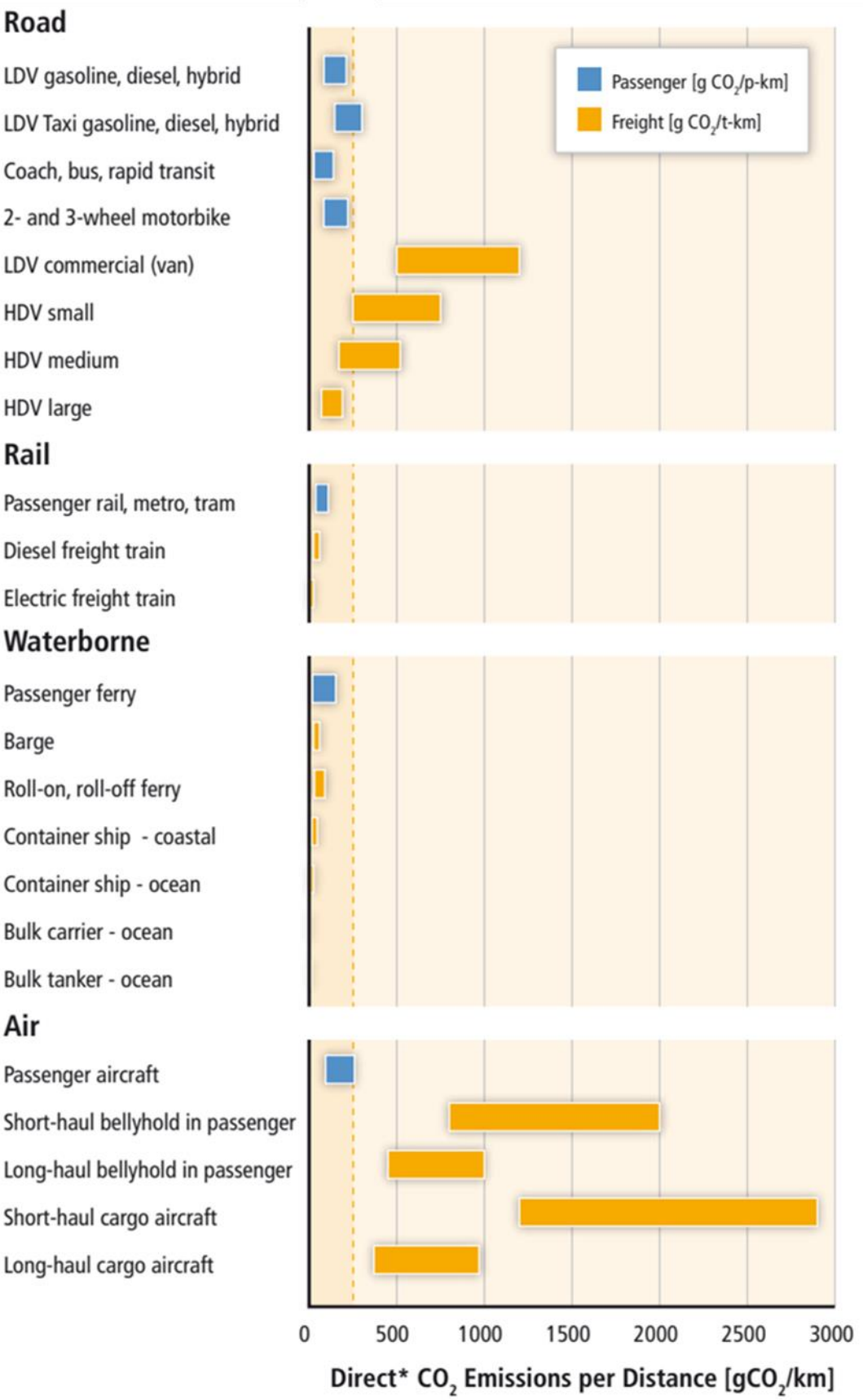
9. Rail transportation sector encompasses multiple modes of urban travel (including electrified or non-electrified trains, trams, underground rail), medium and long-distance journeys (involving regional or highspeed trains), as well as goods transport (mainly freight)

[16]. Amongst the environmental impacts due to rail transport, GHG emissions, air pollution and noise pollution are the most significant environmental impacts. Globally, rail is a mode of transport that does not emit much in the way of greenhouse gases (1per cent of global CO_2 emissions from transport). However, significant differences exist in the CO_2 emissions from the railway transport sector as emissions are based on the types of trains, their power requirements and further characteristics [17, 18]. In terms of the determining factors of GHG emissions in rail transport, these are a combination of rail travel demand along with factors such as the GHG emission intensity of energy consumed, rail traffic management procedures, number of passengers and the specific energy consumption of the passenger trains [19].

10. Inland waterway transport has a small participation in the total amount of emissions from transport (about 0.5per cent of total GHG from transport), but locally, this share can vary [20, 21]. One study showed that 30per cent of ships cause more than 80per cent of the total emissions [22]. It appears that this is the case due to engine longevity and less strict emission restrictions for inland shipping as compared to other land-based transport mods. In addition, the fairly specific and small market for inland vessels causes disadvantages of scale. Therefore, while it is concluded that inland waterway transport emits relatively few GHG emissions, these can have rather high values for pollutant emissions (NOx), when compared to trucks and railways [21]. It is understood that although there are not many inland waterway vessels, the ones which are being currently used have old diesel engines that result in an increased pollution.

11. Figure 1 shows the typical ranges of direct CO2 emissions per passenger kilometre and per tonne-kilometre for freight, for the main transport modes, when fuelled by fossil fuels including thermal electricity generation for rail. Based on the data presented in Figure 1, it appears that for each mode of transport, CO_2 emissions per kilometre of each vehicle vary widely. Inland transport, mainly road transportation contributes significantly to the global CO_2 emissions. For waterborne transport, the particularly wide range of boat sizes and types gives higher variance [23, 24].

Figure I
Typical ranges of direct CO_2 emissions per passenger kilometre and per tonne-kilometre for freight (Adapted from Sims et al., 2014 [24]).



B. Transport, the Sustainable Development Goals and Paris Agreement

1. Sustainable transport

12. Sustainable transport is a cross-cutting accelerator that can fast-track progress towards other crucial goals such as eliminating poverty in all its dimensions, lowering inequality, and combatting climate change. As a result, sustainable transport is crucial in achieving the 2030 Agenda for Sustainable Development as well as the Paris Agreement on Climate Change. These goals can only be realised if interlinkages between Sustainable Development Goals (SDGs) and sustainable transport, as demonstrated in Figure 2, are well understood along with recognising the targets of these goals [25, 26, 27].

Figure II
The Sustainable Development Goals and their interlinkages with the transport sector.

2. UNFCCC GHG mitigation target as defined in the Paris Agreement

13. The Paris Agreement is a legally binding global treaty on climate change which sets out a goal to limit global warming to well below 2°C, while engaging in efforts to limit it to 1.5°C. This agreement has been adopted by several Parties to the United Nations Framework Convention on Climate Change (UNFCCC). The treaty is also intended to reinforce the ability of involved countries in tackling the impacts of climate change, mainly through long-term temperature goal, global peaking and climate neutrality, and mitigation efforts. Appropriate mobilisation as well as the provision of financial resources along with the setup of a new technology framework and enhanced capacity-building is needed to reach these ambitious goals of the Paris Agreement [28, 29, 30].

3. Transport NDCs and contributions from inland vs maritime vs aviation

14. Nationally Determined Contributions (NDCs) are the centre of the Paris Agreement and represent each country's effort in reducing national emissions while adapting to the impacts of changing climate. As part of communicating their NDCs and as a contribution to the objectives of the Paris Agreement, involved Parties have submitted comprehensive national climate action plans [29, 30].

15. The Sustainable Low Carbon Transport (SLoCaT) review of NDCs confirmed that several countries around the world have acknowledged and identified the significance of their transport sector in achieving the national emission reduction targets while identifying that transport is an important source of GHG emissions. As a result, mitigation actions for the transport sector have been defined in more than 100 NDCs [31].

16. Analysis of the transport mitigation actions provided in the NDCs from emerging and developed countries demonstrate that the list of mitigation actions is strongly focused on fuels, vehicles and urban transport. Another area that was highly recognised was the road and railway infrastructure while only few counties noted the freight logistics.

17. With respect to the Avoid-Shift-Improve strategies, a closer look at the NDCs show that a majority (52per cent) of the mitigation measures listed in the NDCs correspond to 'improve' strategies, while only 38per cent represented 'Shift' strategies and a very few (10per cent) represented the 'Avoid' strategies [32, 33, 34].

18. Aviation and maritime are among the top ten recommendations provided for raising ambitions for the transport NDCs as these are considered the two fastest growing sectors.

Using the full range of Avoid-Shift-Improve strategies is essential for addressing the rapidly growing emissions from the aviation and maritime transport sectors while also aiming to meet the objectives of the Paris Agreement. Examples of "avoiding" strategies for aviation include receiving support for aviation taxes and charges and providing teleworking arrangements. In terms of "shifting" strategies, these can include for example the attempt to shift to high-speed rail services that can help replace domestic flights or even international flights in some cases. "Improving" strategies look at the adoption of newer fuels, better operations and development of more efficient aircraft designs. It has been recommended that countries use the support of the International Civil Aviation Organization (ICAO) and the International Maritime Organization (IMO) in proposing and supporting goals on international aviation and maritime transport, respectively.

19. In terms of maritime transport, several countries have taken some initiatives for including domestic maritime emissions in their transport NDCs. These include [35]:

- Promoting the growth of coastal shipping and inland water transport;
- Improving maritime traffic management;
- Accelerating promotion of energy efficient measures for domestic fleet;
- Implementing projects on green ports.

20. Overall, some common examples from the NDCs for the transport sector include setting targets for increasing the size of fleets of electric vehicles, replacing domestic flights with high-speed rail services, phasing out the sale and usage of internal combustion engines, promoting and increasing the share of walking and expanding mileage of mass transit [31].

III. Overview of international transport sector initiatives and identification of lessons learned for inland transport

A. Aviation

1. International Civil Aviation Organization Carbon Offsetting and Reduction Scheme for International Aviation (ICAO CORSIA), including Sustainable Aviation Fuels (SAF)

21. To lessen the impact of aviation transport on climate change, a scheme known as CORSIA has been developed by ICAO. CORSIA, is a carbon offset and carbon reduction programme to lower CO_2 emissions for international flights. The scheme aims to have a carbon neutral growth from 2020. To do so, CORSIA makes use of market based environmental policy instruments for offsetting CO_2 emissions.

22. Long term sustainability in aviation will need to be supported by cross-stakeholder collaborations and technological improvements. With regards to technological innovations, key areas of focus need to be aviation design, alternative propulsion systems and long-term vision on the development of sustainable aviation fuels (SAF). The development of SAF will require multiple angles of attack such as capital investments in the production, distribution, policies on transporting them, and financial feasibility. The ICAO estimates that through technological advancements, 33per cent of emissions can be reduced in lieu of business as usual scenario. It also estimates that 100per cent of the estimated demand can be met with SAF, which will in turn lead to a 63per cent reduction in global aviation emissions. As stated before, this will require massive levels of investment that exceed current levels for ethanol and biodiesel for road transportation.

23. Fuels for commercial flights have to meet a particular standard, and this also applies to SAFs. To accelerate the global market adoption for SAFs, governments of France and Netherlands are leading the way to position SAFs to have a competitive advantage. This is targeted to an ever-increasing segment of customers who seek environment and green initiatives in order to reduce the carbon footprint, green-fuel purchasing coalitions and propose investments for both new and existing production plants and refineries.

24. ICAO has established a global framework to facilitate the reduction in carbon footprint and explore the usefulness of targeting long-term CO_2 reduction. It will have a blend of key metrics and measures, which can include technology and innovations, performance measures, and CORSIA with a vision for 2050 by which most fuels used in aviation will be SAFs.

25. Domestic aviation is estimated to produce 40per cent of total emissions as they account for 2/3 of all flights. Policies implemented will need to focus on both CO_2 and non-CO_2 effects and further investigation is required to develop the right actions plans. With the vision of SAF adoption by 2050, Climate Champions are targeting a 10per cent adoption by 2030 and 90per cent by 2040, thus representing an S-curve. Current forecasts of the SAF range for top-down and bottom-up levels suggest that it will form a significant mix in the next decade. This analysis makes assumptions about the availability of bio-fuels, synthetic fuels and technological advancements [32, 36].

2. Other ICAO initiatives

26. The International Coalition for Sustainable Aviation, consisting of several non-profit organisations is working on reducing air travel pollution. It is the only environmental civil society group recognised as an observer by the ICAO. ICAO Global Coalition for Sustainable Aviation is a forum of stakeholders that look at promoting sustainable growth of international aviation. This is done by accelerating the progress of innovative concepts and solutions that can further reduce GHG emissions at source, on the ground or in the sky. Additionally, the Coalition can deliver critical inputs needed to make advance progress in the development and implementation of the basket of measures, as well as for the exploration of a long-term environmental objective for international aviation. Stakeholders part of this Coalition are involved with aviation infrastructure, operations, technology, and Sustainable Aviation Fuels, along with the CORSIA as the complementary measure to achieve the environmental objective. As part of this Coalition, a CO_2 emissions reduction initiatives tracker tool is produced that offers a wide range of information relevant to initiatives for reducing the environmental footprint of aviation, including details on past and ongoing measures and initiatives [37, 38].

27. ICAO has also launched a State Action Plan initiative in 2010 to provide States with the capacity and tools to take action. The initiative is designed to enable all member States to determine a long-term strategy on climate change for the international aviation sector. Involved parties work together to find a quantified baseline scenario, select appropriate emissions mitigation measures from ICAO's basket of measures, and calculate the expected results of implementing those measures [39].

28. Another excellent initiative of ICAO is the development and maintenance of several environmental tools that are made available to States and the general public. These tools, which include the carbon emissions Calculator, the Green Meetings Calculator, Fuel Savings Estimation Tool amongst many other tools, are designed to support the development of State Action Plans, the implementation of CORSIA and to support initiatives to reduce aviation's carbon footprint [40].

B. Maritime

1. International Maritime Organization (IMO) Ship Emissions Toolkit

29. It has been estimated that over 80per cent of the international goods trade is carried by sea. However, due to the sheer scale of the international shipping industry as compared to other transport modes, emissions from the shipping sector remain a cause of concern. With the growth in international trade, shipping is also forecasted to grow.

30. Over the years, IMO has implemented and shown strong and decisive leadership skills in creating legal as well as technical frameworks within which the shipping industry can become progressively safer and cleaner. In 1997, great efforts were taken for reducing air emissions from ships, by adopting the 1997 Protocol to the International Convention for the Prevention of Pollution from Ships, known as MARPOL Annex VI. This protocol controls

air emissions from more than 95per cent of the world's shipping tonnage and sets limits on Nitrogen Oxide emissions while imposing strict measures that require ships to make use of fuel with low sulphur content.

31. Quantification of ship emissions followed by a strategy on reducing them is needed for reducing emissions across the maritime sector. To tackle these issues, IMO has produced a Ship Emissions Toolkit, which offers a well-defined framework along with decision support tools [41].

(a) Rapid assessment of ship emissions in the national context

32. The first practical guide of the Ship Emissions Toolkit is based on the "Rapid assessment of ship emissions in the national context". This guide offers steps on gathering and analysing relevant qualitative and quantitative data that can be used to assess the overall maritime emissions from a country, followed by providing a foundation for developing and implementing a national ship emissions reduction strategy. The guide suggests the importance of comprehending the interlinkages between different institutions and ministries for the effective implementation of policies at the national level.

33. Countries are required to adopt laws and regulations for preventing, reducing and controlling pollution from the marine environment by taking necessary measures. Usually, regional collaborations tend to focus on the research, development and demonstration of low-carbon energy technologies along with the development of policy frameworks that can all be used for promoting the implementation of efficient technologies within various national contexts. The recommended rapid assessment must comprise of a list of key national, sub-national or local institutions as well as agencies that are deemed to have a part in this area.

34. The guide encourages the inspection of foreign ships in national ports. This can help in verifying the conditions of the ships and ensuring whether the relevant equipment comply with the international regulations, while making sure that the ships are equipped with the right personnel that comply with these rules. The guide also supports the application of various ship environmental evaluation schemes and port incentive schemes for monitoring a ship's air emissions and energy efficiency.

35. The rapid assessment guide also discusses the importance of assessing the volume, type and value of goods imported and exported internationally by a country along with identifying the main trading partners for each cargo category for bettering understanding of the importance of seaborne transportation in each country.

36. As part of the rapid assessment activity, it is advised to identify relevant stakeholders and why they are important and how they can contribute to either this activity or to the development and implementation of strategies in the future. It is also important to identify the ships that are of importance to the country and their respective characteristics. To do so, fleet components are considered and analysed based on registered fleet, domestic fleet, international fleet, fleet passing territorial waters and fleet owned by national shipowners. Thereafter, it will be easy to estimate emissions and fuel consumption of each of these components. For possible emission scenarios, the rapid assessment suggests looking at the predicted economic development levels of each country. Such data is most likely presented in the national development plans of each country [41].

(b) Incorporation of MARPOL Annex VI into national law

37. The second practical guide of the Ship Emissions Toolkit is based on the incorporation of MARPOL Annex VI into national law. The guide provides an outline of the different considerations a state needs to take in account when deciding to accede to the 1997 Protocol and to thus become a part of the MARPOL Annex VI. Prior to the accession process, it is suggested that the interested states form a good understanding of their shipping industry, based on the guidance provided in the first practical guide. Such information can be relevant in developing a strategy for reduction of national ship emissions. Thereafter, a series of actions may be taken for the incorporation of MARPOL Annex VI into national law. These can be achieved through conducting an evaluation of the existing policies, legal and institutional frameworks to establish the actions required for accession or for the incorporation. Surveys of existing legislation can also be performed to identify any barriers

that may exist to the accession or full implementation of the obligations. Finally, periodic reviews and regular updates to the national legislation should be provided. Once again, consistent engagements and consultations with relevant stakeholders in all of these steps are strongly recommended. To do so, national workshops or any other consultation approaches may be utilised. Also, involved states may develop a broader national policy framework for addressing maritime emissions. On the other hand, broader government policies for addressing air emissions from all sectors may provide incentives to include maritime emissions as well [42].

(c) Development of a national ship emissions reduction strategy

38. The third guide of Ship Emissions Toolkit discusses the crucial planning, development and implementation phases that are involved in the creation of a national ship emissions reduction strategy. Although IMO has adopted MARPOL Annex VI for reducing air pollution from maritime transport while increasing the energy efficiency of ships, it seems that these and other international policies, regulations and strategies are often generic in nature and are usually designed to be applied as broadly as possible. Such approaches need to be operationalised within a national context, which includes looking at the local, national and regional issues.

39. For the process of developing and implementing an appropriate national strategy that includes consultations and collaborations with all relevant stakeholders and agencies, it is recommended that a lead agency is established, a task force is set up, and a national focal point and project coordinator is chosen. Also, securing political buy-in at the soonest is crucial throughout the process. To maintain regular participation of all stakeholders and government entities involved, it is important to have effective communication and dissemination schemes. Development of any national strategy would require the aim, objectives and actions, and capabilities of the strategy to be aligned with the broader national interest. This is to be followed by the implementation plan [43].

(d) IMO's Energy Efficiency Design Index (EEDI)

40. IMO has taken numerous positive steps towards concentrating on reducing GHG emissions from ships. One such technical measure is the development of the Energy Efficiency Design Index (EEDI) that has been made obligatory for all new ships. This measure looks at encouraging the use of more energy efficient and less polluting equipment and engines by requiring a minimum energy efficiency level per capacity mile for different vessels.

41. The EEDI offers a precise value for each ship design, where the lesser the EEDI is, the more energy efficient is the ship design. EEDI is calculated using a specific formula based on the given ship's technical design parameters. The first phase's CO_2 reduction target is set at 10per cent, and this ratio will be adjusted every five years to keep up with technical advances in the new efficiency and reduction methods [44, 45].

(e) Other initiatives, including measures aimed at electrification and the use of green hydrogen to fuel vessels

42. The maritime transport sector must discontinue the use of fossil-based bunker fuels and move towards implementing zero-carbon alternatives in order to reach the climate targets set out in the IMO's initial GHG strategy. Such alternatives must look at emitting zero or at most very little GHG emissions throughout their lifecycles. A few research studies have examined a number of such zero-carbon bunker fuel options which include synthetic carbon-based fuels, hydrogen and ammonia and biofuels. Green hydrogen and green ammonia seem to demonstrate the best balance of favourable features because of their GHG emissions, safety and technical implications, economics, scalability and overall wider environmental factors. It also appears that many countries including developing countries have the potential to produce zero-carbon bunker fuels i.e., hydrogen and ammonia. However, to unlock these potentials, strategic policy interventions are required [46].

43. Furthermore, in accordance with the Paris Agreement's temperature goals and consistent with the IMO GHG strategy, work has been done to understand the role of

liquefied natural gas (LNG) in the transition toward low- and zero-carbon shipping. LNG is commonly mentioned as a fuel pathway towards cleaner maritime transport because of its substantially lower air pollution and potential GHG benefits. However, there are also concerns regarding the ability of LNG in decarbonising the shipping industry. It appears that due to methane leakage issues, which could negate any GHG benefits of LNG, and based on the extra capital expenditures needed, LNG is unlikely to play a significant role in reducing emissions in the maritime transport sector. On the other hand, LNG is expected to be used only in niche shipping applications or in its non-liquefied form for feedstock to initiate the production of zero-carbon bunker fuels. It is also advised that new public policies supporting the use of LNG as a bunker fuel must be avoided, while any existing policies must be reconsidered, and methane emissions be regulated [47].

C. Cross-cutting

1. SLOCAT Partnership on Sustainable Low Carbon Transport

44. Sustainable, Low Carbon Transport (SLOCAT), as a multi-stakeholder international partnership is primarily focused on inland transport through three mutually reinforcing work packages, which are the knowledge and policy analysis; advocacy and engagement, and dialogue and networking.

45. The partnership involves engagements from more than 90 entities including transport sectors associations, academic organisations, governmental bodies, and several other industries as well as world-class experts and change-makers. The partnership looks at setting new and ambitious global agendas and for catalysing innovative thinking towards finding solutions for the urgent need of transforming mobility systems.

46. This shall be achieved with the integration of sustainable, low carbon transport in global policies on sustainable development and climate change and through action in support of the adoption of these global policies [48].

47. The partnership also looks at synthesising and translating data and knowledge on combined transport, climate change, and sustainability issues by providing leadership and advocacy skills. As part of this initiative, a platform is also provided to individuals within and beyond the transport sector to collaborate, learn and exchange information [49].

2. European Commission – European Strategy for smart and sustainable mobility and the EU Green Deal

48. To tackle transport-related emissions, in 2020, the European Commission presented its “Sustainable and Smart Mobility Strategy”, with the aim of accomplishing European Green Deal’s climate targets. To support the EU's goal of being the first climate-neutral continent, a significant goal of this strategy is to achieve a 90per cent reduction in transport related GHG emissions by 2050. The strategy looks at providing more cleaner, healthier, accessible and affordable transport alternatives. It also contributes to the mitigation of climate change impacts due to the transport sector by considering approaches on the reduction of air, noise and water pollution. The strategy lays foundation for the digital transformation of the EU transport system and highlights the significance of enhancing transport resilience. Overall, the strategy is aimed on making all modes of transports sustainable and ensuring sustainable alternatives are available in a multimodal transport system. To do so, the strategy also looks at placing the right incentives for driving the transition. In addition, the initiative discusses the need for investments in sustainable alternative fuels and cleaner technologies along with renewals of transport fleets by public authorities and companies to achieve the much-needed transition.

49. The strategy builds on the other Green Deal actions and initiatives that have already been deployed by the sector. Thereafter, a roadmap shall be set up towards a European mobility that is suitable for a digital, green and resilient future. A clear policy framework is to be set by the strategy that looks at the following points [50, 51]:

- By 2050, reduce the transport sector's GHG emissions by 90per cent while significantly reducing air pollution and overall environmental footprint of transport sector by:
  - enhancing the uptake of zero-emission vehicles;
  - creating incentives for the deployment of large-scale new technologies, including usage of sustainable alternative fuels and associated infrastructure;
  - facilitating the shift towards low emission transport modes;
  - improving efficiency and multimodality;
  - creating incentives for sustainable consumer choices;
  - revamping the European agenda on sustainable urban and regional mobility, including cycling, intermodal transport and transport-on demand.
- Utilise the digitalisation and automation concepts fully for achieving sustainable, safe, smart and seamless transport mobility across all modes;
- Identify actions to revitalise and strengthen the Single Market for transport;
- Mobilise research and encourage innovative solutions for a leading EU transport industry;
- Ensure a fair, affordable, accessible and attractive transition and mobility.

50. Overall, EU Green Deal's comprehensive strategy is an outstanding initiative that covers all modes of transport and imposes a target to reduce transport related GHG emissions. The objectives are some exceptional ideas that should be very effective in accelerating a shift towards low emission passenger transport modes, if applied successfully. These policy proposals for zero-emission vehicles need to be adopted in a manner which allows regions and cities to keep pace with the essential expansion of various concepts such as fuelling and charging infrastructure, regional and local distribution networks, and renewable energy production.

3. COPERT model to estimate emissions from road transport

51. The Computer Programme to calculate Emissions from Road Transport (COPERT) model is the most advanced method to calculate emissions of almost all important pollutants from road transport, using data on vehicle population, mileage, speed and ambient temperature, among others. The use of the COPERT software tool allows for a transparent and standardized, hence consistent, and comparable data collecting and emissions reporting procedure. It incorporates results of several technology, research, and policy assessment projects and is continuously supported by the European Environment Agency through consecutive ETC budgets. The model covers all classes of vehicles and can be applied in all European countries, in Asia, South America and Oceania. In fact, the model can be used to produce emission estimates from 1970 to 2050 as well [52].

4. Transport Climate Action Directory of the International Transport Forum

52. The Transport Climate Action Directory of the International Transport Forum is a part of the Decarbonising Transport initiative. It covers almost all transport modes including aviation, maritime, rail, road, walking and cycling. It presents an online database of policy measures for reducing CO2 emissions from the transport sector. The database consists of 80 mitigation measures as well as an evidence base required to evaluate the effectiveness of these measures. The directory is created with the aim of assisting decision makers with a range of options which can be used to deliver concrete decarbonisation outcomes and translate transport decarbonisation ambitions into actions while achieving climate objectives. The database also intends to help nations with their NDCs [53].

53. Decarbonisation measures in the directory are presented in the following categories:

- Improved design, operations and planning of transport systems;
- Electrification;

- Low-carbon fuels and energy vectors;
- Mode shift and demand management;
- Innovation and up-scaling.

54. The directory is created in partnership with more than 70 governmental bodies, companies, foundations, institutions and organisations under the umbrella of the International Transport Forum. The directory is an ongoing initiative, where additional measures are reviewed and added constantly [54]. It appears that this provision of a list of mitigation measures in a unique platform is an extremely beneficial idea as decision makers can filter the measures by geographic scope, transport mode, and type of measure.

55. Each measure in the directory features a concise overview that includes how the measure impacts CO_2 emissions as well as relevant benefits and costs of implementing the measure. Information on potential drawbacks can also be found that should help make the right choices.

5. GHG mitigation instruments in the Inland Transport Committee and its subsidiary bodies

56. The Inland Transport Committee (ITC), its Working Parties and the secretariat consider climate change as a cross-cutting subject and have been working to contribute to mitigation and adaptation measures for climate change. These activities supported by the ITC range from high-level policies and regulatory frameworks to assessment of impacts on transport and promotion of adaptation measures that include the sustainability aspect. The activities of some of ITC's Working Parties are summarised in Table 1[55]. A full overview of these activities is available in ECE/TRANS/2022/16**.**

57. In addition to the Working Parties, there are other programme as well such as The Transport, Health and Environment Pan-European Programme (THE PEP) that aim to make transport more sustainable by reducing the environmental impacts of transport, mainly in cities but also in rural communities. THE PEP involves carrying out investigative studies on the adoption and support of green transport. Further work by the ITC also includes looking at understanding and implementing modelling approaches for analysing and quantifying potential impacts of a set of policies on GHG emissions.

58. To analyse and quantify the potential impacts of a set of policies on GHG emissions, For Future Inland Transport Systems (ForFITS) modelling is used in ECE Environmental Performance Reviews (EPRS). As part of the tool, low carbon scenarios are developed to show quantitatively what is needed at the country level and to mitigate carbon emissions and climate impacts from the transport sector. The ITC secretariat is now involved with the development of a ForFITS add-on module to look at the real-time emission of EV during recharge, together with a paper looking at the potential impacts of time resolution and user behaviour on CO2 emissions during EV recharge [55]. Similarly, other activities of the secretariat include looking at e-mobility, Mobility-as-a-Service and Resource-as-a-Service to lower the environmental and climate impacts from electric mobility over the whole supply chain.

6. Other initiatives

59. Quite similar to the aviation and maritime transport sectors, the inland transport sector is also involved in producing several innovative and remarkable ideas for responding to climate change. TNO, the Netherlands Organisation for applied scientific research, has been looking at deploying numerical models for inland transport that can calculate CO_2 emissions for passenger as well as freight vehicles, based on a number of factors. For passenger vehicles, this includes looking at the CO_2 intensity of the vehicle and the mobility demand (activity). The former involves working out the fuel carbon intensity (i.e. looking at what fuel type is being used or if it is an Electric Vehicle), the efficiency of the vehicle (understanding the engine characteristics, weight, aerodynamics and other properties) and the number of occupants of the car (if the vehicle has a single user or multiple users). The latter, mobility demand, depends upon the distance the vehicle travels as well as the alternative options which

are present with the vehicle. For freight vehicles, CO_2 emissions are to be calculated based on the CO_2 intensity of the transportation mode and the respective demand. The CO_2 intensity of the transportation mode can be calculated based on the carbon intensity of the vehicle, the efficiency of the vehicle and the load factor (i.e. looking at the modal share). Understanding the demand for the transport mode includes looking at the distance travelled by the vehicle (supply chain, the logistical systems and the urban planning aspect), different features (sustainability) and the size as well as scale (circular economy, longevity). Overall, these two numerical models, adopted by TNO for the inland transport sector are great initiatives that help obtain an understanding of the real-world emission performance of passenger as well as freight vehicles. A similar concept has also been suggested in Sims et al. (2014) that for each transport mode, direct GHG emissions can be decomposed into [24]:

$$\text{Total GHG Emissions} = \sum_{\text{Modal Shares}} \sum_{\text{Fuels}} \left[\text{Fuel Carbon intensity} * \text{Energy intensity} * \text{Activity}\right]$$

- System-infrastructure modal choice: urban form, transport infrastructure (roads, rail), behavioural choice between modes (speed, convenience, cost, comfort);
- Fuel carbon intensity (Hydrogen, electricity, biofuels, CNG/LPG, gasoline, diesel);
- Energy intensity of light and heavy-duty vehicles, occupancy/loading rate, cycling walking, trains);
- Activity: number of journeys, journey distance, journey avoidance;
- To discuss some other initiatives, it appears that most measures looking at emission reductions in the inland waterway transport sector are also aimed at reducing fuel consumption, thus providing both, economic as well as ecological benefits. Nevertheless, adopting single solutions for small vessels may have side effects mainly because of the insufficient capacity or simply the size of the vessel. A new strategy in this sector is the use of electric power. It seems that conversion of inland ships to electric power is an interface between sustainability and technology. Moreover, digitalisation is also a powerful tool for providing multimodal integration [21].

60. To accelerate the worldwide transformation towards a net-zero emission mobility system, a unique collaboration known as the Transport Decarbonisation Alliance (TDA) is set-up among companies, cities, regions and countries. The alliance intends to design a common vision for 'front-runners' through substantiated scaled-up ambition for the overall transport sector along with setting up Communities of Interest (CoIs) as part of a tangible action. In addition, the alliance is determined on promoting effective advocacy which would include influencing political decision-makers in key international fora on climate change (e.g. UNFCCC), sustainable development (e.g. UN High Level Political Forum – SDGs), international political processes (e.g. EU, G7, G20, B20) and through bilateral dialogues [56].

61. In COIs, members develop important policy recommendations, online courses, reports, and other products or outcomes. COIs benefit and contribute from networking, peer-to-peer learning, thought leadership, and shaping international ambition and action by means of participation and initiatives. Some best practices that have been identified by TDA include the example of France, Netherlands, and Portugal. France has committed over $5 billion each to maintain a high level of investment and to develop new national railway services as part of the green stimulus packages. In addition, France has also announced a $9 billion bailout for its auto industry, which includes imposing strict compliance with EU CO_2 emission performance standards and commitments on enhancing the share of low and zero-emission engines. Quite similarly, the Dutch Environment Ministry along with several municipalities in Netherlands have signed a joint agreement to enact zero-emissions zones for delivery trucks by 2025. Some other excellent initiatives taken by countries include France and Portugal's policies which offer tax credits and rebates for the purchase of electric bikes, equipment and bicycles. Emissions can be significantly reduced with the incorporation of a bicycling infrastructure, funded by national and local-level investments. This is reflected by the Netherlands experience which demonstrates that an integration of policies and funding opportunities for road safety can lead to high rates of cycling usage [57].

62. Another similar initiative is the International Zero-Emission Vehicle Alliance (ZEV Alliance), which is a collaboration of national and subnational governments to accelerate the adoption of ZEVs (Fuel cell, plug-in hybrid, electric vehicles). Participants set ambitious yet achievable targets for the adoption of this initiative by taking appropriate actions to achieve individual and collective targets while encouraging and supporting other jurisdictions in setting and achieving ambitious ZEV targets. The initiative involves governments striving to make all passenger vehicles sales in their jurisdictions ZEVs by 2050 while also actively working on the design and assessment of current electric vehicle policy instruments [58, 59].

63. On the whole, some key developments in the inland transport sector include:

- Increase in number of electric vehicles and bus rapid transit systems;
- Increase in the use of sustainable fuels;
- Increased access to mobility services in developing countries;
- Reduced carbon intensity of operations by freight logistics companies;
- Enhanced conception of the importance of urban planning and expanding infrastructure for light-rail, buses, bicycles and pedestrians;
- Better analysis of comparative costs between passenger and freight transport modes;
- Emerging policies on the slowing of rapid growth of Light duty vehicles;
- Increased GHG emission vehicle performance standards and fuel economy standards;
- Widely implemented local transport management policies.

7. ITC and other ECE sectorial committees to help measure and monitor EV GHG emissions and its mitigation potential

64. The use of Electric Vehicles (EV) is expected to exponentially rise over the coming decades, where the industry is projected to reach $800 billion by 2027. Companies such as Uber plan to have a fleet of 100 per cent EVs by 2030 in US, Canada and Europe [56]. Even though EVs have zero tailpipe emissions, the net carbon is not zero. Well to Wheel (WtW) analysis provides the means to interpret the true carbon emissions. A great initiative undertaken was the development of Electric Vehicles and the Environment (EVE IWG) which focuses on Life Cycle Costs (LCC), and Automated, Autonomous and Connected vehicles (AACV). This was hosted by ITC World Forum for harmonization of Vehicle Regulations. This initiative has led to the development of a tool to compare WtW emission of different powertrains [61].

65. ECE have successfully delivered multiple workshops to quickly set-up collaborations and partnerships to assist the stakeholders with understanding the measures introduced to reduce carbon emissions. By publicly reporting the CO_2 emissions, awareness is raised, and EV users are motivated to act [62].

66. Another sustainable strategy demonstrated at the ECE workshops is ECO charge systems. Real-time data upstream, artificial intelligence and machine learning can be implemented to deliver smart and economical charge systems. These can reduce load on the infrastructure by optimising charging times and implementing dynamic current limits. It has been suggested that new ideas such as vehicle to home or vehicle to grid can be used to implement better load sharing [63, 64].

IV. Proposals for accelerating climate change mitigation by the inland transport sector

67. In the context of the assessment provided above, this section discusses proposals which have been identified as several intersectional opportunities for the decarbonisation of inland transport.

- Provide multiple opportunities to fund research and development into emerging zero-emission fuels and technologies. ITC should set up clear targets and investment in clean research and development along with adoptability for zero-emission fuels.
    - ITC should encourage the blending of true low-carbon fuels for decarbonising heavy-duty road freight.
- ITC may assist with stabilising and reimagining public transport. This can be done with the support of local and national governments. For strong services, transit stakeholders will need to reimagine public-private partnerships, data and modal integration, priority infrastructure, finance and governance.
- ITC should assist cities and countries on expanding their current bicycling and walking facilities. This can be done by investigating prospects to integrate micro mobility services (such as bike sharing).
- ITC should support the acceleration of electrification. Enhancing vehicle fuel efficiency and increasing the adoption of EVs can play an essential role in combating climate emissions whilst improving air quality.
    - Production and adoption of EVs must parallel a transition to renewable energy generation and smarter vehicle-grid integration for achieving net-zero emissions.
    - To capture private sector EV investments and procurements, it is important to have public policy incentives and mandates.
    - Instituting zero-emission zones or installing public charging infrastructure are great examples for cross-sector collaboration.
    - To improve the emissions, a heavy involvement of car manufactures is also required. Major EV manufactures like Tesla, BMW, Volkswagen, Nissan etc. could provide life cycle analysis on each component of the car to analyse true impact on emissions. Implement a continent wide (if possible, worldwide) standard for charging infrastructure.
    - Most critical part of EVs is its traction battery, the impact of mining minerals to manufacture these should be considered in the long-term. Overall, EV manufacturers are best suited to implement procedures which are carbon neutral and determine efficient ways to repurpose, reuse or recycle batteries at the end of life.
    - Investigate the infrastructure that is required for supporting the deployment of hydrogen and electric vehicles, as well as understanding the safety needs of transporting batteries.
- ITC should support investments in further electrification of rail transport (for both, passenger and freight transport) while also enhancing the shift from highly energy intensive passenger and freight modes, such as long-distance car and truck trips and short-distance air to rail transport.
    - A hassle-free cross-border rail travel would help strike a better balance between air and rail travel. Perhaps, initiatives such as integrated booking and ticketing across ECE countries can go a long way towards achieving this target.
    - Public-private participation opportunities must be leveraged through investors. For example, installation of amenities (Wi-Fi), franchise contracts and rail and railcar-sharing schemes.
- ITC could work out schemes for measures to incentivise use of more carbon-efficient modes. E.g. tax credits could be imposed on those automotive companies that have large volumes of goods to be transported at long distances. Such corporations could be asked to pay a premium that can be further reinvested for innovative solutions such as green technologies.

- ITC could develop and deploy a CO_2 emissions reduction initiatives tracker tool for inland transport that would monitor and provide a wide range of information relevant to initiatives for reducing the environmental footprint of inland transport, including details on past and ongoing measures and initiatives.
- ITC could develop an inland transport emissions toolkit, which would provide a structured framework along with decision support tools for the evaluation of emission reduction opportunities in the inland transport. The toolkit could offer guidance to countries around the world on how to design, develop and strengthen national policies and regulatory frameworks related to the reduction of GHG emissions and prevention of air pollution from inland transport modes.
    - A rapid assessment of the emissions from different inland transport modes could be done. This can include identifying those vehicles that are most significant sources of pollution and then imposing regulations on controlling emissions from such vehicles.
    - Stakeholder maps can be developed to identify and map the relevant stakeholders and for recognising different relationships.
    - Understanding and estimating emissions and fuel consumption for each type of inland vehicle or vessel is needed. Thereafter, key regulations on controlling emissions must be tightened.
    - For possible emission scenarios, predicted economic development levels of countries should be investigated, possibly through national development plans of each country.
    - Existing strategies, policies and regulations that look at reducing emissions are often generic. Such approaches should be operationalised by looking at local, national and regional issues.
    - For developing appropriate national strategies, a lead agency must be established with a setup of a task force, national focal point and project coordinator.
    - An Energy Efficiency Design Index could be made obligatory for all new trains and different road vehicles. The measure would require a minimum energy efficiency level per capacity mile for different vehicles.
- ITC should lead the digitalisation effort as this can prove to be a powerful tool to provide multimodal integration. It could incentivize a modal shift towards less polluting modes of transport such as rail or inland waterway transport.
- CO_2 emissions of international road freight transport are increasing all over the world. Yet, there is no sign that this trend is to be curbed shortly. A single measure will not be able to tackle this challenging problem. Thus, a mix of measures such as logistical improvements, alternative fuels and improving fuel efficiency of vehicles is required.
- ITC should consider how indirect GHG emissions, which arise from the transport infrastructure construction, vehicle manufacture and fuel provision, should be addressed through possible policies, regulations and initiatives.
- ITC could accelerate the incorporation of environmental and social lessons learned from the Covid-19 crisis to develop an approach that promotes initiatives such as working from home or avoiding unnecessary travel that can help reduce emissions.
- ITC must encourage efforts on improving skills of automotive personnel on immerging technologies as well as SDGs. There is a cross-cutting need for knowledge sharing and the development of capacities to gather and analyse reliable real-time data and statistics.
- ITC should investigate into developing online tools to provide real time monitoring and reporting of traffic congestions. Advising commuters to replan their journeys can reduce congestion on the roads.

- ITC can provide a platform for successful collaborations between stakeholders inside and outside the inland transport sector to make use of the knowledge acquired in other sectors and to identify effective, innovative and tailored solutions for mitigating climate change by the inland transport sector.
- ITC could look into finding and getting involved more academic researchers, who have an understanding of climate change, transportation resilience, and the need for mitigation, with the Committee's group of experts.
- In addition, ITC can try to get more transport companies and manufacturers involved. Since companies are now focusing more on the social and environmental issues of their businesses, as part of the triple bottom line, it will be a good idea to get these transport companies involved with ITC's activities.

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