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THE LONG-TERM FORECAST OF LAND PASSENGER TRANSPORT RELATED CO_2 EMISSION AND ENERGY USE IN HUNGARY

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Abstract: Hungary as the part of the European Union has to deal with the reduction of CO_2 level. Reaching the 2050 target requires to examine and develop every sector of the emission. Transport has a dynamic and significant part in CO_2 emission but generally policymakers do not have the courage to change significantly the modal shift by political decisions because of their popularity. Transport investments are generally long-term investments that show a return in around 30 years. ForFITS is a software tool for policymakers to simulate the effects of different transport scenarios and gives outputs about the transport activity, energy consumption and emission of the next 30 years. Hungary take its' part of the UNDA project as being one of the pilot countries of using ForFITS. After the collection of data different scenarios were made. The aim of this study is to present the most realistic scenario for Hungary especially in the case of passenger transport.

Keywords: CO_2 emission forecasting, energy consumption, transport strategy making, sustainability, ForFITS.

1. Introduction

Forecasting future trends at any field of the economy has an essential role in strategy making. If we are able to make a good sophisticated scenario of the future we can plan actions in the right times and in the right fields to control the long-term processes of the examined systems. With this kind of information a competent management of a country or any region is well prepared to keep their managed country or region competitive against their competitors.

The mitigation of the CO_2 emission (as a part of decreasing the GHG effects) is a global problem; every nation in the World is involved in this process. But being environmentally friendly is usually against making the maximal achievable economic growth (Armstrong and Green, 2013; Török and Török, 2014). This is the reason why decision-makers need the support of future scenarios to look through: what actions have to be planned and achieved when to reach the optimal level of their environmentally friendly strategy (Andrejszki et al., 2014).

Virtually all the energy used in transport is obtained from the combustion of oil - based fuels (largely diesel and gasoline): this is why GHG emissions in transport are dominantly

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CO_2 emissions. Transport is responsible for about 13% of GHG emissions and 22% of the total CO_2 emissions from fuel combustion (UNDA Seventh Tranche, 2012). White Paper 2011 examines four policy options (European Commission, 2011; Bokare and Maurya, 2013). Three of them want to reduce CO_2 emissions by 60% over 1990 levels until 2050 and the most pessimistic scenario shows also a little reduction over the 2010 level.

It is trivial that there is a close relation between the energy consumption of transport and the emissions of it. There are studies that examine the driving factors and impacts of transport-related energy consumption (Mraihi et al., 2013; Chandran and Tang, 2013). In Croatia a forecasting model was set up for making future scenarios of Croatian energy consumption related with transport activity (Pukšec et al., 2013).

But how can a government see how much CO_2 can be saved by making concrete strategic decisions? How can they know how many percentages of CO_2 emission can be reduced by an environmentally friendly transport project? Giving a help for these questions was one of the causes why UNDA project was established: to foster sustainable transport policies: ForFITS (**For F**uture **I**nland **T**ransport **S**ystems).

In 2008 the UNECE Transport Division called on the UN Development Account (UNDA) for funds to build this project together with all UN Regional Commissions. After the preparation of a global review on existing statistical data, policy measures and assessment tools concerning CO_2 emissions in transport a questionnaire was made to provide inputs for the preparation of the review. After the reconciliation with selected experts the first model prototype was released in 2012 (UNECE, 2013).

Hungary as the part of the European Union has to reach the goals of the directives made by the Commission. According to the White Paper 2011 (COM/2011/0144 final) Hungary also has to deal with the reduction of CO_2 level. To fulfil the expectations the government worked out mid-term and long-term strategies which contain the planned actions. In the actual status of the National Transport Strategy environmental expectations can be found at the point of social targets (NKS, 2013). It says there are two main fields in the reduction of the environmental effects. The first target is to develop the conditions of the environment and elements of it. The second one is about the sustainable usage of the natural sources through the efficiency of energy consumption, recycling and using renewable energy resources. The Hungarian National Energy Efficiency Action Plan (HNEEAP, 2010) contains actions to develop energy efficiency until 2020. In the transport sector there are two planned measures. The first is about the maintaining and expanding the road toll system of heavy duty vehicles to stimulate a better organising of logistics. The other is developing P+R systems to have a more efficient individual passenger transport.

According to these Hungary needs forecasts and scenarios of the future energy consumption and CO_2 emission to monitor the ongoing processes and to be able to create and update action plans to be able to accomplish the European Union standards. Being part of the Pilot project of UNDA was a good opportunity for the country to co-operate with UNECE and get useful information from the ForFITS simulations.

2. Methods

ForFITS was developed as a software tool capable to satisfy two sets of key requirements:

1. the estimation/assessment of emissions in transport;
2. the evaluation of transport policies for CO_2 emission mitigation.

To achieve these targets, ForFITS evaluates transport activity (expressed in terms of passenger kilometers – pkm, ton kilometers – tkm, and vehicle kilometers – vkm), related vehicle stocks, energy use and CO_2 emissions in a range of possible policy contexts.

ForFITS is suitable for the analysis of transport systems having a regional, national and/or local dimension, with a primary focus on national systems. ForFITS is a sectoral model, covering both passenger and freight transport services on all transport modes (including aviation and maritime transport), but mainly targeting inland transport (especially road, rail, and inland waterways). Pipelines are also considered in the model. Each mode is further characterized in sub-modes (when relevant) and vehicle classes. Vehicle classes are further split to take into account of different powertrain technologies and age classes. Finally, powertrains are coupled with fuel blends that are consistent with the technology requirements (UNECE, 2013).

ForFITS covers several aspects of the transport system, from non-motorized passenger transport to freight pipelines. The following points describe the ranges of parameters covered in ForFITS:

- 2 areas (urban and rural);
- 2 transport services (passenger and freight);
- 9 transport modes;
- 6 vehicle classes;
- 10 fuel blends;
- 31 powertrain technologies;
- 26 age classes.

ForFITS does not provide information on the evaluation of the overall effects of changes in the transport system on the economic growth (UNECE, 2013). The assessment of emission estimates from fuel consumption is addressed by the multiplication of the energy used by emission factors reflecting the characteristics of the fuels with respect to tank to-wheel and well-to-tank emissions.

The model is mainly sensitive to three different aspects:

1. Macroeconomic parameters such as GDP and population which are correlated with transport activity;
2. Effect of changes in the cost of driving and moving goods through elasticities;
3. Structural changes in the transport system (mainly related to the role of public transport in the passenger service in order to assess modal shift policies, and associated to the economy structure in the case of freight transport).

Behavioural aspects and technology choice are also tacked in the model.

ForFITS was developed in the Vensim modelling environment and is structured in two components: a Vensim Packaged Model file (.vpm) and an Excel file (.xls). The VPM file is where the model is implemented.

Several types of variables are defined by equations and connected between each other by means of arrows. This file takes information from the Inputs Excel file, in which the user must introduce the necessary data to run the model.

There are four categories detailing the importance of user involvement in the definition of the data entered into the model:

- M → Data is absolutely required.
- A → Inputs expected to be introduced by the user. The current value in the ForFITS Inputs file is for guidance only. This category includes policy inputs that allow exploring different scenarios.
- B → Input containing a (often technical) default value that may remain unchanged, depending on data availability. Defaults are set on the basis of research activities involving literature reviews and statistical analyses.
- C → Changes to these inputs would likely result in modifications to the structural characteristics of the model. Unless the user acquires sufficient experience, modification of these inputs is highly not recommended.

The lack of data availability and the poor quality of the information led to the exclusion of selected transport vehicles and modes. In Hungary bicycles, road, vessels and rail were taken into account. As it was offered by the model the initial year of the simulations was 2010 and the last year of projections was 2040. Population and GDP data were obtained from international databases that contain information for each country. The sources of the population figures used for the characterization of the pilots were the World Bank and the United Nations. The GDP in current USD and the GDP deflator were taken respectively from OECD Statistics and the World Bank. The vehicle stock data were gathered from EU statistical pocketbook 2013 and the reports of the International Energy Agency were also used to get information about powertrain technologies and fuel consumptions. The average annual travel data estimation was based on assumptions on vehicle speed and vehicle usage, and the annual loads per vehicle were estimated form vkm (vehicle kilometre) data which also came from the EU statistical pocketbook 2013. The number of new vehicles registered in the past for Hungary was obtained from the data published by the European Automobile Manufacturers Association, the European Environment Agency, Eurostat and the EU statistical pocketbook. The Tank-To-Wheel (TTW) emission factors depend on the combustion of fuels and were derived from the guidelines published by the Intergovernmental Panel on Climate Change. The Well-To-Tank (WTT) factors refer to upstream emissions. They vary for different fuels (UNECE, 2014).

According to these the following input data were used in the simulation (Table 1).

Table 1

Basic Input Data of Hungary

		Number of active vehilces	Powertrain groups [%]			Annual travel per vehicle [km]	Vehicle load [-]	Fuel Consumption [lge/100 km]*	Newly registered vehicles		
			Gasoline	Diesel	Electric				2000	2005	2010
Passenger transport	Walking	912892	-	-	-	490	1	-	-	-	-
	Ccling	45645	-	-	-	3600	1	-	-	-	-
	Two wheelers	142251	100%	0%	0%	4400	1	2.3	18181	27760	7900
	LDVs	2608000	88%	12%	0%	10750	2	6.7	130323	198982	4960
	Buses	17000	2%	98%	0%	48500	20	18.0	647	698	439
	Trams	595	0%	0%	100%	48000	20	20.1	27	7	60
	Metros	103	0%	0%	100%	78000	350	31.8	9	10	10
	Local Trains	522	0%	40%	60%	92000	118	159.2	53	16	53
	Intercity Trains	131	0%	40%	60%	133100	118	159.2	13	4	13
Freight transport	LDVs	337900	0%	100%	0%	20000	1	8.9	35672	35610	15000
	Vessels	160	0%	100%	0%	20000	750	9161.5	16	16	16
	MDVs	76000	0%	100%	0%	60000	3	16.0	5020	1532	2278
	HDVs	51000	0%	100%	0%	80000	5	24.1	3255	1106	1965
	Rail	280	0%	40%	60%	47000	675	700.5	28	28	28

**Note: lge - liter of gasoline equvivalent*

The simulations were run on the basis of a consistent set of hypotheses, defining five sets of scenarios:

A. Reference;
B. Oil up;
C. Oil up and shift;
D. Oil up, shift and tech;
E. Oil up, shift, tech, and biofuels.

The Reference scenario considers:

- constant fuel prices and taxes, maintaining the levels identified for the base year;
- a constant passenger transport system index, reflecting a development of the share of transport on personal motorised passenger vehicles that follows the default driving curves;
- constant powertrain technology shares for all vehicles and all modes, maintaining the levels identified for the base year;
- constant CO2 emission factors, reflecting no changes in fuel blends with respect to well-to-tank and tank-to- wheel emission characteristics (and therefore excluding a switches towards more or less energy - and carbon - intensive fuel options) (UNECE, 2014).

In the case of Hungary the most realistic scenario for the next 30 years is the “Oil up and shift” scenario. On one hand this scenario considers a doubling of the oil price from the base year to 2040. In between the base year and 2040, the evolution of the average oil price is assumed linear for simplicity. The changes in the oil price are assumed to influence directly the fuel cost of the gasoline and diesel fuel blends. On the other hand this scenario considers an evolution of the passenger transport system index towards a condition where a significant fraction of the passenger transport task is performed by public transport modes. The practical implementation of this input relies on the possibility to modify the ForFITS “passenger transport system index”, an instrument that was specifically developed to help understand the changes in the passenger transport system associated with shifts to/from private vehicles from/ to public transport. The gap between the value of the passenger transport system index calculated in the base year and the 0.7 value characterizing high density and public transport oriented regions is assumed to be progressively reduced by 20% between the base year and 2040. The evolution of the passenger transport system index between the base year and 2040 is assumed to be linear, for simplicity. In practice, this assumption represents the implementation of a wide number of policies favouring public transport over personal vehicles, such as parking and access restrictions for personal vehicles, land use policies that encourage the vertical development of the city and mixed use areas, and support for the provision of appealing, widely available and high-quality public transport services (UNECE, 2014).

So the "Oil up and shift" scenario was in the focus of the examination. The comparison with the reference scenario (and with the "Oil up" scenario) is essential because it can be seen that how much energy and CO2 can be saved if the decision makers follow the guidelines of shifting the passengers towards public transport usage. The increment of the oil price can be partly influenced by the politicians because it mainly depends on the market. But motivating people to use public and greener transport is absolutely a field where transport strategy can work. The other two scenarios (D and E) have conditions about technological developments which is mostly independent from decision makers (except the supporting of researches) so these scenarios were diagnosed to be too optimistic and it is not necessary to deal with these cases.

In this article passenger transport is in the centre of the examination to make a logical delimitation for having a deeper insight into to processes that work around passengers.

3. Results

The development of personal computer made feasible to build up such simulation processes in MS Excel and Vensim environment and made it viable to run the simulation within a reasonable time. For instance in case of Hungary the simulation had been running Intel® Core™ i3-2350M CPU T2250 2.30 GHz 4 GB RAM laptop for 9 minutes each time.

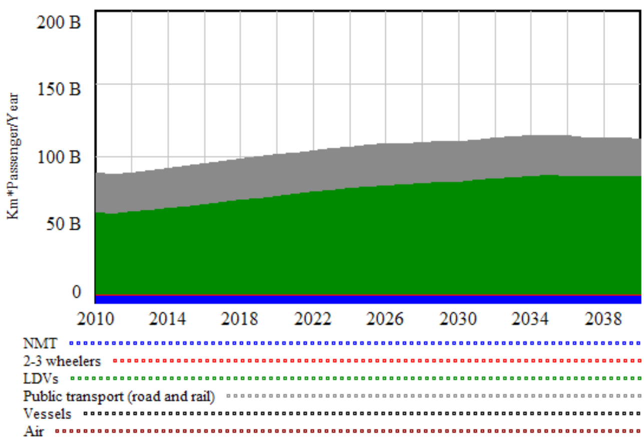

Fig. 1.
The Activity of Passenger Transport (pkm) in the Reference Scenario

In Fig. 1 and Fig. 2 the changes of passenger kilometres are shown. The simulation distinguishes between performance of NMT (non-motorised vehicles), 2-3 wheelers (mopeds and motorcycles), LDVs – which are passenger cars and light duty vehicles – and Public transport – both road and rail were considered. Although the simulation environment was capable to handle aviation and inland navigation as well, but in case of Hungary these modes have insignificant shares.

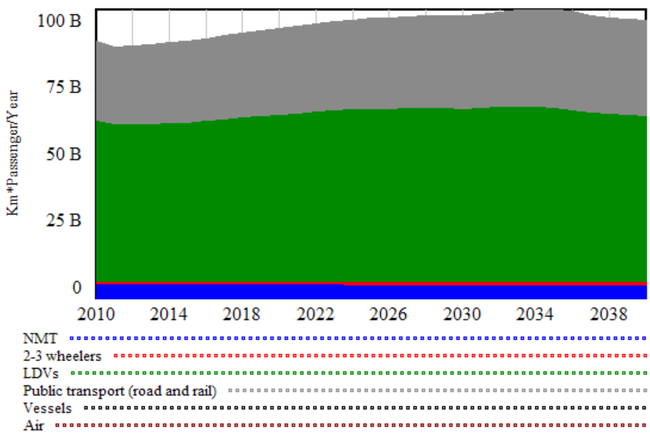

Fig. 2.
The Activity of Passenger Transport (pkm) in Scenario "Oil up and shift"

At the "Oil up and shift" scenario in 2010 the curve starts from 84 billion passenger kilometres. There is a solid growth at the beginning which reaches the maximum point in 2034 by 95.5 billion passenger kilometres. In 2040 the closing value is 92 billion passenger kilometres.

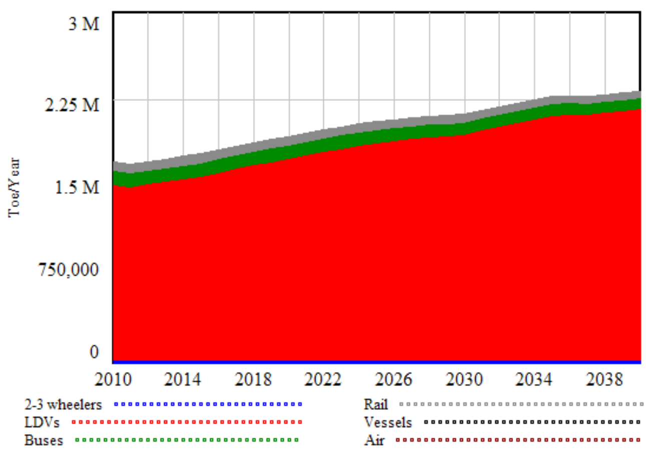

Fig. 3.
The Energy Consumption of Passenger Transport (Toe) in the Reference Scenario

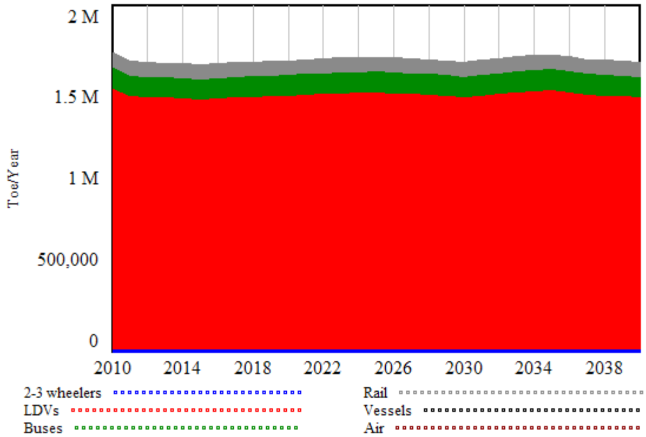

Fig. 4.
The Energy Consumption of Passenger Transport (Toe) in the Scenario "Oil up and shift"

Fig. 3 and Fig. 4 show a slowly decrease with more local minimum and local maximum points in the energy consumption of passenger transport. The starting (2010) and ending (2040) values of the graph are 1.72 million and 1.67 million Toe so this little decrease is about 3%. Except 2-3 wheelers every mode has a reduction. Compared to "Oil up" scenario the individual modes (2-3 wheelers and LDVs) have a 15 and 25% reduction. On the other side, buses and rail produce about 30% increment.

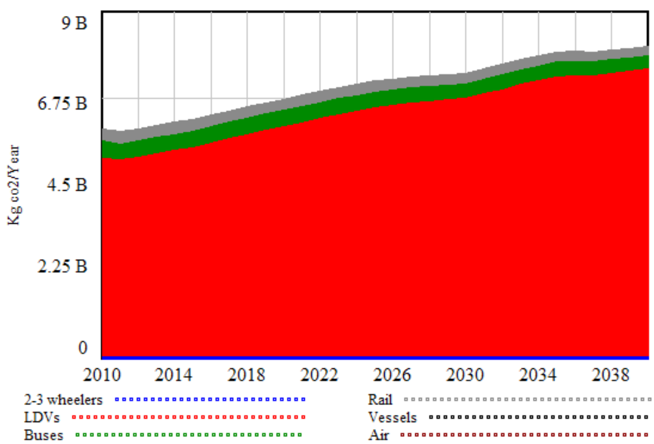

Fig. 5.
CO_2 Emission of Passenger Transport (kg CO_2e) in Reference Scenario

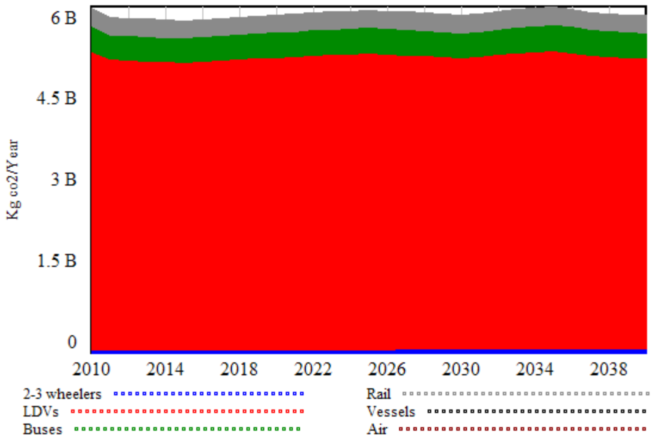

Fig. 6.
CO_2 Emission of Passenger Transport (kg CO_2e) in Scenario "Oil up and shift"

Fig. 5 and Fig. 6 have a strong relation with Fig. 3 and Fig. 4 because the CO_2 emission is estimated from the data of energy consumption. That is why the proportions are similar. From the amount of 6 billion kg CO_2 the curve goes down to 5.8 billion kg CO_2.

4. Analysis and Discussions

As it was mentioned the "Oil up and shift" is entirely a policy scenario. The hypotheses characterizing this scenario are also contributing to the avoidance of transport and mobility and the shift towards more energy efficient mobility options. Its impacts, however, are due to structural changes in the system (reflected in a variation of the behaviour of modelling parameters) and not by a response driven by the characteristics of the system, as in the case of the "Oil up" scenario (UNECE, 2014).

The reduction of passenger kilometre in Fig. 2 is caused by the decreasing of LDVs activity. Compared with the reference scenario a modal shift from private vehicles to public transport can be noticed, which triggered a reduction in the total performance. The total amount of passenger transport activity reduced by 16 billion passenger kilometres compared to the reference scenario. This was due to doubling the oil price makes a huge extra cost for the users of LDVs but might have a less significant effect on public transport prices as well that can lead to a redistribution in the shares of modes.

According to Fig. 2 non-motorized transport and the two-wheelers do not have a significant part in passenger transport performance. The reason of this is complex. Firstly the distances that passengers use non-motorised or two-wheelers mode of transport are much shorter than the average distances of using public transport, e.g. the non-motorized transport has a reduction of 8 % in 2040 (compared with the 2010 value) which is quite few. Two-wheelers increases by 58%, LDVS by 2% and public transport by 22%. This scenario is pessimistic from non-motorized point of view. Supporting bicycle usage and promoting walking as healthy and green modes of transport are in lot of countries transport strategy so these outputs might be better in the future.

The difference between the 2040 energy consumption of the reference and "Oil up and shift" scenarios is 652,000 Toe which means 28% of reduction. 9% come from the increment of the oil price and the other 19% are caused by the changing of modes. These amounts are almost the same at CO_2 emissions. Another important point here is the participation of the society. If people are informed about how much they can save in energy and CO_2 and how much responsibility they have they might take part of reducing CO_2 level by travelling in a more responsible and sustainable way.

From another point of view the outputs of the "Oil up and shift" scenario can be compared with the initial data. The emissions increased by 18% at two-wheelers, 1% at buses and have an increment at LDVS by 3% and at rail by 4%. These numbers are more restrained than the increments were at passenger kilometers. The reason why passenger kilometers increased and emission decreased (or not increased as much) is in the technical evolution of vehicles. New vehicles have better characteristic than the old ones and the greener powertrain groups get more and more part in the vehicle stocks.

5. Conclusion

To sum up the Hungarian government should design and support a future transport system that is sustainable. The guidelines of the European Union always give mid-term goals to reach and this is essential to follow in Hungary under the critic values of emission. As it was shown by the analysis, Hungary can expect a doubling of the oil price in the recent decades which might change the mobility level of relevant actors. But Hungary can take little steps toward sustainability by:

- supporting the usage of vehicles (or modes) that have better energy efficiency;
- supporting researches and projects of creating and testing advanced technologies;
- supporting alternative fuels to use;
- taxing the bad conditioned fuels that pollute the air and the environment.

There are several good plans, environmentally friendly projects and sustainable technologies but in Hungary the bottlenecks of these projects are usually the implementation. For example the plan of Metro 4 had a EU supported general interested plan which ended in much more expensive, less cost effective implementation. The projects of BUBI (Budapest Bike Sharing System), FUTÁR (Traffic Control and Passenger Information System) the renewal of tram networks and the acquisition of new (more sustainable) vehicles show that Budapest (and Hungary) wants to shift toward a more sustainable path in implementation Hungary has to develop.

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