INTRAPLAN Consult GmbH

Study in addition to the traffic forecast for the FBFL about possible traffic diversion from Great Belt to Fehmarn

- Interim Report

Report
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on behalf of

Femern A/S

Copenhagen

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1 CONTEXT

The Danish Ministry of Transport, Building and Housing had evaluated with help of COWI the so called FTC forecast for the Femern Belt Fixed Link (FBFL)[1]. This forecast prepared by the FTC-consortium led by Intraplan Consult, Munich, had been providing inputs for the financial analysis of the FBFL-project.

In this quality assurance of COWI[2] the underlying method and the results of the FTC-study were approved. Two elements were identified for which **additional research could strengthen the results**: the expected transfer of car traffic from the Great Belt and the newly generated traffic. The focus of this paper is on the expected transfer of car traffic from the Great Belt.

Differently from the ferry lines, for which detailed statistics about the international traffic between Germany and Denmark/Scandinavia are available, the international traffic crossing the Great Belt Bridge cannot be derived from regular statistics. There is a good knowledge about the total traffic on the Great Belt Bridge from toll statistics, but this traffic is dominated by intra-Danish traffic between Eastern and Western Denmark and no statistics are available on international traffic over this route. This traffic had to be estimated in the FTC-study by route choice model calculations using the parameters of costs, time and availability[3], which in the case of Great Belt were based on licence plate counts on international traffic, which is a standard approach for traffic models.The model calculations came to 854.000 cars in 2022. From this figure, according to the FTC-study, 718.000 cars would shift to the Fehmarn route per year, or 1.967/day, when the FBFL is open[4]. This latter route then would provide a faster connection whereas today the travel time between the Great Belt route and the Rødby – Puttgarden route is quite similar, when considering waiting time and time for boarding and disembarking.

In 2017 it was decided to do a toll reduction on Great Belt. Therefore new calculations were made showing how the number of vehicles shifting to the Fehmarn route is affected by this. These calculations showed that 545 cars/day less would choose Femern Belt to Great Belt after a toll-reduction of 25 % on Great Belt. That means that 1.422 cars would shift to the Fehmarn route per day[5]. This number of transferred cars is the number used in the Financial Analyses of the project[6].

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1 Intraplan Consult GmbH and BVU Beratergruppe Verkehr+Umwelt GmbH: Fehmarnbelt Forecast 2014 – Update of the FTC-Study of 2002, on behalf of Femern A/S, 2014

2 COWI: External quality assurance of the updated traffic forecast on the Fehmarnbelt project, November 2015

3 See FTC-study, chapter 4.2/4.3

4 See FTC-study, chapter 6.1.3, table 6-12.

5 Fehmarnbelt Forecast 2014 – Update of the FTC-Study of 2002, effects of Great Belt toll reduction on the Fehmarn Fixed Link, on behalf of Femern A/S, 2017

6 Fakta om effekter for Storebæltsforbindelsen og Femern Bælt-forbindelsen, Transport-, og bygnings- og Boligministeriet, december 2017.

In an attempt to strengthen these results of transfer of car traffic from the Great Belt, further studies have been made on this topic. First, a study was conducted mainly based on distribution of postcards and licence plate counts. The study confirmed that there is a substantial share of international traffic on Great Belt but the results of the study was still based on smaller samples and did not fully close the data gap pointed out by COWI.

Therefore it was decided to use technological advances in a new approach and carry out a completely new study based on extended study on data collected via cellular phones at large scale; collection of data on origins, destinations, location/route and time.

There is some experience in UK, in USA and in Germany with the exploitation of such data for similar cases. In the case on hand such analyses are obvious and sensible and this would close the data gap critized by COWI. This study will be examined in this paper.

2 BASIC APPROACH – USE OF MOBILE PHONE DATA (MND)[7]

2.1 Technical Background

Mobile phones generate among others "events", i.e.

- when calling or receiving a telephone call
- when submitting or receiving a SMS
- when sending or receiving data (via Internet)
- when switching on or off the device
- periodically when on, but inactive

These "events" are saved at the mobile phone provider among other with three relevant information:

- ID number (IMEI)
- location area code
- time

From that it is possible to analyse a movement pattern for each device, which, in compliance with data protection regulations, can be used for transport planning issues. Indeed, some mobile

7 MND = mobile network data

phone companies use this big data source for side business and provide among others analyses for transport related questions.

By using intermediate locations on the trip and by analysing the pattern of change from one area to the next (rail: larger groups changing at the same time from one location to the next, whereas road traffic is more constantly "flowing") the modal-split between road and rail can be analysed as well.

2.2 Data Privacy

The use of these data, however, is strictly regulated and restricted by the EU directive on data protection and the activities of the mobile phone companies are under observation and review of the data protection authorities. Even in the case on hand the use of the data for this project had to be approved legally.

Generally there are organisational and technical measurements to safeguard data protection.

Organisational: Data leaving (the inner core of) the telephone company's databanks have to be anonymized and aggregated. No one of the analysis team, including the transport planner resp. the author of the study on hand, as well as the data analyst as subcontractor had access to any original data.

There are three **technical measures** to exclude any data abuse:

(1) The device-ID (IMEI) is anonymized (by automatic, certified random generator)
(2) The anonymization is renewed every 24 hours
(3) The anonymized data have to be aggregated: cases less than five have to be suppressed

By the approved measures it is absolutely impossible to assign any detail to individual persons.

2.3 Extrapolation

The single companies have no monopoly, neither in Denmark nor anywhere else. Because, for the reasons described in chapter 2.2, they cannot exchange their data even if they would be willing to cooperate any analyses based on mobile phone data are sample surveys. So, the surveys have to be extrapolated to 100 % of the basic population.

However, generally the mobile phone companies know their clients structure with regard to age, sex and kind of contract (business, private, etc.). From general market data (size of overall

mobile phone market per segment, number of multiple users, persons not using mobile phones) and **by regional demographic statistics** they can figure and relatively accurate their market share per region and segment: By that they can extrapolate the data to 100 % of the mobile phone holders.

2.4 Expertise of Intraplan Consult GmbH

Intraplan was among the first in Germany and Europe to use mobile phone data for transport analyses and planning. We provided studies based on mobile phone data among others for public transport associations (Hamburg, Rhein-Main), Municipalities (Nuremberg, Munich region) and airports (Munich, Stuttgart). In these projects we co-operated among others with the **Swiss company Teralytics**, Zurich, which is specialized on data analyses of MDN (Mobile Network Data). For the project on hand Teralytics is serving as sub-contractor, exploiting, extrapolating (see chapter 2.3) and providing the base analyses. They used data of the mobile phone company 3DK.

3 STUDY DESIGN

3.1 Analysis of MND

The study was carried out with the following specifications:

Relevant are (mobile phone) users, who cross the Great Belt Bridge: There are tracked with origin (location of start before crossing the bridge) and destination (location of destination after crossing). Apart from the immediate trips of the users crossing the Great Belt Bridge the follow up trips were analysed: origin and destination of the precedent trip and the same for the next trip after the trip with the bridge crossing. This is necessary due to possible breaks on longer trips which could be misinterpreted as trip end and the location of the break as destination. By analysing the preceding and follow-up trips traffic chains could be analysed and the final origin and destination within 24 hours could be found. As a "side product" of that it could be found if there are round trips crossing the bridge within 24 hours. With regard to the international traffic they could help to find out whether there was only a short stay abroad. This is important in the German case: There may be trips from Eastern Denmark to Northern Schleswig-Holstein, which are not relevant for a shift from Great Belt to FBFL. Because only the border crossing could be tracked, but not the final destination or first origin in Germany, it may be an indication if there is a retour trip within 24 hours that this traffic may be ending or originating close to the border. Apart from that a split-up into road and rail traffic has been made.

Origins and destinations have been aggregated into provinces (see Figure. 1). Apart from that it had to be found out, whether a border has been crossed before reaching Great Belt resp. after crossing the bridge. The locations of the relevant border crossings are shown in Figure 1. There may be trips between two border crossings (i.e. between Germany and Sweden).

Apart from the users of 3DK mobile phones inbound roamers crossing the Great Belt Bridge had to be tracked with origin and destination. To be able to expand the inbound roamers separately the nation (network) was analysed.

With regard to the survey periods a good representation of the year is important. The following weeks had been chosen for the analyses of MND:

- Week 23/18
- Week 28/18
- Week 31/18
- Week 38/18
- Week 42/18
- Week 47/18

and (not yet included in the results presented here)

- Week 51/18
- Week 05/19
- Week 09/19
- Week 16/19

Apart from that the results were edited per weekday.

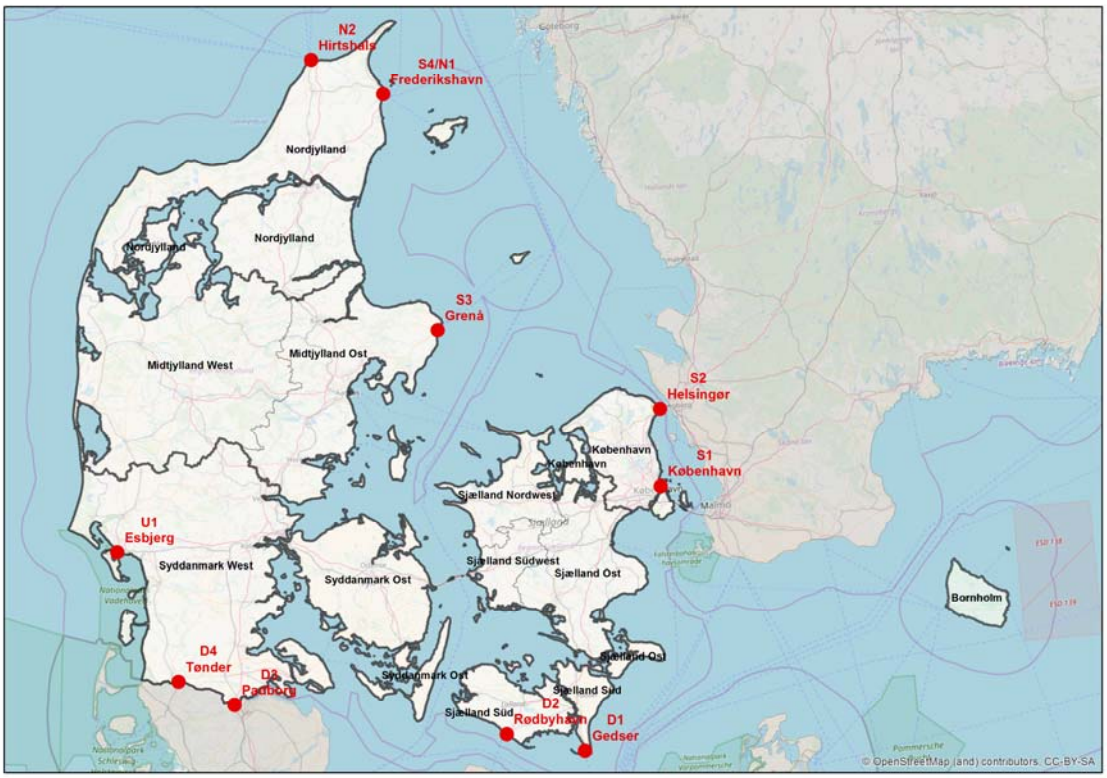

Figure 1: Zones and border crossings, to which the results were aggregated

3.2 Basic Extrapolation

Basic extrapolation was made by Teralytics using the regional and sectoral market shares of 3DK in Denmark.

With regard to inbound roamers a first extrapolation was made on the basis of inbound tourism data (Statsbank DK).

3.3 Expansion to yearly Figures

Toll statistics of Great Belt were available for each day, the day of the survey periods as well as the other days. By that it was possible

(1) to verify the extrapolation of Teralytics (see chapter 3.2).
(2) to expand the results of the survey periods/survey days to yearly figures.

With regard to (1) there was a strong correlation between the extrapolated results of Teralytics with the toll counts. With regard to (2) each day of year was assigned to a "typical" survey day (this is still preliminary due to the fact that four survey periods are still missing).

3.4 Quality Assurance

The preliminary results (bridge crossing) of the first two survey weeks we compared with the toll statistics plus the railway traffic measured in train seats offered. Altogether in this period (weeks 23 and 28) 559.000 vehicles crossed Great Belt, of which 487.000 were passenger cars (see Table 1). There were 525.000 train-seats available (two-way totals). Compared to these figures the MND analysis gave 1,540 million trips of which 1,265 million were road trips and 275.000 railway trips. Given a (generally high, but in summer reasonable) occupancy rate for car with 2,2 and bus with 35 and a seat occupancy rate of 50 % for train, the figures of the MND analysis fit quite quell to the Great Belt statistics without any additional necessity to change the extrapolation process for the MND data.

	toll counts vehicles	**estimated passengers**	**MND bridge crossing**
motorcycles	8.212	8.212	
pass. cars	487.331	1.072.128	
buses	2.083	72.905	
lorries	60.887	60.887	
total	558.513	1.214.132	1.265.428
rail (seats)	525.000	262.500	275.297
total (pass)	**-**	**1.476.632**	**1.540.725**

Table 1: Comparison between toll statistics and extrapolated MND counts on Great Belt for the first survey weeks

4 RESULTS

4.1 Total Great Belt Traffic

Traffic totals of the MND for the six weeks considered in this interim report were at 4,938 million, of which 3,998 million were on the road and 940.000 in trains (see Table 2). Extrapolated to the whole year 2018, using the different survey periods and assigning it to comparable periods (see chapter 3.3), there were 33,5 million persons, crossing the bridge of which 25,9 million were on the road and 7,5 million in the trains.

	MND analysis (six weeks)	**extrapolated to whole year 2018**
road passengers	3.998.132	25.940.673
rail passengers	940.341	7.509.798
total GB passengers	**4.938.473**	**33.450.472**

Table 2: MND cases and (preliminary) extrapolation for 2018

Considering the countries of the providers of the mobile phone holders which should correlate strongly with nationality, there are the following shares (see Table 3).

	MND analysis (six weeks)	**network shares (in %)**	**extrapolated to whole year 2018**	**network shares (in %)**
Denmark	**4.694.886**	**95,07**	**31.993.004**	**95,64**
Germany	84.329	1,71	509.610	1,52
Sweden	53.641	1,09	305.869	0,91
Netherlands	16.339	0,33	105.760	0,32
Norway	2.162	0,04	7.446	0,02
Poland	20.853	0,42	128.399	0,38
UK	7.601	0,15	44.366	0,13
Other	58.662	1,19	356.018	1,06
total	**4.938.473**	**100,00**	**33.450.472**	**100,00**

Table 3: Share of mobile phone networks (countries of networks)

For the whole year around 96 % of the bridge crossers use mobile phones registered at a Danish mobile phone provider. 4 % are roamers with the biggest share of Germany (mobile phones registered at a German provider) and Sweden.

4.2 International traffic

The share of international traffic crossing the Great Belt according to the MND survey is, extrapolated to 2018, at 10,4 %. This is quite a substantial share of the total traffic. Even for rail the share of international traffic is at 8,7 %.

	MND analysis (six weeks)	extrapolated to whole year 2018
road passengers		
domestic DK	3.540.515	23.104.925
international	457.616	2.835.748
total	3.998.132	25.940.673
share of international	11,4	10,9
rail passengers		
domestic DK	839.488	6.857.017
international	100.854	652.781
total	940.341	7.509.798
share of international	10,7	8,7
total GB passengers		
domestic DK	4.380.003	29.961.942
international	558.470	3.488.529
total	4.938.473	33.450.472
share of international	11,3	10,4

Table 4: Share of international traffic at Great Belt (passengers)

4.3 International Traffic with the German Land-border

International traffic on Great Belt is not only related to the German land-border, i.e. traffic between Eastern Denmark and Germany and between Sweden and Germany, but there is a considerable traffic between Denmark west of Great Belt and the Scandinavian Peninsula. Even some trips between UK (via Esbjerg ferry) and between Norway and Eastern Denmark (via Hirthals or Frederikshavn) can be observed on Great Belt. The relevant traffic in the sense of the FTC study, that is between Germany/the Continent and Eastern Denmark and the Scandinavian Peninsula, is only a part of the international traffic on Great Belt. This is shown in Table 5.

	MND analysis (six weeks)	extrapolated to whole year 2018
German land-border – Sweden	21.568	125.273
German land-border – DK East	201.455	1.250.931
other international ODs	234.594	1.459.545
total international traffic	**457.616**	**2.835.748**
thereof German land-border	223.023	1.376.203

Table 5: International road traffic on Great Belt (passengers)

Of the total 2,836 million persons crossing Great Belt in 2018 for international road trips 1,376 million are related to the German land-border. This is a share of around 49 %. We assume the fact that this share for passenger traffic is higher, because there are few lorries taking the detour via Great Belt.[8] This is because lorries have a lower cruising speed than passenger cars and so the detour via Great Belt is much longer measured in time. Apart from that the ferry crossing can be used for rest time. This is valid also for buses. Therefore it can be concluded that much of the nearly 1,4 million persons crossing the Great Belt Bridge on the way to or from Germany are car passengers. Given an occupancy rate of 2,2[9] this would mean a yearly number of **around 626.000 passenger cars** using the Great Belt Bridge to/from Germany.

Around 19 % of the travellers between Germany and Eastern Denmark/Sweden via Great Belt return within 24 hours (see Table 6).

	MND analysis (six weeks)	extrapolated to whole year 2018
return within 24 hours	40.383	259.364
share of intern. Germany based traffic	18,1	18,8

Table 6: International traffic on Great Belt with Germany for which the return is within 24 hours

These short trips should be related mostly to the German regions of Schleswig-Holstein and Hamburg. Some of those trips would be bound for regions in the north of Schleswig-Holstein which would be traffic not being a potential for route shift to the FBFL when this connections is

8 See Intraplan Consult GmbH and BVU Beratergruppe Verkehr+Umwelt GmbH: Fehmarnbelt Forecast 2014 – Update of the FTC-Study of 2002, on behalf of Femern A/S, 2014: see also page 2 of this report

9 At the average of the ferries it is 2,5 to 2,6, but we expect a higher share of business travellers with lower occupancy rates

on place. There may be shifts of trip destinations though, for example shopping or leisure trips from Eastern Denmark to Flensburg which will be shifted to Ostholstein in consequence to the FBFL. Considering that:

- on the one hand interaction between Northern Schleswig-Holstein and Denmark is more intensive than between Southern Schleswig-Holstein/Hamburg and Denmark due to the shorter distance and the Danish minority in Germany living mostly in the north of Schleswig-Holstein
- on the other hand only 30 % of the Schleswig-Holstein population and 20 % of the joint Schleswig-Holstein and Hamburg inhabitants are living in the areas not influenced by the future FBFL. For areas north/north east of Neumünster the shortest route with Eastern Denmark will be the Great Belt route even when the FBFL is in place

we would estimate that 5 to 10 percent of the traffic measured by mobile phone tracking between the German landborder and Eastern Denmark/Sweden is bound to Northern Schleswig-Holstein and thus we estimate that, related to 2018, between 90 % (550.000) and 95 % (600.000) car trips are a potential for a route shift to FBFL.

5 SUMMARY AND COMPARISON WITH THE FTC 2014 STUDY

In the following table 7 the analyses shown above are compared with the FTC 2014 study.

In the FTC 2014 study 718.000 cars per year (related to the year 2022) have been expected to shift from the Great Belt to the FBFL route (line 1, in table 7). By the toll reduction on Great Belt which could not be considered in the FTC 2014 study, the transfer from the Great Belt to the FBFL route will be reduced by 198.900 (line 2), giving a total of 519.100 cars per year or 1.422 per day (see line 3), which would be transferred from Great Belt to the FBFL.

In the MND analyses international traffic has been found to have a share of 10,9 %, corresponding to nearly 1,289 million cars in 2018 (see line 4). From these international car trips around 626.000 cars are related to the German landborder (see line 5). 18,8 % of these cars are returning the same day (around 118.000, see line 6). A share of these day trips are related to the relation Northern Schleswig-Holstein – Eastern Denmark/Sweden which will be only partly subject of transfer to the FBFL, because for these regions – differently from Southern Schleswig-Holstein and all regions south of it - the Great Belt route will remain the shortest connection

Line			Cars per year	Cars per day
	Summary of results of transfer of cars from Great Belt to the Femern tunnel			
1	FTC 2014 - number of cars to be transferred (related to 2022)		718.000	1.967
2	Toll reduction in 2017 on Great Belt		-198.900	-545
3	Transfer of cars after reduction of Great Belt tolls		**519.100**	**1.422**
	Summary of results of the mobile phone data analysis in 2018[1)]	**share**		
4	International traffic on Great Belt	10,9 %	1.288.636	3.531
5	Crossing Great Belt and the DK/DE landborder same trip[2)]	49 %	**626.364**	1.716
6	Hereof returning same day	18,8 %	117.756	323
7	High estimate for trips to/from close to the border	90 %	550.000	**1.507**
8	Low estimate for trips to/from close to the border	95 %	600.000	**1.644**

1) Based on 2,2 persons per car
2) Very few lorries and busses use the Great Belt DK/DE landborder route

Table 7: Comparison of the results of the MND analyses with the FTC study 2014 including the effects of the Great Belt toll reduction

Taking that into consideration the traffic potential for a shift from Great Belt to FBFL is between (90 %) 550.000 (line 7 of line 5) to (95 %) 600.000 (line 8 of line 5) cars per year or 1.500 to 1.650 cars per day related to the year 2018 when the MND analyses have been made.