A Satellite-based Optimisation of the European Freight Transport Network

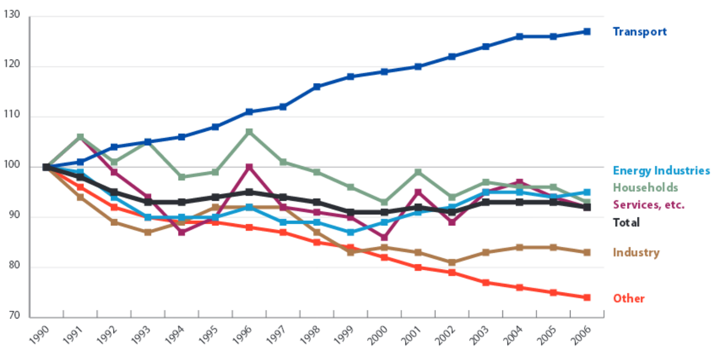
Transport is a major source of air pollution, causing millions of deaths worldwide. Despite efforts made to reduce its environmental impact, transport emission levels continue to increase. A new sustainable approach is required in order to meet transport needs today while preserving air quality for the next generation.

The aim of this project is to develop a multi-modal optimised European freight transport network model, updated using satellite information such as air quality, traffic, weather alerts, and fleet position. A network model will be developed and an algorithm will offer a choice of possible routes associated with a cost in terms of environmental impact. This tool will provide freight transporters with a mean to reduce their environmental impact by choosing more environmentally friendly transport modes and routes.

The following section reviews transport contribution to air pollution. The optimised transport network model idea is then introduced, followed by arguments supporting its feasibility. Finally expected results and associated risks are presented.

1. Background

Air pollution is currently the largest environmental risk to health, with an estimated 3.7 million deaths worldwide due to outdoor air pollution exposure in 2012 [1]. In Europe, air pollution decreases the life expectancy of every inhabitant by almost a year [2]. Air quality can be assessed by measuring greenhouse gases (GHG) emissions. These gases include carbon dioxide CO_2, ozone O_3 and nitrous dioxide NO_2.



1. GHG emissions in the EU by sector [4]

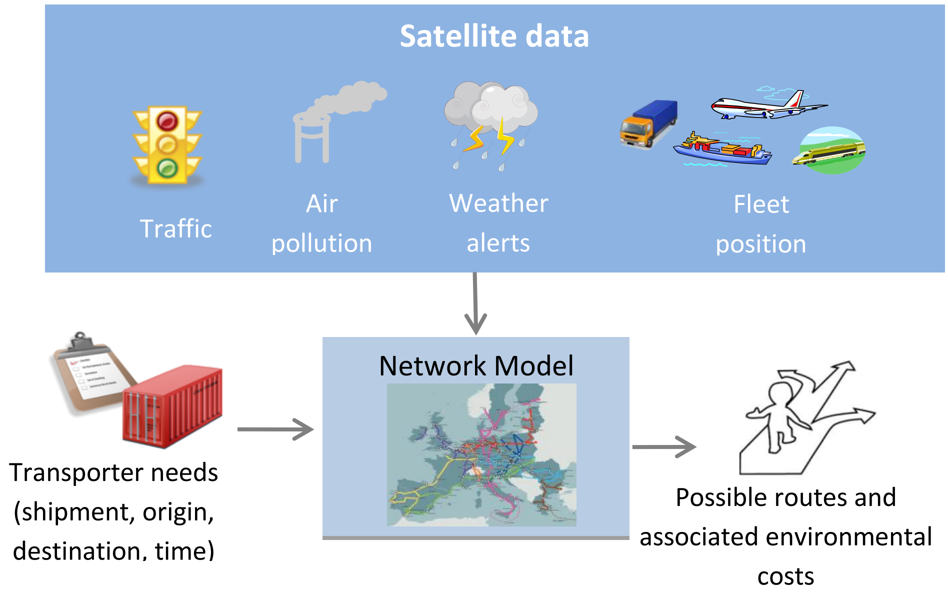
Being responsible for 24.3% of GHG emission and 28.8% of CO_2 emission in 2010 [3], transport is one of the major source of air pollution in Europe. While other sectors, such as industry or services, succeeded to reduce their GHG emission with respect to 1990 levels, transport emission keep on increasing. Moreover, despite the progress made to develop new fuel efficient vehicles, 97% of transport energy of transport energy needs still depend on fossil fuel, raising concern over transport environmental sustainability [4].

While road vehicles have a large environmental impact, road largely dominates transport in Europe with 45.3% modal share. More resource efficient modes such as railways and inland waterways remain minor actors with a respective share of 11% and 3.7% [5]. New transport patterns must emerge, in order to fulfil the reduction of 60% of GHG emission with respect to the 1990 levels by 2050, as requested by the European roadmap for moving a low-carbon economy [3]. A clever combination of modes is required to carry large volume of freight in an efficient, economic and sustainable manner.

The idea presented below is to optimise the use of existing freight corridors in order to minimise environmental impact and congestion.

2. Description of the idea

The idea is to create a tool that could be used by transporters to optimise their route choices with respect to their environmental impact.



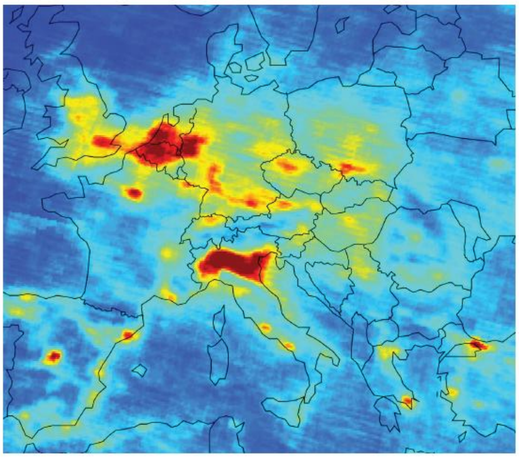
A real-time multi-modal adaptive freight transport network model will be developed along with an optimisation algorithm to choice the routes. In addition to the classic models focusing on traffic flows, this model will integrate additional space data relating to air pollution, weather alert and the position and schedule of transport fleet.

Such data will enable the computation of an adaptive cost associated with each route, reflecting their environmental impact. For instance, if congestion is detected in a city centre, bypasses will be given priority by associating them to a lower cost. Or, if a railway route exists between two cities, this route will be given a lower cost than the road route connecting the same cities but with a higher level of emissions. The user will input the nature and amount of its shipment along with its origin and destination. The algorithm will then compute the different routes and their associated cost in terms of time, price and environmental impact.

3. Realistic implementation

3.1. Satellite data

As stated previously, satellite data will be used to update the model. Earth observation satellites are already used to monitor air pollution and to issue weather alerts. Former mission ENVISAT used atmospheric sensors to monitor traces of gases. Unfortunately, the mission ended in May 2012, following a loss of contact [6]. A new programme named Copernicus Sentinels is currently developed to perform atmospheric, oceanic and land



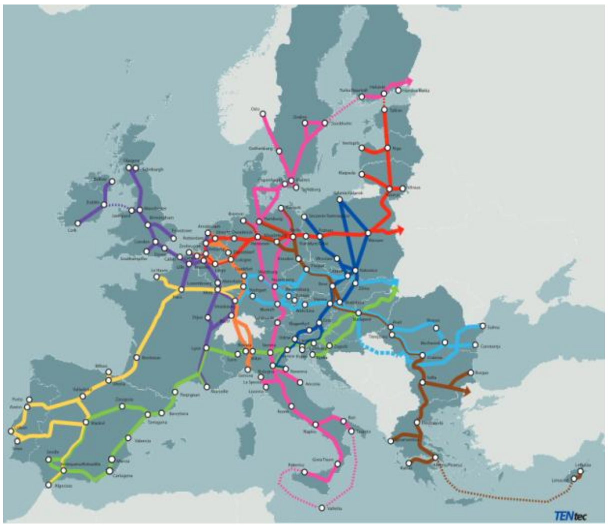
2. Mean density of NO_2 over Europe between January 2003 and June 2004, as measured by Enivsat satellite [8]

monitoring [7]. Among the six Sentinel missions, three will provide air quality measurements and climate monitoring. The first satellite, Sentinel 5P, will be launched in 2016. It will provide near real-time, continuous and accurate atmospheric composition information that can be integrated in the model presented previously.

Additionally, with the increasing number of vehicles equipped with satellite navigation receivers, a large amount of data is now available to study and estimate traffic flow and congestion. The European global satellite navigation system, Galileo, which should reach Full Operational Capability (FOC) by 2020, will provide additional data with an improved accuracy [9]. With sufficient computational power, this data could be used to update the freight transport network model in real time, and though to limit congestion.

Moreover, with the use of the European satellite based augmentation system, EGNOS, fleet location can be pinpointed with an accuracy as high as 3 m, 99% of the time [10]. Galileo and EGNOS will be crucial to track shipment and to estimate their time of arrival at different waypoints.

3.2. Network modelling

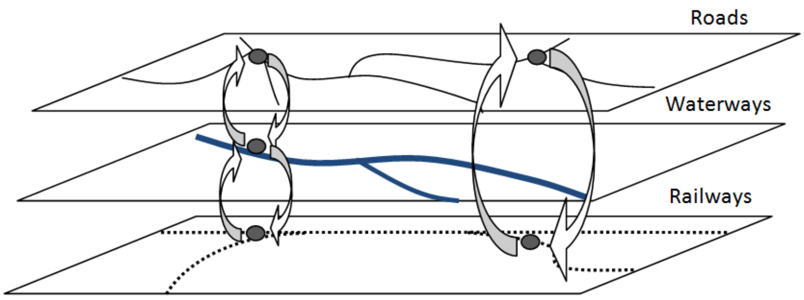


3. TEN-T core network corridors [11]

The European Commission has been working on the development of a Trans-European Transport Network (TEN-T) since 1990. It focused on the construction of key infrastructures to support a planned set of road, rail, air and water routes. The network will be composed of 9 main corridors connecting North and Baltic seas to the Mediterranean, Atlantic Ocean to central Europe and Eastern borders to the ports in the West [11]. This network can undoubtedly be modelled using current modelling techniques.

Transport network modelling is extensively used to simulate transport traffic flows. The network is usual composed of nodes and links. Each node represents a possible origin or destination, and the links depict the different routes that connect them.

In case of a multi modal network, layers corresponding to each mode can be used. Transfer link between the different layers are then needed to enable the shift from mode to the other, as illustrated here opposite.



4. Illustration of a multi-modal network model

A large database will be required to store information relative to each node and links in terms of location, congestion, current air quality, etc. A cost can then be associated with each link that will reflect the environmental impact. For example, a trip from point A to B by road will be given a higher cost than the same trip by rail as it will produce a higher level of emission. An algorithm can then be developed to determine the possible routes between two points and their associated costs. The weather alert can be used to turn off some link. For instance, if a road is flooded, the associated link will be removed from the network model.

Such a model will be dealing with a large amount of data (commonly referred as Big Data) requiring high computation capabilities. However, they will provide a more realistic model of the transport network and thus finer optimised solutions.

4. Expected results

The use of an optimal freight transport network model will make a better exploitation of the existing network capacity by offering a multi-modal approach. Moreover it will support transport demand increase while limiting congestion and emission, initiating a sustainable traffic growth.

It will promote alternative modes of transport with a lower environmental impact and create new sustainable transport pattern. Railway and inland waterways which are currently underused could be promoted easily through the use of such a tool.

Moreover, this model offers a framework to develop a European tax system, pushing further existing initiatives such as the Euro-vignette or the French distance-based eco-tax on lorries. Freight transporters could be taxed on their environmental impact, which will help to promote cleaner transport solutions.

Finally, this tool is based of the two major European satellite programmes, Galileo and Copernicus, and will promote the benefits of such programmes to each European citizen.

5. Potential risks

Despite the benefits seen above, certain risks must be addressed. Transport employs 10 million people through Europe [3] and a shift of modes will fatally suppress some jobs. Job lost must be anticipated and managed properly, for example by offering specific formations to support career changes. This is especially true for truck drivers as the idea is to shift long-distance freight to other modes such as railway or waterborne transport.

The limited compatibility between the national networks also represents a risk. For instance, in Europe, more than 20 different train control systems are currently used, preventing trains to cross national borders. However, several projects are underway to make national networks interoperable at a European scale. These projects are ERTMS for railway, ITS for roads, RIS for waterway, SafeSeaNet for ships and SESAR for aviation [3]. In addition to these initiatives, efforts must be also be made to expand transport infrastructures in countries where they are limited.

Finally, competitiveness must be protected. Transport accounts for about 5% of GDP in Europe [3] and it is important to protect this sector.

Conclusion

A satellite-based optimisation of the European freight transport network will not replace the efforts made to develop more fuel-efficient vehicles. However it will contribute to the reduction of emission and the development of new sustainable transport patterns. It also opens the way to a European transport eco-tax based on environmental impact.

Such a tool will support the growth in transport demand while limiting its environmental impact, corresponding to the Brundtland report definition of sustainable development: 'a development that meets the needs of the present without compromising the ability of future generations to meet their own needs'.

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