EVALUATING A REPLACEMENT FERRY FOR THE ISLES OF SCILLY USING A DISCRETE CHOICE MODEL FRAMEWORK

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1. INTRODUCTION

The Isles of Scilly are located 28 miles off the south west tip of England. The Isles comprise five inhabited islands, with a combined population of about 2000, and many smaller uninhabited islands and rocky islets. The main industry on the Isles is tourism, which is highly dependent upon the transport links to and from the mainland.

At present there are three commercial services operating between the Isles and the mainland: a sea ferry, a helicopter service and fixed-wing aircraft services. The ferry is now nearing the end of its operational life and will be taken out of service after 2014. In response, Cornwall County Council, on behalf of the Penzance to Isles of Scilly Route Partnership, are preparing a Major Bid Submission to the UK Department for Transport for capital funding support for improved transport links. As part of this bid, a robust Cost-Benefit Analysis (CBA) was required to quantify whether a replacement ferry between the Isles and Penzance was justified.

The aim of the work undertaken specifically in this study was the development of a travel demand model and the quantification of travellers' benefits from different ferry service options, including the option of abandoning the ferry service, to support the CBA.

2. DATA

Because of the importance of ferry for travel to the Isles, it was necessary that the travel demand model reflect both changes in modal shift and changes in total travel demand as a result of changes in ferry service level. A modal choice model was estimated using preference data and a trip frequency model was estimated using stated intentions data.

Both revealed preference (RP), i.e. observed travel choice data, and stated preference (SP), i.e. hypothetical choice data, were collected to develop the mode choice model. The strength of SP data is in deriving the relative importance of the different aspects of service (price, crossing time, comfort, etc.) in ferry travel demand. However, to derive forecasts and elasticities it is necessary to quantify the absolute scale or sensitivity of mode choice responses and in this respect RP data is essential. Current best practice is to combine RP data with SP data, where relevant, and this methodology was used in the present study. In a joint analysis, the main information concerning the relative importance of price and service comes from the SP data, while information concerning the overall likelihood that a traveller will choose a particular mode is derived from the RP data.

A programme of SP and RP surveys was therefore undertaken during the summer operating season in 2005. The surveys were conducted with both non-resident visitors and residents of the Isles. This survey is described in Burge *et al*. (2006).

Over 1800 face-to-face RP surveys were carried out with non-resident travellers to the Isles of Scilly, across the day-trip and long-staying visitor segments. As part of the RP survey, respondents were asked whether they were willing to participate in a subsequent (telephone) SP survey and over 400 SP surveys were conducted with the non-resident travellers to the Islands. Residents were posted RP surveys and over 250 RP surveys were returned, reflecting a response rate of nearly 30%. Of those residents who responded to the RP surveys, about 60 went on to participate in a detailed SP survey.

After respondents had finished the SP exercises, they were asked to state their number of intended trips to/from the islands under certain scenarios (e.g. current conditions, discontinuation of the ferry service, improvement of the ferry service).

3. MODEL ESTIMATION

Disaggregate discrete mode choice and travel frequency models were developed for the different travel segments (day-trip travellers, travellers that stay overnight on the Isles, and residents).

3.1 Mode choice model

The models were developed incrementally in order to reduce the chance of input errors, i.e. first SP within-mode choice models were developed, then SP between-mode choice models were developed, then RP models were developed, then joint SP within-mode and between-mode choice models were developed and finally all data sets were used jointly to estimate the final mixed logit model (for methodological details, see Bradley and Daly, 1991).

The resulting model coefficients were highly significant for all segments. A selection of the most important coefficients are displayed in Table 1.

- The price of travel was found to be important in all traveller segments and had a significantly negative impact on choice of mode, i.e. all travellers preferred alternatives with lower costs, all else being equal; in all segments, travellers from households with income less than £60,000 were observed to exhibit higher price sensitivity than those from households with income greater than £60,000; in the day-trip segment, business travellers were observed to have lower price sensitivity that those travelling for non-business purposes.

We have undertaken tests to identify the optimal specification of cost; the best models incorporate a term representing the cost per person in the group (specifications based on cost per group, cost per adult and non-linear cost valuations have been tested);

- Ferry time is valued negatively, i.e. travellers prefer shorter ferry journey times, this term is also highly significant; significant variations in the value of ferry time were observed by income group in the long-stay visitor segment, i.e. those with higher incomes had significantly more negative valuations of ferry time.

  We have undertaken tests to examine whether there was any evidence from the SP responses of non-linearity in the value of ferry travel time; the evidence is that the valuation of ferry time is linear.

- Access time was found to be valued negatively and significantly in the day-trip and long-stay visitor segments; no significant access time coefficient could be identified for the resident travellers.

- A new modern ferry had a positive and significant valuation for all traveller segments.

- Improvements at St. Mary's harbour were not valued significantly for any of the traveller segments.

- On the other hand, improvements at Penzance were valued positively and significantly by visitors to the Isles of Scilly; they were not valued significantly by Island residents.

- for the day-trip segment there was a preference for 2 sailings per day, this is likely due to the fact that these options allowed for more time on the Islands (earlier outward departure and later return trip); for the long-stay visitor segment the number of sailing and departure time alternatives were not valued significantly, in the context of choice of mode.

A number of socio-economic impacts were also identified, i.e.:

- negative terms on the helicopter alternative, if someone in the travelling group was fearful of flying in helicopters;

- negative terms on the airplane alternative, if someone in the travelling group was fearful of flying on an airplane;

- negative terms on the ferry, if someone in the travelling group was prone to seasickness.

In the estimation procedure we also tested for 'inertia', i.e. a preference for the currently used mode, in the mode choice models. These constants were found to be positive and highly significant. However, they were not used in the final models as they were considered to be short-term effects.

Table 1 Selection of model estimates (including t-ratios)

	Day-trip		Stay		Residents	
Cost coefficient on single way fare p.p.	*Estimate*	*t-ratio*	*Estimate*	*t-ratio*	*Estimate*	*t-ratio*
Trip for any purpose, income < £60,000/yr			-0.076	(-7.4)	-0.0673	(-11.6)
Trip for any purpose, income > £60,000/yr			-0.0549	(-5.8)	-0.0526	(-7.8)
Trip for any purpose, income unknown			-0.0741	(-7.5)	-0.0581	(-9.8)
Personal trip, income < £60,000/yr	-0.11	(-5.7)				
Personal trip, income > £60,000/yr	-0.0808	(-5.0)				
Personal trip, income unknown	-0.0884	(-5.1)				
Business trip, any income	-0.054	(-4.7)				
Time coefficient for single way trip						
Ferry time, any income	-1.3	(-4.2)			-0.663	(-2.4)
Ferry time, income < £60,000/yr			-0.381	(-2.3)		
Ferry time, income > £60,000/yr			-1.22	(-5.4)		
Ferry time, unknown income			-0.986	(-4.6)		
Access time to departure port (max. 8 hrs)	-0.816	(-5.6)	-0.273	(-6.7)		
Quality improvement constants *(relative to current situation)*						
New boat (less prone to seasickness)	0.965	(4.2)	0.956	(5.7)	0.446	(2.1)
Improved Penzance quayside facilities	0.567	(3.2)	0.363	(3.3)	0.166	(0.8)
Improved St. Mary's quayside facilities	0	(*)	0	(*)	0.474	(1.4)
Other constants						
On heli alt. if origin/destination is Tresco					0.54	(1.6)
On heli alt. if any in group fears flying heli					-0.347	(-1.6)
On plane alt. if any fears flying on a plane					-0.417	(-1.6)

3.1.1 Values-of-Time

The (household) income-specific price sensitivity results in income-specific values of time for access time (for the visitor models only) and ferry time. The model for day-trip visitors also incorporated separate values of time for business travellers. Separate business values of time could not be identified in the other segments. The resulting values of time are presented in Table 2.

Table 2 Ferry values-of-time (£/hour, 2005 prices)

	Day-trip Visitors		Staying Visitors	Residents & Others
	business trip	*non-business trip*	*any purpose*	*any purpose*
Household income < £60k per year	£24.07	£11.82	£5.01	£9.85
Household income > £60k+ per year		£16.09	£22.22	£12.60
Unknown/not stated income		£14.71	£13.31	£11.41

For non-business travel, the values of ferry time have been well estimated. However, it is clearly higher than the WebTAG[1] recommended value of £5.16[2] (2005 prices). One way in which this value and the WebTAG value may differ is with regard to journey distance/duration of the journey, where evidence suggests that values of time increase with journey distance. Mackie *et al.* (2003) identified an elasticity of 0.31 with respect to distance. Whilst the distances travelled by ferry are not large, the trip durations are long - the ferry journey takes 2 hrs 40 mins – and comparable to long distances travelled by road. Using the elasticity to distance to correct for trip duration effects average ferry time valuations for non-business journeys are only slightly higher than the WebTAG values (adjusted to a 2005 price).

Another way in which the Isles of Scilly values and WebTAG values for non-business travel may differ is with regard to the distribution of household income, where we see that travellers to the Isles of Scilly have a higher average household income than on average in the UK. However, with an income elasticity of 0.16 (Mackie *et al.* 2003) there is little change on the journey time corrected figures.

3.1.2 Values of quality improvements

The resulting valuations for the quality improvements, both for the new ferry and for the harbour improvements at Penzance and St. Mary's, also appear to be reasonable. Table 3 compares the average willingness-to-pay to save 30 minutes of ferry travel time to the average valuations for the quality improvements investigated in the study, namely the introduction of the new ferry and for harbour improvements (both at Penzance and at St. Mary's together).

Table 3 Willingness-to-Pay for Ferry Time Savings and Quality Improvements (2005 prices)

	Day-trip Visitors	Staying Visitors	Residents & Others
Faster ferry (30 minutes saving)	£7	£5	£5
New ferry (less prone to seasickness)	£10	£13	£7
Harbour improvements	£6	£5	£10

3.1.3 Calibration of mode-specific constants

A secondary estimation procedure was employed to re-estimate appropriate mode-specific constants, using RP information only, as is recommended in the upcoming WebTAG advice on development of demand forecasting models for major public transport schemes.

3.2 Trip frequency model

The frequency models reflect changes in total travel demand as a result of changes in ferry services. For visitors, separate trip frequency models were estimated for day-trip and long-stay travellers. For residents, separate models were estimated for leisure and business travel.

The resulting trip frequency models reproduce the reported changes in trip making estimated by the survey respondents in the Stated Intentions (SI) survey (as part of the SP survey). It is noteworthy, however, that in none of the models is the accessibility term significant (at the 95% confidence level). It is our experience that it is difficult to identify significant relationships between trip frequency and level-of-service changes at a disaggregate level.

Table 4 Trip Frequency Model Results: Predicted and Reported Increases and Decreases in Trip Making

	Improved Ferry Services		No Ferry Services	
	Model	SI Data	Model	SI Data
Day-trip Visitors	55% ↑		19% ↓	
Staying Visitors	25%↑		9% ↓	
Overall Visitors	34%↑	30% ↑	12% ↓	20% ↓
Residents – Personal	29%↑	20% ↑	13% ↓	30% ↓
Residents - Business	16% ↑	15% ↑	8% ↓	20% ↓

As Table 4 shows, both the visitors and the residents tend to predict much higher increases in trip making for the situation with improved ferry services than decreases as a result of the removal of ferry services. It is not clear how reliable these responses are. The model does not reflect this asymmetry, rather it reflects the average response, generally under-predicting the reduction in trip making with the removal of ferry services, but over-estimating the increase in trip making with ferry service improvements; we think the model is reasonable in this respect as a predictor of long-term response. Additionally, for visitors we see that the day-trip visitors are more sensitive to ferry accessibility changes and for residents we see that personal trips are more sensitive to ferry accessibility changes: both of which we would expect.

4. CONSUMER SURPLUS

Consumer surplus is the level of economic benefit derived by transport users from using the transport system. The calculation of the change in consumer surplus (or user benefits) is therefore a fundamental part of an economic appraisal. Technically the measure of consumer surplus used in appraisal is that deriving from a Marshallian demand function and is equivalent to the area under the demand curve minus the price paid for the good. If the demand curve is known this can be calculated through a direct integration of the demand curve. For a variety of reasons however the demand curve often cannot easily be expressed mathematically. In such situations by assuming the demand curve to be linear and using the Rule of a Half an estimate of the change in consumer surplus can be made. In the vast majority of situations this makes the problem straightforward to solve and results in little loss of accuracy in the measure of consumer surplus.

Appraisal practice in many countries in Europe often requires the use of standard appraisal values for non-work time and the disaggregation of user benefits between the different cost categories (time savings, fare changes and vehicle operating cost savings) (Odgaard, Kelly and Laird, 2005). In many situations the standard appraisal values differ from those used in the demand forecasting for political and decision-making reasons. The primary rationale for the adoption of standard appraisal values for non-work time is equity – as the use of local valuations, as used in the demand forecasting, may weight appraisal outcomes and the prioritisation of a national investment programme in favour of high income areas. A strength of the Rule of a Half methodology is the ability to meet both these appraisal requirements – the use of standard values and disaggregation between cost components. Increasingly however national appraisal frameworks (e.g. the Netherlands and Switzerland) are adopting valuations that vary with income groups with the emphasis for equitable treatment between socio-economic groups and between projects (in different regions of a country) relying on other aspects of the appraisal framework – rather than the cost benefit analysis. Mackie *et al.* (2003) also recommended such an approach be adopted for major transport projects in the UK, but this has not been implemented as yet.

Unfortunately, the Rule of a Half approximation breaks down in several situations one of which is the introduction or loss of a mode. This is of particular relevance to the appraisal of a new ferry for the Isles of Scilly, as this needs to be be compared to a scenario in which the ferry service is not continued at all. Nellthorp and Hyman (2001) set out several alternatives to the Rule of a Half and argue that numeric integration should be used in such situations if it is too complex to integrate the demand function. Neither numeric integration nor direct integration allow either the use of standard appraisal values nor the disaggregation of user benefits between the cost categories. In such situations adjustments for equity impacts need to be undertaken external to the consumer surplus calculation – as would be the case if impact valuations (e.g. value of travel time savings) reflected different income groups. Given that it is possible, in the present study, to integrate the demand function and that this function could be monetised, consumer surplus was calculated directly using the formulation set out below. Checks were made on whether equity related adjustments to these calculations were necessary and this is also discussed further below. This study represents one of the few applications in which economic benefits have been calculated directly from the demand function (see de Jong et al., 2005, for a review of other applications, and Kohli and Daly, 2006, for a discussion of the benefits of the two approaches).

Changes in consumer surplus for a population segment in the sample are calculated in utility terms using the analytic integral of the demand function. They are converted into units of money using the model cost coefficient (which has units of utils per pound) for the relevant model segment.

Where no shadow price is used, the difference in consumer surplus from a reference scenario is given by:

$$\Delta CS = \frac{\exp\left(\theta \Delta V^*\right) - 1}{\theta}$$

or, for staying visitors (where frequency response is switched off, i.e. θ=0):

$$\Delta CS = \Delta V^*$$

Daly and Miller (2006) set out a justification of these formulae and that the second formula is in fact a correct simplification of the first when θ=0.

In certain forecasting scenarios the demand for ferry travel predicted by the models may exceed the ferry capacity. In these cases the demand forecasts are adjusted by introducing a ‘shadow price’ for ferry that reduces overall demand to the exact capacity of the boat. When a shadow price is used for the ferry, the consumer surplus calculation is more complicated. The shadow price reduces the utility of the ferry until the demand reaches capacity; but using this reduced utility in the consumer surplus calculation does not take account of the fact that those passengers who still choose the ferry benefit from the full, unreduced utility.

The correct consumer surplus calculation in this case is:

$$\Delta CS' = \frac{\exp\left(\theta \Delta V^*\right)-1}{\theta} + D\left(ferry\right)\cdot\left(-V_{shadow}\right)$$

or, without frequency response,

$$\Delta CS = \Delta V^* + D\left(ferry\right)\cdot\left(-V_{shadow}\right)$$

The logsum, V*, is based on the reduced ferry utility, but the shadow price utility is 'returned' to those travellers who choose the ferry anyway. It has been verified that this consumer surplus function has the necessary properties (Daly & Miller, 2006).

The consumer surplus values calculated by this method are based on the time and cost sensitivities, and hence values of time, found during model estimation. As discussed earlier (section 3.1.1) average values for non-working time found in this study are comparable to standard appraisal values once distance/duration effects have been accounted for. Average incomes of travellers to/from the Isles of Scilly are similar to the UK national average. No adjustment for equity effects to the consumer surplus measure for non-work travellers is therefore needed.

Whilst there are no guidance appraisal values for business travellers on ferries it was found that the values found in this study for two of the three market segments (residents and long-stay business) are significantly lower than guideline values for the average business traveller in the UK (Kouwenhoven *et al.*, 2006, Appendix A). Such differences may arise for a variety of reasons including that average wages of business travellers that use the ferry service are much lower than average values found on other modes in the UK, and secondly that not all the time spent travelling for business purposes is lost to production. Given the data on average earnings for ferry travellers we would be inclined to favour the latter reason. That is savings in ferry travel time may generate limited additional productivity for the firm as the employee may be able to undertake some work whilst travelling on the ferry and/or the length of the journeys involved may mean that savings in travel time are transferred to leisure time by the employee rather than into more production for the firm (see Hensher, 1977, for a fuller discussion of this concept). Given that appraisal values for business time in the UK are based on a cost saving approach rather than the Hensher approach the consumer surplus measure for business travellers was factored so that for each of the market segments the average value of time was consistent with those in UK appraisal guidance. This slightly crude adjustment arises as a consequence of the imbalance between behavioural and appraisal values – particularly when appraisal values may be based on a cost saving approach.

A final difference between a consumer surplus measure calculated directly from the demand function and a standard appraisal in the UK is that all the components in the generalised cost function influence the consumer surplus measure in the case of a direct integration of the demand function. In the case of this study this means that the value of the new boat, the willingness to pay to avoid sea-sickness, the willingness to pay for harbour improvements, the willingness to pay for better scheduling all affect the consumer surplus measure. It is not 'standard' to include such values in a normal appraisal. There is also a lack of corroborating evidence on the values of such attributes, compared to the vast literature on say values of time, so it is difficult to know if the local valuations found in the study are having a realistic influence on user benefits. This is particularly relevant here as using the direct integration approach that had to be adopted in this study (due to the introduction of a new mode) it is not possible to disaggregate the consumer surplus measure between the traditional cost categories (e.g. time savings) and these 'other' cost categories.

5. FORECASTING TOOL

A forecasting tool was developed using a sample enumeration technique to produce future year demand forecasts by applying the estimated mode choice (section 3.1) and trip frequency models (section 3.2) to the survey samples. The tool also calculates the consumer surplus as described in section 4.

In sample enumeration, the RP survey sample used to estimate a demand model is also treated as a representative sample of the travel population for the purpose of forecasting. The response of each group in the sample to changes in the attributes of the travel modes is predicted using the mode-choice model: specifically, the probability of choosing each mode is calculated. These probabilities are then weighted and summed over the whole sample to produce forecasts of demand, and in this case revenue and consumer surplus.

Because the Isles of Scilly models also predict changes in travel frequency in response to changes in the attributes of the travel modes, the demand attached to each group in the sample will change in response to these attributes to simulate the effect of increased or reduced travel frequency.

The tool takes the form of an Excel workbook with macros. Figure 1 shows diagrammatically the inputs required and outputs produced.

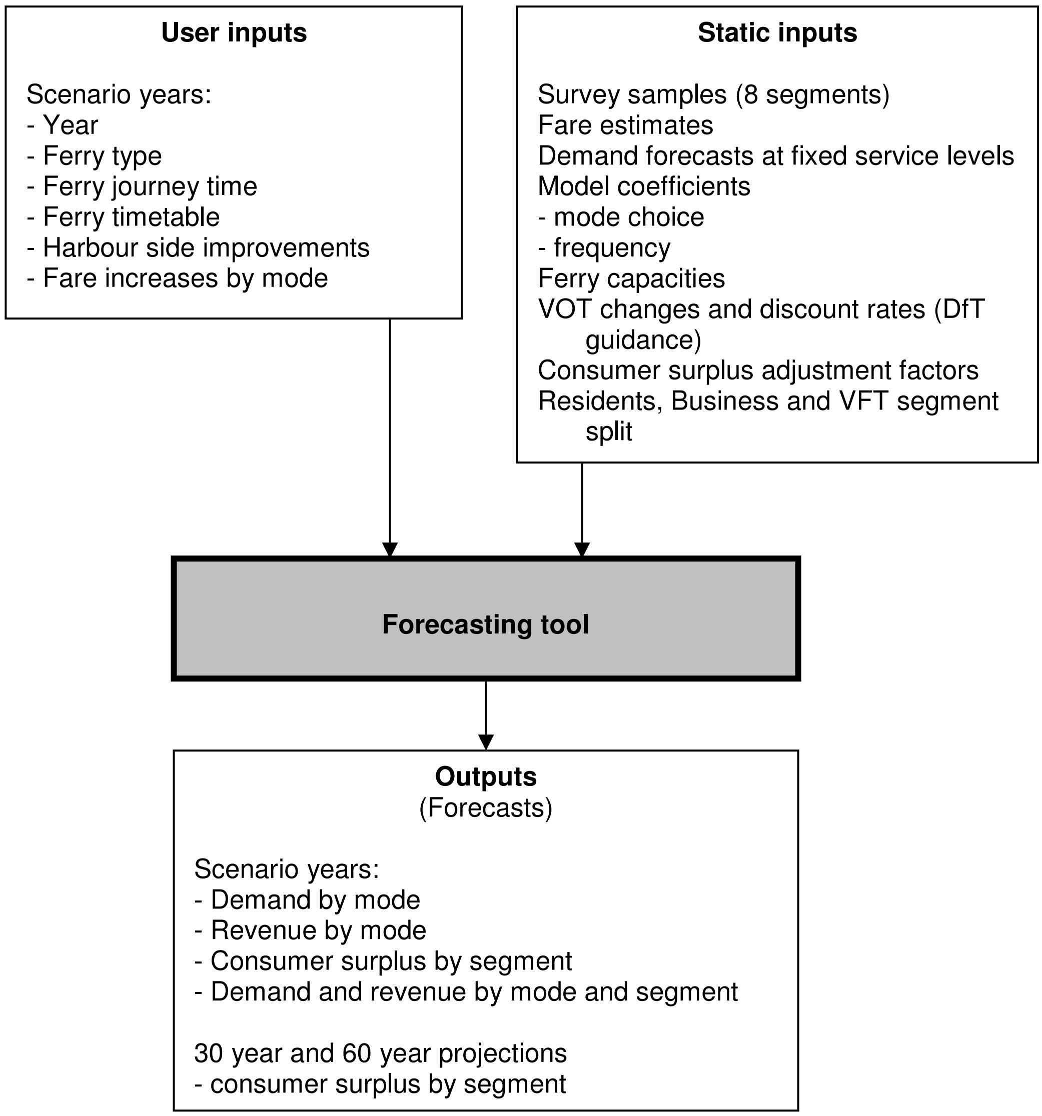

Figure 1: Forecasting tool inputs and outputs

6. TEST RESULTS

Tests have been conducted to examine the resulting ferry fare elasticities obtained from the model. These are presented in Table 5.

Table 5 Ferry Fare Elasticities by Travel Segment

Segment	Elasticity
Day-trip	-0.7
Day-trip (for VFR purpose)	-1.1
Day-trip (for business purpose)	-0.8
Long-stay Trip	-2.0
Long-stay Trip (for VFR purpose)	-1.9
Long-stay Trip (for business purpose)	-2.2
Residents (for leisure purpose)	-2.0
Residents (for business purpose)	-2.0
Total	-1.3

It is difficult to compare these elasticities with elasticities reported in other studies, since none of these other studies are directly comparable with the Isles of Scilly situation. Perhaps the most comparable are ferry passenger elasticities provided by the Scottish Office Industry Department study on fare price elasticities (SOID 1992), which ranged from -0.8 to –1.5 for specific Scottish ferry routes. Certainly the elasticity figures found from this study are consistent with these figures, with higher elasticities for those segments, i.e. staying visitors and residents, who may consider a wider range of travel alternatives to the Isles.

The model has since been used to quantify the specific traveller benefits for a number of different ferry service options by the Penzance to Isles of Scilly Route Partnership.

7. CONCLUSIONS

We have developed a tool which calculates the travellers' benefits and disbenefits of changes in the transport services between the Isles of Scilly and Penzance. The model is based on a mode choice model and a trip frequency model and predicts changes in modal shift and in total travel demand as a result of changes in the services.

The mode choice model was derived from stated and revealed preference surveys of visitors to and residents of the Isles of Scilly. We have found significant coefficient values for most parameters. The values-of-time that were derived from this model are consistent with expected values based on previous studies. Whilst, the values-of-time for non-business ferry trips to the Isles of Scilly are much higher than standard WebTAG values this difference is fully consistent with with the impact that trip duration can have on values of time.

The trip frequency model was derived from stated intention questions in the surveys mentioned above. Since the model was based on relatively small sample and a limited number of questions, the model coefficients were not very significant. Furthermore, it is important to underline that this model predicts only the number of trips made by current travellers and not by people that are currently not travelling to/from the Isles but might decide to do so if the (ferrry) service is improved.

There is very limited data on price elasticities of demand for ferry travels to islands. The elasticities that are obtained from our model range from -0.7 for day-trip travellers to -2.2 for long-stay business trips, and these are comparable to values found in one other study.

The tool will be used by the Penzance to Isles of Scilly Route Partnership as part of a robust Cost-Benefit Assessement (CBA) of a possible replacement of the current ferry that is nearing the end of its operational life. The CBA is required by the UK Department for Transport in order to receive possible capital funding for improved transport links.

Our tool provides an enhancement to normal transport appraisal procedures because:

- it includes travellers' benefits from improved quality of the boat and from the harbour facilities;

- it uses exact consumer surplus calculations allowing for heterogenity in travellers preferences and the possibility of a discontinuation of the ferry service.

Our tool is one of the few examples that uses a logsum measure in the consumer surplus calculation. A further challenge is to investigate whether the inclusion of non-standard elements of benefits (such as the aversion to sea sickness) has any influence on the consumer surplus calculation in this way.

Acknowledgements

This research study was funded by Cornwall County Council and the Department for Transport. The views expressed in this paper are those of the authors and do not necessarily reflect those of project sponsors. We would also like to acknowledge the contribution of Peter Burge who provided valuable input throughout this research study. We also acknowledge the contribution of Accent during the fieldwork phase of this research.

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Notes

[1] WebTAG is the UK Department for Transport's website for guidance on the conduct of transport studies, including advice on the modelling and appraisal appropriate for transport schemes.

[2] The standard appraisal value for non-work trips on 'other' trip purposes is £4.46 in 2002 prices and values. Adjusting for inflation and GDP/capita growth this is equivalent to £5.16 in 2005 prices and values.