1. INTRODUCTION

Rostock is a city on the north German coast. It is a major ferry port for Denmark and Sweden and also handles goods in the docks. The population is approximately 200,000 people.

The project is a tunnel beneath the River Warnow between the ferry port and the harbour for Rostock on the east side of the tunnel and the suburb of Lütten Klein with a population of 100,000 on the west side. Some of the suburbs are on the east side of the river. However, the central business district and the majority of the population are on the west side of the River Warnow. The tunnel connects the A19 Federal Motorway on the east side with the Federal Road B103 on the west side. The tunnel opened to traffic in September 2003. The tunnel is shown in Figure 1.

Figure 1 Rostock Tunnel

The tunnel is a dual 2-lane carriageway standard with toll booths for both directions on the eastern side of the river as shown in Figure 2.
The main road through the city centre is the B103/B105. This runs parallel and close to the river over most of its length. There are a substantial number of signal controlled junctions which result in significant queuing and delay, particularly at peak periods. The tunnel enables drivers to avoid congestion in the centre of the city and make substantial time savings.

2. ORIGINAL STUDY

The original study was undertaken by Prognos in 1996/97. They had undertaken traffic counts, origin destination surveys, stated preference surveys and journey time surveys. They had built a traffic model to undertake the assessment. Their work was audited by Kessel and Partner in 1997. They updated their forecasts in 1999. The Central Case forecasts produced in 1999 started at over 26,000 vehicles per day (AADT) with a modest rate of growth as shown in Figure 3.
The tunnel opened for traffic in September 2003. At this stage it was realised that the actual traffic and revenue were much lower than forecast. This is the reason that Faber Maunsell undertook a post opening study of the Warnow Tunnel Concession in Rostock.

This paper explores the reasons for the discrepancy between forecast and outturn by comparing the various Prognos assumptions with either the outturn situation (if known) or the Faber Maunsell assessment. We distinguish between those items which cause uncertainty and those which cause bias. We compared all aspects of the modelling as follows:

- Surveys
- Networks
- Base Year Matrices
- Assignment Technique
- Growth

At the end, I summarise the assessment and comment on the changes in traffic and revenue since our assessment.

3. SURVEYS

Counts and surveys of the following types were undertaken:

- Automatic traffic counts
- Origin destination interview surveys
- Journey Time surveys
- Stated preference surveys
Much of the survey information was not available for our review. For example, the origin destination data was only available as built matrices. However, we found no evidence that there was anything wrong with the data collection exercise. In fact, the number of survey sites indicated that the data collection exercise was extensive. This gives the potential for reliable matrix building and appropriate networks.

One aspect which could have caused uncertainty was the fact that the non-summer surveys were undertaken in September when traffic levels are significantly higher than the non-summer average.

4. NETWORKS

Network assumptions cover the links included and their characteristics. Also included is the zone loading.

4.1 Speed flow curves and Capacities

The roads included in the Prognos model were adequate for the assessment. Hence, we need only to consider the characteristics of the links. Prognos used 42 different link categories. A different speed flow relationship applied to each of these link types. A very rapid increase in journey time was modelled if capacity was reached. Some of the road capacities appeared to be quite low.

Despite this, Faber Maunsell did not consider that these assumptions materially affected the forecasts.

4.2 New roads

Other new roads were expected to be completed in addition to the Warnow Tunnel. The Prognos model included the new Federal Motorway A20 to the south of Rostock and a new link between the A20 and the B103 to the west of Rostock. These roads have been constructed according to the programme. The A20 and the western bypass provide an attractive route from the western suburbs towards Berlin as an alternative to the tunnel.

Hence, we consider that the new roads they have included in their model are correct.

4.3 Complementary measures

Complementary measures are measures which might be undertaken elsewhere which would have a beneficial effect on traffic on the concession. This affects link characteristics. Prognos included an assumption of major traffic calming on the B103/B105 between Am Strande and Petridamm. They had agreed this with the consortium. They had modelled this as a maximum speed of 30 km/h and reduced the capacity to a single 2-lane carriageway standard. The reduction in capacity led to significant delays and reassignment to avoid the delays. Some of the diverted traffic made other routes more congested. Some diverted traffic went through the tunnel.
At the time of our assessment, nothing had happened in the form of traffic calming. The road had two lanes in each direction and a speed limit of 60 km/h. The consequence is that the alternative route is much more attractive than was assumed. In this case, the more significant aspect was the capacity assumption rather than the reduced maximum speed.

Faber Maunsell made an investigation into what complementary measures would be possible.

The biggest problem with complementary measures is that they are outside the control of the concessionaire. There can be no guarantee that anything will happen. We considered that the Prognos assumptions were most unlikely to be implemented for local political reasons. It would be seen as forcing people to use the tunnel and pay for the privilege.

Faber Maunsell considered that there may be some measures which could be introduced which would improve the city environment and slow down traffic on the B103/B105 as a by-product. The objectives would be to reduce the severance between the town centre and the waterfront, and to increase the capacity for traffic turning into the city centre.

There might be some scope for an increase in the number of pedestrian/cycle crossings but only in conjunction with waterfront development. This could result in a small amount of additional delay for through traffic.

Horizontal and vertical traffic calming including junction tables. These could reduce severance and slow down traffic.

Alterations to signal timings. This could enhance access to the city centre by giving more time to turning traffic while reducing capacity for through traffic.

The speed limit could be reduced, but probably only to 50 km/h. The actual increase in journey time resulting from this would be small. However, there would be a psychological effect indicating that this was no longer the major road.

Some measures which will be complementary are already programmed. These are a new junction and changes at two other junctions. The closure of Doberaner Platz to through traffic would push more local (city) traffic onto the B103/B105. These changes may add 2 minutes to the journey time for through traffic. This may result in an additional transfer of 1000 trips per day to the tunnel.

More significant changes including reduction in speed limit and signal changes to give priority to the side roads could increase the journey time for through trips by 5 minutes and result in approximately 2000 more trips per day through the tunnel.
Very severe measures, including removing lanes, new pedestrian crossings and priority measures for public transport could result in increased journey times for through traffic of 10 minutes and result in an extra 4000 trips per day through the tunnel.

4.4 Zone System

For assignment purposes, there were a total of 69 internal zones and 30 external zones in the Prognos model. This was adequate for the size of the model. External zones were loaded at the model boundary, that is, the approach road to the city was fixed in the assignment.

This has an unfortunate effect when combined with the new roads. Though the new roads are correctly included in the Prognos model, the interaction with the zone loader assumption creates a situation where too much through traffic is assumed to enter and leave the city on the B105. In the model, this traffic has the choice of diverting down the A19 and along the A20 then up the western bypass. However, in reality, most of this traffic will use a longer stretch of the A20 to bypass Rostock entirely. This leads to a very significant reduction in in-scope traffic for the tunnel. This modelling error is a major reason for the shortfall of traffic.

The effect of this can be seen by plotting the traffic flow on the B110 approach to Rostock from the east. The new A20 motorway opened in August 2002 and this approach road lost approximately one third of its traffic as shown in Figure 4.

Figure 4 Influence of Opening of A20 on the B110 East of Rostock

5. BASE YEAR MATRICES

Prognos had two sources for the creation of the base matrices: interview surveys and matrix estimation. 11 interview surveys were undertaken in July.
1996 with a further 7 undertaken in August, and another 11 in September. Some of these were undertaken on the road with others being at petrol stations to minimise disruption. These surveys should have captured nearly all of the in-scope traffic.

We have not seen the original data so it is not possible to determine if the matrices have been built correctly from the data. However, the resulting trip pattern was somewhat different to expectations. In particular, there were a greater number of trips to external zones compared to those to the city centre. This may be a genuine effect as a result of extremely good public transport within Rostock. However, it may result from errors in the matrix building process, specifically, the failure to eliminate the double counting of trips that were observed at more than one survey site. For cross city trips there were up to 5 survey sites in series. This view is supported by some of the movements within the matrix. One matrix showed that 50% of the traffic entering Rostock on the B105 in the east had external destinations. This seems most unusual for a city the size of Rostock.

Though we cannot prove it, we think that it is most likely that there were matrix building errors which probably resulted in too much in-scope traffic.

5.1 Ferries

In 1996, there were two ferry crossings of the River Warnow. One of these operated very close to the location of the tunnel. This ferry was expected to close when the tunnel opened. Prognos undertook surveys on this ferry in 1998. These indicted that most of the trips were local and over 70% were journeys to work. These trips have already demonstrated a willingness to pay to cross the river. Hence, all of these trips were expected to transfer to the tunnel when the ferry closed. Except for those vehicles which are banned from using the tunnel (bicycles and over-height trucks), we believe that complete transfer was achieved.

6. ASSIGNMENT TECHNIQUE

The matrices are assigned to the networks. The assignment technique determines the routeing pattern. Prognos used POLYDROM software. They used a generalised cost assignment where every driver minimised their cost of travel. The normal parameters are a combination of time and distance. There are three other aspects for this concession. Firstly, there is the toll itself. This is a disincentive to use the tunnel. This was included as a link impedance. This can tend to produce an all or nothing assignment. This may mean that too many or too few are modelled as using the toll. Secondly, there is the potential for delays in the toll payment process. Thirdly, there is the possibility of a route constant.

6.1 Journey Time Savings

The journey time savings used in the Prognos model are derived from the levels of traffic flow and volume delay functions in the model. The maximum
time saving would be for trips between the A19 east of Rostock to Lütten Klein in the north west. The approximate time savings are shown below.

<table>
<thead>
<tr>
<th></th>
<th>AM Peak</th>
<th>Off Peak</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>via B103/B105</td>
<td>29 minutes</td>
</tr>
<tr>
<td></td>
<td>Via A19 and Tunnel</td>
<td>8 minutes</td>
</tr>
<tr>
<td>Time Saving</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Time Saving</td>
</tr>
<tr>
<td></td>
<td></td>
<td>21 minutes</td>
</tr>
</tbody>
</table>

This is a demonstration that there are some significant time savings for some trips.

The opening of the A20 and the Westzubringer link to the A20 occurred after the Prognos assessment. It was estimated by Kessel and Partner that use of these roads would be 7 minutes slower than using the Tunnel and the A19. Our own measurements demonstrated that this was correct.

6.2 Toll Structure

The toll rates assumed by Prognos in their modelling varied by time of day. In Euro (2003) they were as follows:

- Overnight €1.07
- Off Peak €1.60
- Peak €2.14

In the event a single toll is being used for cars in the winter (€2) and a higher one in the summer (€2.50). Regular users can obtain a discounted rate of €1.50. The average toll rate is slightly higher than the assumption, which may result in some reduction in traffic prepared to pay the toll. However, this is not a major effect.

6.3 Delay at toll barriers

A reason often cited for not using a toll road is that there are delays at the toll barriers. In fact, in this case, delays were very low; mainly because the traffic flow was much lower than forecast. Up to four tollbooths are available in each direction, though the payment mechanism at some of them is restricted. Methods of payment include:

- Cash paid to the cashier;
- Cash in the machine;
- Prepayment card;
- Automatic tolling.

Automatic tolling and prepayment cards are encouraged by the use of a discount.
We did see some traffic being delayed at the tollbooths. This was mainly the result of drivers drawing up to a barrier, deciding that they could not use this method of payment, reversing back then using a different barrier.

We concluded that delays at the toll barriers were not a disincentive to use the tunnel.

6.4 Route Constant

People often have a preference for a higher standard route quite apart from any time savings that may accrue. This relates to additional comfort, easier driving, better signage etc. This is termed a motorway bonus or route constant. For their central case, Prognos used motorway bonuses of

- +0.1DM/km for cars
- +0.4 DM/km for trucks
- +0.5 DM/km for trailers

Our revealed preference surveys indicated that there was a positive route constant. Hence, we do not consider that this has resulted in significant bias in the forecasts.

6.5 Willingness to Pay Tolls

GIBB undertook some stated preference surveys to establish willingness to pay. They had a very difficult task because tolling was rare in Germany.

What they found was a marked reluctance to pay a toll. Just over two thirds of people in the survey were prepared to trade money for savings in travel time. About two thirds of the non-traders said that they would always use the non-tolled route as they objected to paying a toll. The other one third of non-traders would always use the faster route.

Values of time and route constants were derived from these surveys. There will often be a positive route constant for the higher standard route reflecting greater comfort. In this case, all of the route constant for the toll route were negative reflecting huge anti toll feelings.

Prognos used the values of time in their model but ignored the (negative) route constants. This exaggerates willingness to pay. They also included the 20% of drivers who said they would never pay a toll in with all other drivers. This exaggerated the potential market.

Our assessment showed that taking the route constant into account would reduce the forecast capture rate for typical (non-business) trips from about 50% to about 20%. Capture of business trips would reduce from about 55% to about 35%. This would be a significant reason for overestimating traffic.
I have considerable sympathy with the organizers of this survey. Faber Maunsell undertook a similar survey after the tunnel opened. This revealed a lower value of time but a positive bonus for tunnel use. More significantly, a revealed preference survey showed that people overestimated the time saved by at least 10 minutes. There are two plausible explanations for this: either they really thought the time saving was greater (because the alternative route had about 20 sets of traffic signals with frequent stopping); or they wanted to appear more justified in their decision to the interviewer. I think that the former explanation is probably correct. This means that there is a positive route constant for tunnel use.

7. GROWTH

There are a number of aspects of growth which are important. This starts with the ramp up effect in the short-term. After this there will be growth in the demand matrix as a result of economic growth and changes in population and employment. There should also be increasing capture over time.

7.1 Ramp up

In their realistic case forecasts, Prognos have used a ramp up by reducing first year flows by 8% and second year flows by 5%. Faber Maunsell considered that the concept was correct but the actual ramp up may be greater as this is the first toll scheme in Germany.

This scheme has all of the characteristics quoted by Standard and Poor as having a very high ramp up. It is a tolled scheme in a location unused to toll schemes. Under these circumstances, a ramp up factor in the first year of 30% would be more likely.

Though this would give a positive bias to the results, the effect would be short-lived.

7.2 Demand Growth

Population

The overall population forecast for Rostock is for decline. Within Rostock, housing is being dispersed to the fringes. Prognos continued this trend in their forecasts. Population in Rostock has declined from 224,000 in 1996 to 198,000 in 2003, a reduction of 11.5%. Some of this is out migration to surrounding towns, with no change in the work place. The population change is shown in Figure 5.
The decline in population in Rostock between 1996 and 2003 was underestimated.

GDP

The GDP forecasts from Prognos and Kessel and Partner were quite high. Prognos were using a growth of GDP between 1996 and 2020 of 127% (3.5% per annum). Kessel and Partner used 137% growth in GDP for the same period (3.7% per annum) and more heavily weighted towards the start of the concession period. The actual GDP growth in Germany between 1996 and 2003 was about 40% of the Kessel and Partner forecast, and it was even lower in the north east of Germany including Rostock.

Growth in GDP was over estimated. The assumptions for GDP growth in the future used in the modelling are considerably higher than current forecasts.
7.3 Increasing Capture

There are two major reasons why capture might be expected to increase in the future. Firstly, as alternative routes become more congested, the journey time saving as a result of using the tunnel may increase. Secondly, increasing wealth should mean that people are prepared to pay more for each unit of time saved.

Prognos assumed that the value of time would increase directly in line with GDP per employee or private consumption per inhabitant. Quite apart from the reservations about the assumptions concerning economic growth, Faber Maunsell consider that these rates are too high. While this rate of increase may be true for individual drivers, the fact that there is increasing vehicle ownership (and the new owners are likely to be less wealthy than existing owners) means that the average for all drivers will not grow this fast.

8. RECONCILIATION OF FORECAST AND OUTTURN TRAFFIC AT THE OPENING YEAR

In the sections above we have highlighted the areas where we think errors in modelling or assumptions have led to optimistic forecasts of concession traffic. In this section, we attempt to demonstrate the consequence of each error and thereby show the influence on the forecast.

The Base Year Matrices are an issue because some of the traffic which was surveyed as being in-scope will actually be using the A20 and will not be in scope. We think that the amount of in-scope traffic will be 40% lower than that surveys and this will reduce forecasts by 40%.

There are two aspects of forecast year matrices which will have resulted in a positive bias to the forecasts. Firstly, the reduction in population in Rostock has been greater than forecast. Secondly, the growth in GDP has been lower than forecast. Between the Base Year and the Opening Year, we consider that this will reduce the forecasts by about 5%.

Ferries. The ferries themselves are not an issue. The problem arises from the surveys which resulted in substantially increased forecasts for the summer period. We assess that correcting this will reduce forecasts by 5%.

We consider that the absence of traffic calming on the scale assumed by Prognos would result in a reduction in the forecasts of approximately 25%.

The willingness to pay surveys proved difficult to interpret. Our own surveys showed that this effect was not as significant as we first thought. We consider that this would reduce forecasts by about 10%.

The average toll rates used by Prognos were below the outturn values. This will mean that the Prognos forecasts will be too high. We assess that this will cause the traffic forecasts to be about 5% too high in 2003. It will not necessarily impact on the revenue forecasts.
The Prognos forecasts make no allowance for Ramp Up. They assume that the full modelled traffic will use the tunnel immediately. We believe that there should be a reduction for ramp up of 20% in 2003, which will decline to zero over a short period. The latest information from Warnow Tunnel shows that growth has been higher than forecast demand growth which is consistent with an unwinding of the ramp up effect.

The overall assessment is shown in the table below.

<table>
<thead>
<tr>
<th>% Change</th>
<th>2003 Traffic Flow/Forecast</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prognos Forecast</td>
<td>26608</td>
</tr>
<tr>
<td>Base Year Matrices</td>
<td>-40%</td>
</tr>
<tr>
<td>Forecast Year Matrix Growth</td>
<td>-5%</td>
</tr>
<tr>
<td>Ferries</td>
<td>-5%</td>
</tr>
<tr>
<td>Road Network</td>
<td>-25%</td>
</tr>
<tr>
<td>Willingness to Pay</td>
<td>-10%</td>
</tr>
<tr>
<td>Toll Rates</td>
<td>-5%</td>
</tr>
<tr>
<td>Ramp Up</td>
<td>-20%</td>
</tr>
<tr>
<td>Outturn Traffic</td>
<td>7200</td>
</tr>
</tbody>
</table>

We consider that the biggest issue in the forecast error related to the construction of the Base Year Matrices and the failure to take account of the diversion to the A20 of traffic which had been using the B105 to cross Rostock. These are both modelling errors rather than errors of assumptions or forecasts.

The road network error relates to assumptions about traffic calming. We think that their assumptions were unrealistic but they were agreed with the consortium.

Willingness to pay is very difficult to assess from a survey where it can not be substantiated by revealed preference data. Hence, I would not criticise Prognos for this error. It was much less significant than most of the other issues.

The differences due to ramp up are much less serious. This is a short-term effect which will work its way through in a maximum of three to four years.

9. COMPARISON OF ORIGINAL FORECASTS, REVISED FORECASTS AND OUTTURN

Faber Maunsell produced forecasts for the purposes of refinancing. Naturally, with their initial experience, the lenders had a cautious attitude with regard to future growth. The revised forecasts are shown with the original forecasts in Figure 6. The actual outturn traffic is also shown. This was slightly higher than the forecast in 2005. The growth in 2006 also appears to be higher than
forecast, though this does not yet represent a full year’s data and there are some lower flow months to come.

Figure 6  Comparison of Forecasts and Outturn Traffic

The comparison has been shown at AADT level. A comparison of revenues is broadly similar but growth has been reduced as there has been a greater than anticipated take-up in discounted trips.

On the basis of these forecasts, the concession has been successfully refinanced incorporating an increase in the concession length to 50 years.