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A comparison of methods for representing random taste heterogeneity in discrete choice models

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Abstract

This paper reports the findings of a systematic study using Monte Carlo experiments and a real dataset aimed at comparing the performance of various ways of specifying random taste heterogeneity in a discrete choice model. Specifically, the analysis compares the performance of two recent advanced approaches against a background of four commonly used continuous distribution functions. The first of these two approaches improves on the flexibility of a base distribution by adding in a series approximation using Legendre polynomials. The second approach uses a discrete mixture of multiple continuous distributions. Both approaches allow the researcher to increase the number of parameters as desired. The paper provides a range of evidence on the ability of the various approaches to recover various distributions from data. The two advanced approaches are comparable in terms of the likelihoods achieved, but each has its own advantages and disadvantages.

Keywords: Random taste heterogeneity; Mixed logit; Method of sieves; Mixtures of distributions.

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1. Introduction

The widespread use of models such as the Mixed Multinomial Logit (MMNL) model (cf. Revelt and Train, 1998; Train, 1998; McFadden and Train, 2000; Hensher and Greene, 2003; Train 2003) has made the issue of choosing a mixing distribution very important. In these models we must specify a mixing distribution, i.e. a distribution of random parameters, that may be interpreted as representing random taste heterogeneity. The trouble is that we never observe these random parameters and that we mostly have little a priori information about the shape of their distribution except possibly a sign constraint. On the other hand, the choice of a specific distribution may seriously bias results if that distribution is not suitable for the data (cf. Hess *et al.*, 2005; Fosgerau,

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2006). This kind of misspecification is particularly damaging when the distribution is itself of interest as is the case in estimation of the value of travel time, the response to tolls, adoption of a new mode, etc.[1]

The point of this paper is to provide a comparison of two advanced approaches for the representation of random taste heterogeneity in discrete choice models. A prominent feature of the paper is the graphical evidence we provide on the ability of the various approaches to approximate various challenging distributions. The range of possible shapes of the mixing distribution is determined by a number of deep parameters to be estimated. The two advanced approaches in this paper are ways of specifying the mixing distribution with a *variable* number of deep parameters such that an arbitrary level of flexibility may be achieved. In the present paper, we limit our attention to univariate mixing distributions; the use of multivariate distributions is a topic for further research.

Various authors have estimated a range of parametric distributions, aiming to gauge the advantages of distributions with a high degree of flexibility (see for example Hensher and Greene, 2003; Train and Sonnier, 2005; Hess *et al*., 2006a; Rigby *et al*. 2009; Rigby and Burton, 2006; Scarpa *et al*., 2008). However, although different distributions have different properties, flexibility is generally determined by the number of parameters for the distributions. A two-parameter distribution corresponds to just a two-dimensional subset of some space of distributions. So, while it may be possible to find a low-parameter parametric distribution that fits well in a specific situation, it will not be more flexible than other parametric distributions with the same number of parameters. This acts as our main motivation for exploring alternative ways of representing random taste heterogeneity.

The method of sieves is a natural choice for generating flexible distributions. Consider some model containing an unknown function to be estimated, where, in the present case, the unknown function is the unknown density of a taste coefficient α. The unknown function can be thought of as a point in an infinite-dimensional parameter space. Rather than trying to estimate a point in an infinite-dimensional space, one estimates over an approximating finite-dimensional parameter space. As the dimension of the approximating space grows, the resulting estimate approaches the true unknown function under quite general circumstances (Chen, 2006). Additionally, the dimension of the approximating space can increase with the size of the dataset such that better approximations to the true function are obtained for larger datasets. In econometrics, the resulting estimators are known as semi-nonparametric (Galant and Nychka, 1987).

There are various ways of approximating an infinite-dimensional space of distributions by finite-dimensional spaces. In this paper, we shall confine attention to just two convenient possibilities and we shall fix the number of parameters to be estimated, corresponding to the dimension of the approximating space, at low values. What we obtain is thus just some very flexible distributions with more parameters than usual. The distributions can be extended with more parameters as desired in a very straightforward way, as discussed in Section 2.

The first approach we consider is that described by Fosgerau and Bierlaire (2007). The main feature of this approach is that it can use any continuous distribution as its base. This is then extended by means of a series expansion, in our case using Legendre polynomials, such that any continuous distribution can be approximated at the limit,

[1] Misspecification has even lead some researchers to think that they have evidence of positive marginal utility of travel time, when in fact they have just specified a mixing distribution that has values on both sides of zero.

providing it has support within the support of the base distribution. The number of parameters can be increased one by one by increasing the number of terms used in the series expansion. Fosgerau and Bierlaire (2007) present the technique as a test of the appropriateness of the base distribution, used by testing the model with additional terms against the base model. Here, we simply use the resulting model as a flexible means of retrieving random taste heterogeneity.

The other approach that we consider employs a mixture of distributions (MOD) estimator, which is another example of the use of the method of sieves. Specifically, we make use of a discrete mixture of Normal distributions with different means and variances that are to be estimated, where such a mixture of Normals can approximate any continuous distribution. In existing work, Coppejans (2001) considers the MOD estimator for the case of cross-sectional binary choice data, deterministic taste coefficients but randomly distributed error terms, paralleling the estimator of Klein and Spady (1993). As such, our use of the idea of a finite mixture of Normals is somewhat different. Another discussion on mixtures of Normal distribution is given by Geweke and Keane (2001).

Both approaches have the flexibility of allowing for multiple modes in a distribution. This can be a significant advantage compared to the typically used distributions (e.g. Normal, Lognormal, ...) that are restricted to a single mode, given the possibility that the sample may be composed of distinct groups with different behaviour.

In this paper, we present evidence from two separate studies. In the first part of the paper, we conduct a systematic study using Monte Carlo experiments. Here, we show that the two flexible approaches are both able to approximate well a range of true distributions, even though the number of deep parameters is kept reasonably low. The two approaches do about equally well in outperforming four commonly used distributions over a range of situations. Hence, we recommend the use of a flexible approach in applied modelling work, at least as a guide to the selection of a simpler distribution. The choice between the two flexible approaches may be guided by considerations on bias and variance, which seem to favour the Fosgerau & Bierlaire approach, or by the ability of the MOD estimator to approximate point masses.

In the second part of the paper, we provide evidence on the methods using data from the Swiss value of time study. Here we simultaneously estimate flexible distribution for four coefficients, which we believe is a first. We find the application of the flexible approaches to be illuminating in that it reveals features of the data that could not be revealed using the simpler approaches. The MOD approach did run into a limitation in that it turned out to be not computationally possible to estimate beyond a mixture of two normals for each coefficient. On the other hand, a larger number of parameters could be estimated with the Fosgerau & Bierlaire approach, with no limit in sight.

We do not provide theoretical results concerning consistency and asymptotic properties of the estimators of the distribution of α that we employ. Fosgerau and Nielsen (2006) prove consistency of an estimator of the distribution of α in a case when the distribution of the error terms[2] is unknown. It seems feasible to extend this result to the case of a MMNL model with an unknown mixing distribution.

The paper is organised as follows. The following section presents the mathematical details of the two advanced approaches used in this paper. This is followed in Section 3 by a discussion of the results from the Monte Carlo studies, and a discussion of the

[2] I.e. the unobserved component of utility ε.

results from the application on real data in Section 4. Finally, Section 5 presents the conclusions of the analysis.

2. Methodology

In this section, we discuss the two main methods compared in this analysis, with the Fosgerau-Bierlaire approach described in Section 2.1, and the MOD approach described in Section 2.2. This is followed in Section 2.3 by a brief description of various continuous distributions used in our experiments.

2.1. Fosgerau & Bierlaire approach

Let Φ be the standard Normal cumulative distribution function with density ϕ and let G be an absolute continuous distribution with density g. We take Φ as the base distribution with which we seek to estimate the true distribution G.[3]

Since both Φ and G are increasing, it is possible to define $Q(x)=G(\Phi^{-1}(x))$ such that $Q(\Phi(\beta))=G(\beta)$. Furthermore, Q is monotonically increasing and ranges from 0 to 1 on the unit interval. Thus, Q is a cumulative distribution function for a random variable on the unit interval. Denote by q the density of this variable, which exists since G is absolute continuous. Then we can express the true density as $g=q(\Phi)\phi$.

Consider now a discrete choice model $P(y|v,\alpha)$ conditional on the random parameter α which has the true distribution G. Then the unconditional model is

$$\begin{aligned} P(y \mid v) &= \int_\alpha P(y \mid v, \alpha) g(\alpha) d\alpha \\ &= \int_x P(y \mid v, \Phi^{-1}(x)) q(x) dx \end{aligned} \tag{1}$$

Thus the problem of finding the unknown density g is reduced to that of finding q, an unknown density on the unit interval. The terms $\Phi^{-1}(x)$ are just standard Normal draws used in numerical simulation of the likelihood (cf. Train, 2003).

Now, let L_k be the k[th] Legendre polynomial on the unit interval (cf. Bierens, 2007; Fosgerau and Bierlaire, 2007). These functions constitute an orthonormal base for functions on the unit interval[4] such that $\int L_k L_{k'}$ is equal to 1 when $k=k'$ and zero otherwise. We can then write:

$$q(x) = \frac{(1 + \sum_k \gamma_k L_k)^2}{1 + \sum_k \gamma_k^2}. \tag{2}$$

Squaring the numerator ensures positivity, while the normalisation in the denominator ensures that $q(x)$ integrates to 1. Thus this expression is in fact a density. Bierens (2007) proves that any density on the unit interval can be written in this way.

[3] It is generally appropriate to choose a base distribution that is a priori thought to be a likely candidate for the true distribution. We choose the Normal distribution to have consistency with the MOD approach.
[4] See Bierens (2007) for a precise definition of this and following statements in this paragraph.

The choice of Legendre polynomials is not a necessity. There are many other bases for functions on the unit interval that could have been used. Legendre polynomials are convenient because they have a recursive definition that is easily implemented on a computer.[5]

To define the estimator that we use in this paper, we simply select a cut-off K for k, such that we only use the first K terms of (2). Thus we have a representation of a flexible q_K with K parameters and a corresponding cumulative distribution function Q_K. This is inserted into equation (1) to enable estimation by maximum likelihood. For more details on this approach, see Fosgerau and Bierlaire (2007).

Figure 1 shows cumulative distribution functions (CDF) for various parameter combinations of a $Q_3(\Phi)$ distribution, where the base distribution Φ is a standard Normal distribution and the three γ_k parameters are set to all combinations of -1, 0 and 1. As the figure shows, this general form is able to take a variety of shapes.

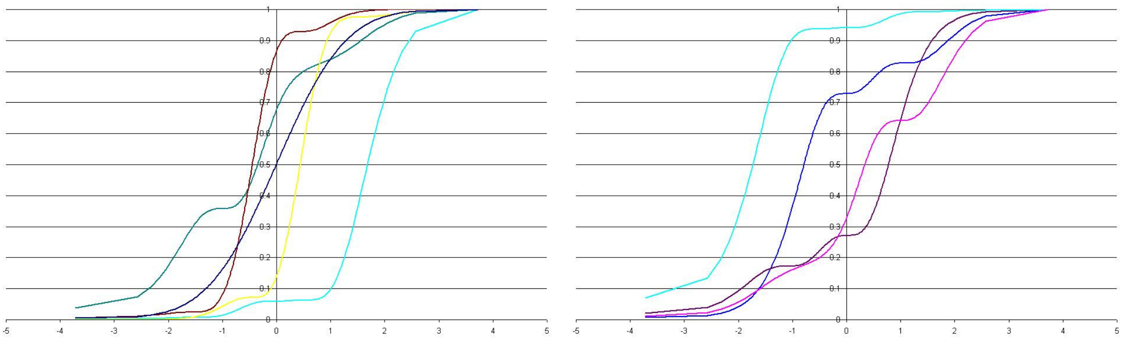

Figure 1: CDF plots for various distributions.

2.2. Mixtures of distributions approach

In our MOD approach, we combine a standard continuous mixture approach with a discrete mixture approach, as described for example by Hess *et al.* (2006b) and, in another context, Coppejans (2001). Specifically, the mixing distribution is itself a discrete mixture of several independently distributed Normal distributions. We define a set of mean parameters, μ_k and a corresponding set of standard deviations, σ_k, with $k=1,\dots,K$. For each pair (μ_k, σ_k), we then define a probability π_k, where $0 \le \pi_k \le 1, \forall k$, and where $\sum_{k=1}^{K} \pi_k = 1$. A draw from the mixture distribution is then produced on the basis of two uniform draws u_1 and u_2 contained between 0 and 1, where we get:

$$
\begin{aligned}
&\alpha = \Phi^{-1}_{\mu_1,\sigma_1}(u_1), \text{ if } u_2 < \pi_1 \\
&\alpha = \Phi^{-1}_{\mu_k,\sigma_k}(u_1), \text{ if } \sum_{l=1}^{k-1} \pi_l \le u_2 < \sum_{l=1}^{k} \pi_l \text{ with } 1 < k \le K-1 \\
&\alpha = \Phi^{-1}_{\mu_K,\sigma_K}(u_1), \text{ if } \sum_{l=1}^{K-1} \pi_l \le u_2,
\end{aligned} \tag{3}
$$

[5] The recursion formula for the Legendre polynomials on the unit interval states that $L_k(x) = \frac{\sqrt{4k^2-1}}{k}(2x-1)L_{k-1}(x) - \frac{(k-1)\sqrt{2k+1}}{k\sqrt{2k-3}}L_{k-2}(x)$. The first four polynomials are $L_0(x)=1$, $L_1(x)=\sqrt{3}(2x-1)$, $L_2(x)=\sqrt{5}(6x^2-6x+1)$, and $L_3(x)=\sqrt{7}(20x^3-30x^2+12x-1)$.

where $\Phi^{-1}_{\mu_k,\sigma_k}$ is the inverse cumulative distribution of a Normal with mean μ_k and standard deviation σ_k.

With k Normal terms, the resulting distribution allows for k separate modes, where the different modes can differ in mass. However, the flexibility of this approach is not limited to allowing for multiple modes, the method also allows for saddle points in a distribution.

Furthermore, it is possible to have point-mass at a specific value, in which case the associated standard deviation parameter becomes 0. This property of the MOD approach is both a blessing and a curse. Coppejans (2001) enforces a lower bound on the variance of the normally distributed components in order to ensure that the estimated distribution is smooth and to prove asymptotic convergence to the true distribution as the number of Normal distributions increases with sample size. Thus imposing a lower bound on the variances is desirable when the true distribution is thought to be smooth and it avoids the estimated distribution becoming degenerate.

It is difficult to make a case for mass-points in a distribution of preference-parameters. However, there is one exception, namely a heightened mass at zero. This is useful in the representation of taste heterogeneity for attributes that some individuals are indifferent to, a concept discussed for example in the context of the valuation of travel time savings (VTTS) by Cirillo and Axhausen (2006). It can also be useful in the context of attribute processing strategies in SP data, with some respondents ignoring certain attributes, such that they obtain a zero coefficient (cf. Hensher, 2006). In the results below we do not impose a lower bound on the variances.

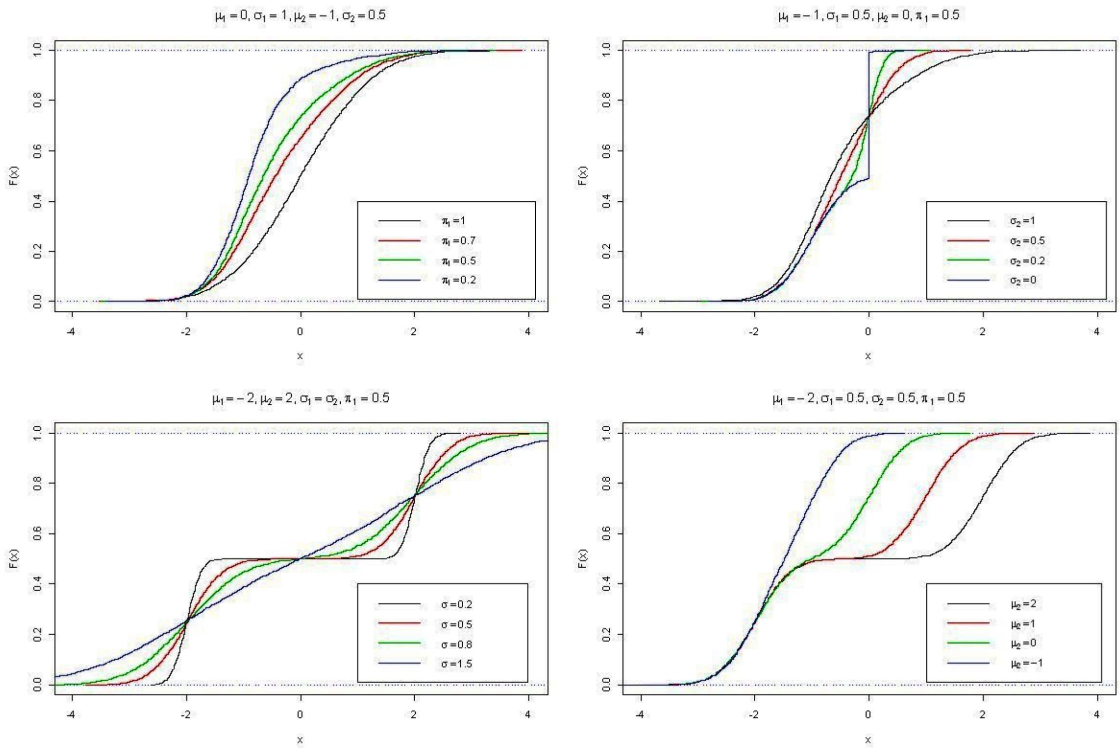

Figure 2: CDF plots for various mixtures of two Normal distributions.

An illustration of the flexibility of the MOD approach is given in Figure 2, which shows cumulative distribution functions (CDF) for various examples of a mixture of two Normal distributions. In the first example, the only parameter that changes is π_1 (and hence by extension also π_2), where, with π_1=1, we have a standard Normal distribution, with the shape gradually changing as we increase the mass for the second Normal, π_2. The second example illustrates the potential of the method to retrieve a point mass at a given value. Here, the standard deviation for the second support point, σ_2 is gradually decreased, where, with σ_2=0, we get a point mass of 50% at a value of 0 (μ_2=0), with the CDF turning into a step function at a value of 0. In the third example, the two support points have mean values at -2 and 2, and share a common standard deviation, while $\pi_1 = \pi_2$=0.5. As we gradually increase the standard deviations, we move from a distribution with two separate peaks (with little mass in between) to a distribution looking like a Normal with a very high variance. In the final example, we again have two Normals with equal standard deviation, fixed at 0.5, along with equal probabilities $\pi_1 = \pi_2$=0.5, and a mean for the first Normal fixed at -2. As the mean of the second Normal is gradually decreased from its initial value of 2, we move from a distribution with two separate peaks to a distribution approximating a Normal.

2.3. Other distributions

Along with the approaches from Section 2.1 and Section 2.2, we also estimated models making use of a set of standard continuous distributions, as commonly used in Mixed Logit analyses. Here, we limit the set of distributions to the Normal, the Uniform, the symmetrical Triangular and the Johnson S_B.

3. Experiments on simulated data

This section presents the results from our systematic Monte Carlo analysis. We first present the empirical framework used in this analysis (Section 3.1). We then briefly discuss the issue of the number of parameters (Section 3.2) before discussing the actual results (Section 3.3).

3.1. Generation of data

The setup for this analysis makes use of binary choice panel data. The conditional indirect utility function for the first alternative is set to zero, while, in choice situation *t* for respondent *n*, the utility of the second alternative is given by:

$$U_{n,t} = \alpha_n + v_{n,t} + \frac{1}{\mu}\varepsilon_{n,t} \tag{4}$$

where ε follows a logistic distribution, $v_{n,t}$ is an observed quantity, and α_n is an individual-specific i.i.d. latent random variable. This is the simplest possible setup that allows us to identify the distribution of an unobserved random parameter. This simplicity is a virtue, since we can then focus on the issue at hand, namely the ability of different estimators to recover a true distribution. The use of panel data is crucial, since otherwise it becomes hard to distinguish the distribution of α from the distribution of ε.

We simulate datasets of a size that is realistic in applied situations, containing 1,000 "individuals" making 8 "choices" each. We generate data for seven different choices of *true* distribution for α_n, with details given below. The observed variable v is drawn from a standard Normal distribution, while the scale parameter μ is fixed at a value of 2.

It is important to realise that results from a single experiment can be influenced by randomness, such that it is impossible to reach general conclusions. Therefore we generate 50 datasets for each distribution.[6] Estimating the models many times for each true distribution of α allows us to take into account the fact that the estimates are random variables obtained as functions of random data. Altogether, we generate 50 datasets for each of the seven *true* distributions, leading to a total of 350 datasets.

The seven *true* distributions were chosen with the aim of representing a wide array of possibilities that challenge our ability to estimate them. An important point here is to select the distributions such that they lie well within the support of $v_{n,t}$ which is standard Normal. Thus we have selected the distributions to lie mostly within the interval [-2,2].[7]

Specifically, we use the following seven data generating processes:

- **DM(2) data:** Discrete mixture with two support points, α=-1 with probability π_1=0.5, and α=1 with probability π_2=0.5
- **DM(3) data:** Discrete mixture with three support points, α=-1, α=0 and α=1, with equal mass of $\pi_1 = \pi_2 = \pi_3 = ⅓$
- **LN data:** Lognormal shifted to the left, generated by $\alpha=exp(u)/2-1$, where $u \sim N(0,1)$
- **N data:** Standard Normal, $\alpha \sim N(0,1)$
- **NM data:** Normal with point mass at zero. With probability π_1=0.8, $\alpha \sim N(-1,1)$, and with probability π_2=0.2, α=0
- **2N data:** Mixture of two Normals, with π_1=0.5, $\alpha \sim N(-1,0.5)$, and with π_2=0.5, $\alpha \sim N(1,0.5)$
- **U data:** Uniform distribution, $\alpha \sim U[-1,1]$

3.2. The number of parameters

The Normal, Uniform and symmetrical Triangular distributions all have just two parameters to be estimated, while the Johnson S_B distribution is more flexible with four parameters to be estimated. In addition there is the parameter μ for the scale of the model. The MOD approach has three parameters for each Normal distribution used (location, variance and mass), minus one since the masses sum to one. With a mixture of two Normals there are thus six parameters to be estimated. Therefore we also elect to use a total of six parameters for the Fosgerau-Bierlaire approach. Generally, we expect the ability of a distribution to approximate an arbitrary true distribution to increase with the number of parameters. Thus we expect the worst performance from the Normal,

[6] With real data it is possible to use bootstrap methods to generate confidence intervals around the estimated distribution. These confidence intervals can then be used to learn how much is determined from the data about the estimated distribution.

[7] This is an issue in real applications, where data may not be sufficiently rich to identify distributions of interest. Such a failure may be hard to detect, see Fosgerau (2006) for discussion of this point.

Uniform and symmetrical Triangular distributions because they depend on fewer parameters, while the best performance is expected from the Fosgerau-Bierlaire approach and the MOD approach, since these can rely on more parameters.

3.3 Results

In this section, we discuss the results of the Monte Carlo analysis carried out to compare the different methods for representing random taste heterogeneity. All estimation is carried out in Ox (Doornik, 2001) using customised code.[8] Altogether we have estimated six models[9] on each of seven datasets, with fifty replications of each dataset. Given the high number of models estimated, only summary results across runs can be presented here. The two advanced models are identified as M(MOD) (mixture of Normals) and M(FB) (Fosgerau-Bierlaire approach), while the four more basic models are identified as M(N) (Normal), M(U)(Uniform), M(T) (symmetrical Triangular) and M(S_B) (Johnson S_B). In addition, a standard Multinomial Logit (MNL) model was estimated on the data.

Two different criteria are used in the presentation of the results. These are the ability to recover the shape of the *true* distribution and the estimated log-likelihoods. A combination of tables and graphs are used in the presentation of the results.

- The performance of the various methods in terms of the recovery of the shape of the *true* distribution is illustrated with the help of CDF plots for the *true* and estimated distributions, where, for the latter, the mean CDF across runs is presented alongside a pointwise 90% confidence band for the CDF. The various plots are shown in Figure 3 for the **DM(2)** data, Figure 4 for the **DM(3)** data, Figure 5 for the LN data, Figure 6 for the **N** data, Figure 7 for the **NM** data, Figure 8 for the **2N** data, and Figure 9 for the **U** data.
- These CDF plots are the main result of the analysis as they directly inform on the ability to estimate the unknown true distributions. Vertical distances in the CDF plots correspond to the L_∞ norm of the difference between true and estimated CDFs; indeed, in the space of CDFs, convergence of estimates to the *true* distribution, as the number of terms increases, takes place in L_∞ norm. We have chosen to present CDFs rather than densities, since many of the true distributions that we use have point masses and hence no ordinary densities. Moreover, convergence in L_∞ norm is easier to interpret visually than convergence in L_1 norm, which corresponds to densities.
- Table 1 shows the final log-likelihood (LL) obtained in estimation of the various models. Here, we give the mean LL obtained across the fifty runs in each model and dataset combination, along with the 5th and 95th percentiles of the distribution of the LL measure across runs, giving an indication of the stability of the methods.

[8] Available from the authors on request.
[9] One for each distribution

Table 1: Model fit statistics across datasets and models.

Data		MNL	M(N)	M(S_B)	M(T)	M(MOD)	M(U)	M(FB)
DM(2)	5th perc.	-4707.76	-3708.26	-3565.42	-3697.21	-3565.34	-3644.74	-3579.57
	mean	-4643.54	-3642.45	-3497.32	-3633.74	-3497.10	-3583.83	-3515.96
	95th perc.	-4575.35	-3567.01	-3428.72	-3558.48	-3428.74	-3510.46	-3444.96
DM(3)	5th perc.	-4456.99	-3866.13	-3846.47	-3860.49	-3845.40	-3849.76	-3845.82
	mean	-4380.80	-3798.70	-3781.05	-3793.08	-3779.00	-3782.95	-3779.66
	95th perc.	-4313.91	-3741.58	-3723.33	-3736.87	-3722.72	-3725.52	-3722.66
LN	5th perc.	-4263.78	-3860.01	-3781.90	-3874.35	-3782.62	-3897.44	-3784.43
	mean	-4165.97	-3792.01	-3713.90	-3805.26	-3716.43	-3827.84	-3718.88
	95th perc.	-4077.56	-3720.00	-3650.01	-3729.76	-3651.23	-3749.12	-3652.85
N	5th perc.	-4555.32	-3821.56	-3821.31	-3822.62	-3821.56	-3834.73	-3820.58
	mean	-4495.58	-3767.88	-3767.63	-3768.38	-3766.50	-3778.44	-3766.68
	95th perc.	-4444.89	-3713.47	-3713.51	-3714.31	-3712.40	-3722.20	-3712.29
NM	5th perc.	-4078.98	-3537.69	-3525.39	-3534.45	-3522.67	-3531.87	-3522.63
	mean	-3990.94	-3456.36	-3446.07	-3455.45	-3442.26	-3454.97	-3442.83
	95th perc.	-3904.82	-3370.11	-3363.78	-3368.02	-3361.03	-3370.84	-3360.67
2N	5th perc.	-4748.22	-3698.21	-3669.81	-3692.69	-3669.53	-3672.41	-3669.80
	mean	-4687.77	-3616.24	-3584.53	-3611.91	-3583.00	-3591.84	-3583.47
	95th perc.	-4616.72	-3542.69	-3505.81	-3538.92	-3503.21	-3516.07	-3503.19
U	5th perc.	-4170.72	-3936.54	-3935.41	-3937.16	-3935.38	-3939.82	-3935.76
	mean	-4088.26	-3855.56	-3850.91	-3853.54	-3850.60	-3851.85	-3850.78
	95th perc.	-4025.88	-3778.32	-3776.16	-3776.89	-3775.04	-3776.54	-3775.61

We will now proceed with a discussion of the results obtained in the various datasets.

DM(2) data: For the data generated by a discrete mixture with two support points, we expect the M(MOD) and the M(S_B) to perform best due to their ability to become degenerate. The M(MOD) can accommodate the DM(2) distribution with two Normals with zero variance, while the M(S_B) can have infinite variance for the Normal distribution.

Figure 3 shows that M(MOD) and M(S_B) are able to reproduce the *true* distribution quite closely. The M(S_B) finds the two mass points and puts almost all the mass there through a very large variance of the underlying Normal distribution. The same goes for the M(MOD), which assigns very low variances to the two Normal distributions at the two mass points. The M(FB) is able to indicate roughly the shape of the *true* distribution but is seemingly not able to generate very sharp kinks in the estimated CDF. Note that the estimated confidence bands are somewhat tighter for the M(FB) than for the M(MOD). The approximations given by M(U), M(T) and M(N) are not able to reveal much about the true distribution except its location and range.

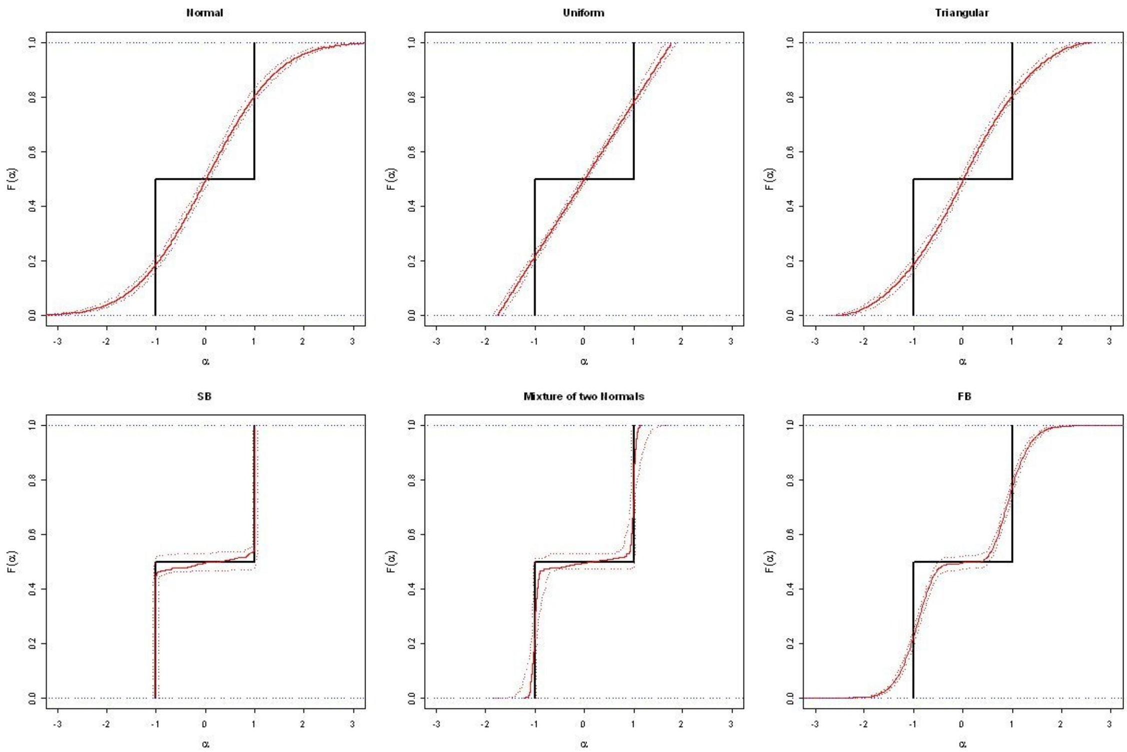

Figure 3: CDF plots for α in models estimated on DM(2) data.

DM(3) data: Now we are looking at a distribution with three mass points. It is clearly outside the capabilities of all the estimated models to reproduce such a shape, except possibly the M(FB) which may have more than two modes with five parameters, the same number of parameters as a mixture of two normals. We therefore replace the mixture of two normals by a mixture of three Normals. This introduces three additional parameters (location, variance and mass), so we also increase the number of parameters in the M(FB) model by three. Given the data, this increase in parameters does not yield a significant improvement of the mean log-likelihood. But it does allow the M(MOD) to reproduce the true distribution under investigation, in principle perfectly.

Figure 4 now shows, as expected, that none of the four simplest distributions are able to provide any information about the true distribution other than its location and rough range. Both the M(MOD) and the M(FB) with the increased number of parameters are able to indicate the shape of the true distribution. The M(MOD) is able to concentrate more of the mass near the three mass points of the *true* distribution but again at the cost of larger confidence bands. In other words, the M(MOD) is able to estimate the true distribution with smaller bias but larger variance.

The log-likelihoods fits obtained by M(MOD) and M(FB) are best, but not much better than M(SB) and M(U).

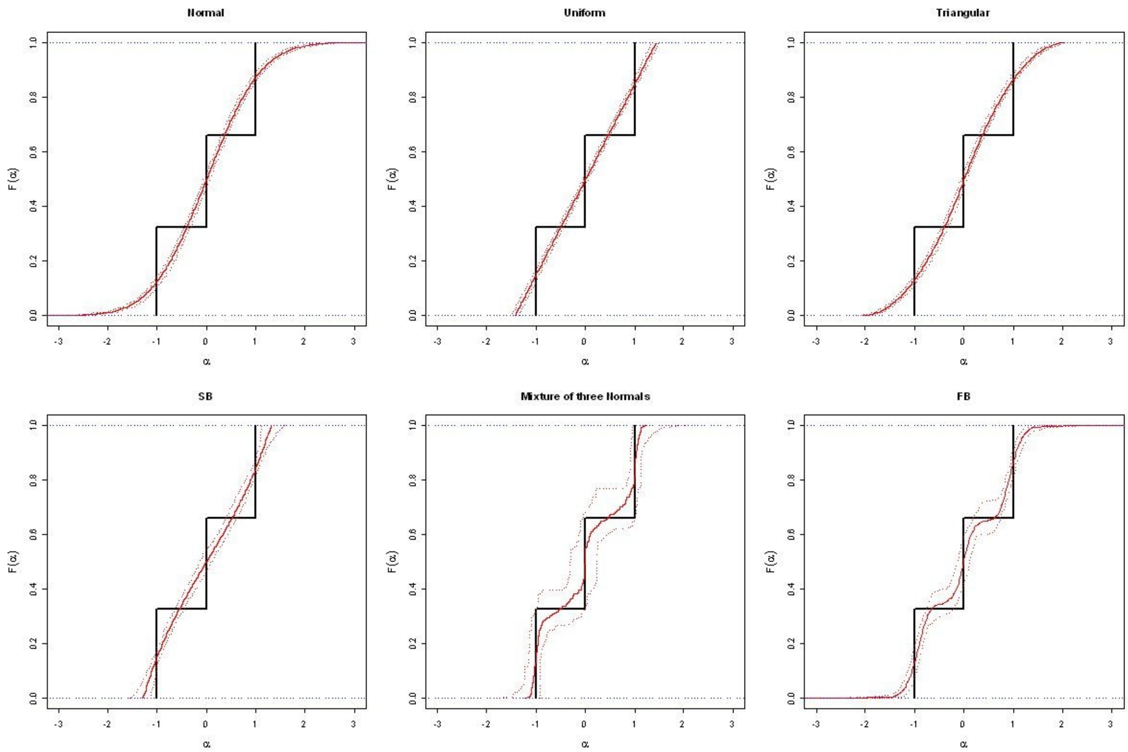

Figure 4: CDF plots for α in models estimated on DM(3) data.

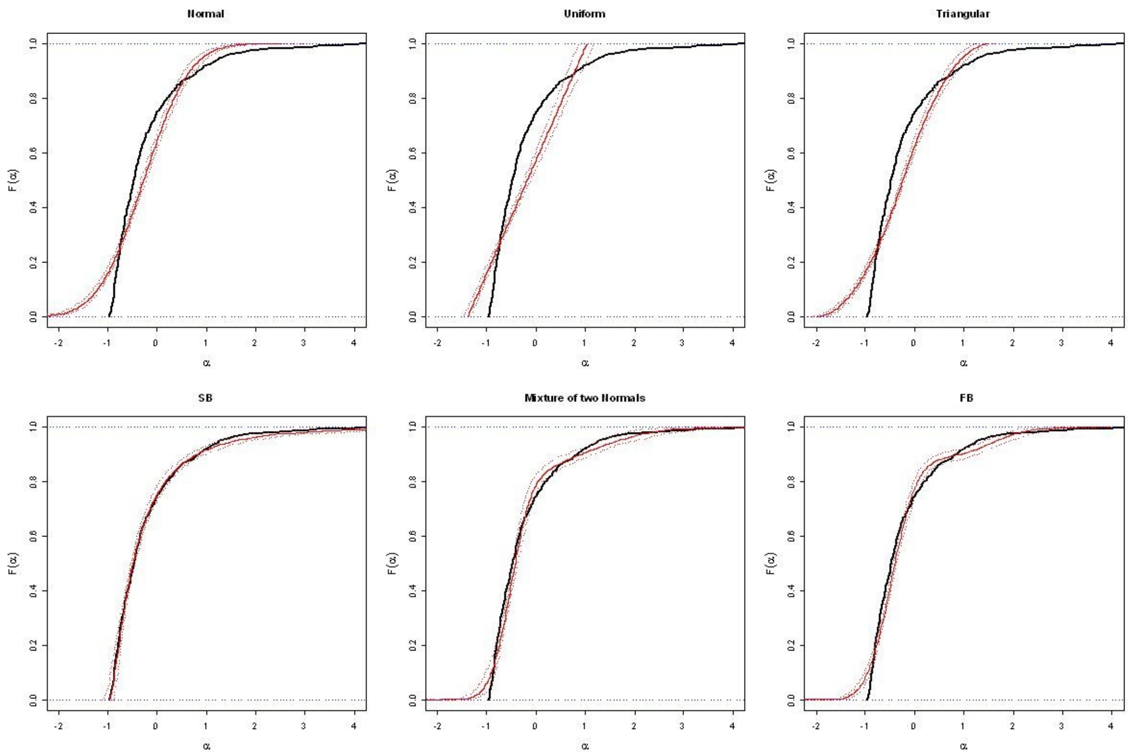

Figure 5: CDF plots for α in models estimated on LN data.

LN data: For the data generated by a Lognormal distribution, we find in Figure 5 that the two advanced distributions along with the M(SB) are able to recover the lognormal shape quite well. This is quite remarkable, since it implies that a true continuous distribution can be recovered even though it is quite different from the Normal distribution which is used as a base. This should be important in applied work where a priori information about the shape of the true distribution is not available. The M(SB) is even able to find the lower bound on the true distribution. These models produce much better log-likelihoods than the simpler models based on normal, triangular and uniform distributions.

N data: For the data generated with a standard Normal distribution we expect the M(N), M(MOD) and M(FB) to do well, since they nest the true model. Also the M(SB) should do well by letting the range of the distribution be large. This is confirmed by the results in Figure 6. In fact, even the Triangular distribution is able to reproduce the shape of the Normal distribution quite closely. Like before, it seems that the estimated CDF from the M(MOD) has somewhat higher variance than M(FB).

The log-likelihoods are close with only the M(U) doing noticeably worse than the rest. The M(MOD) and M(FB) nest the true distribution and given the small differences in the estimated log-likelihoods, it would be almost always possible to accept the null hypothesis that the true distribution is in fact Normal, which is reassuring.

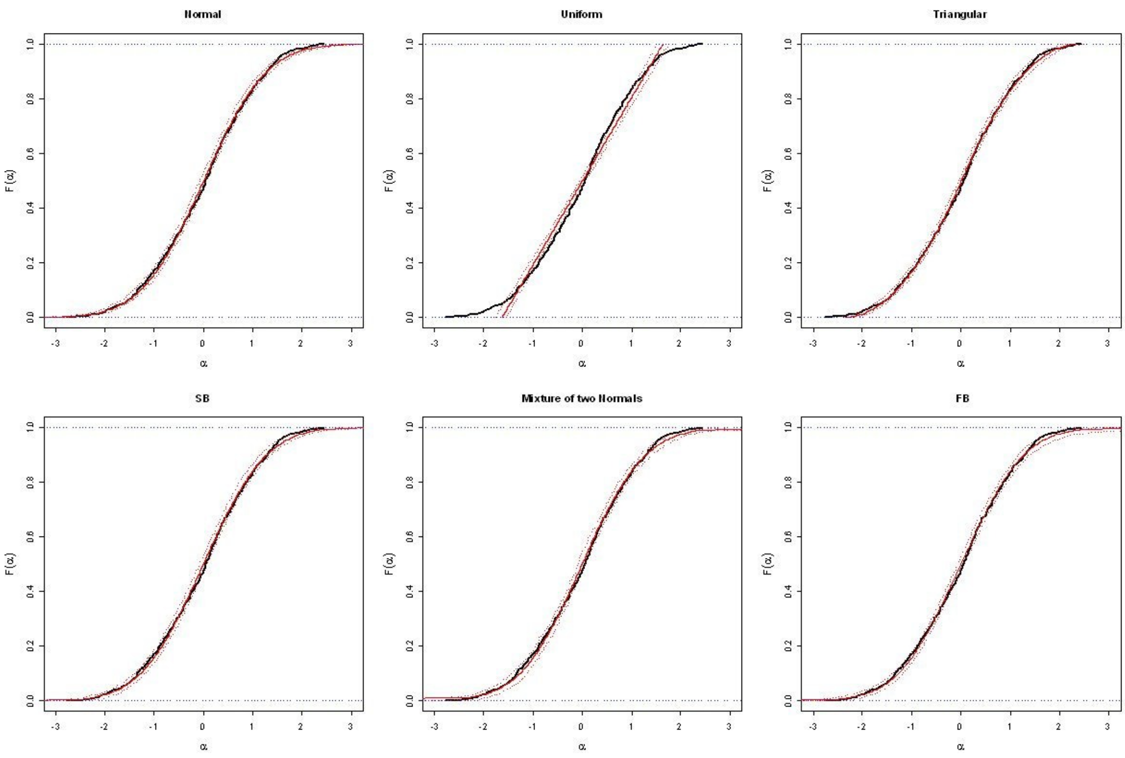

Figure 6: CDF plots for α in models estimated on N data.

NM data: The Normal with an added mass at 0 is a difficult distribution to approximate, even though the M(MOD) does nest this when one variance is set to zero such that the distribution becomes degenerate.

While all the estimated models are able to indicate the location and range of the true distribution, it is only the M(MOD) that is able to provide a hint about the point mass (Figure 7). The cost is, however, that the M(MOD) again seems to have a higher variance.

In terms of log-likelihoods, the M(MOD) and the M(FB) achieve similar fits, while the M(S_B) is somewhat poorer and the remaining are further behind.

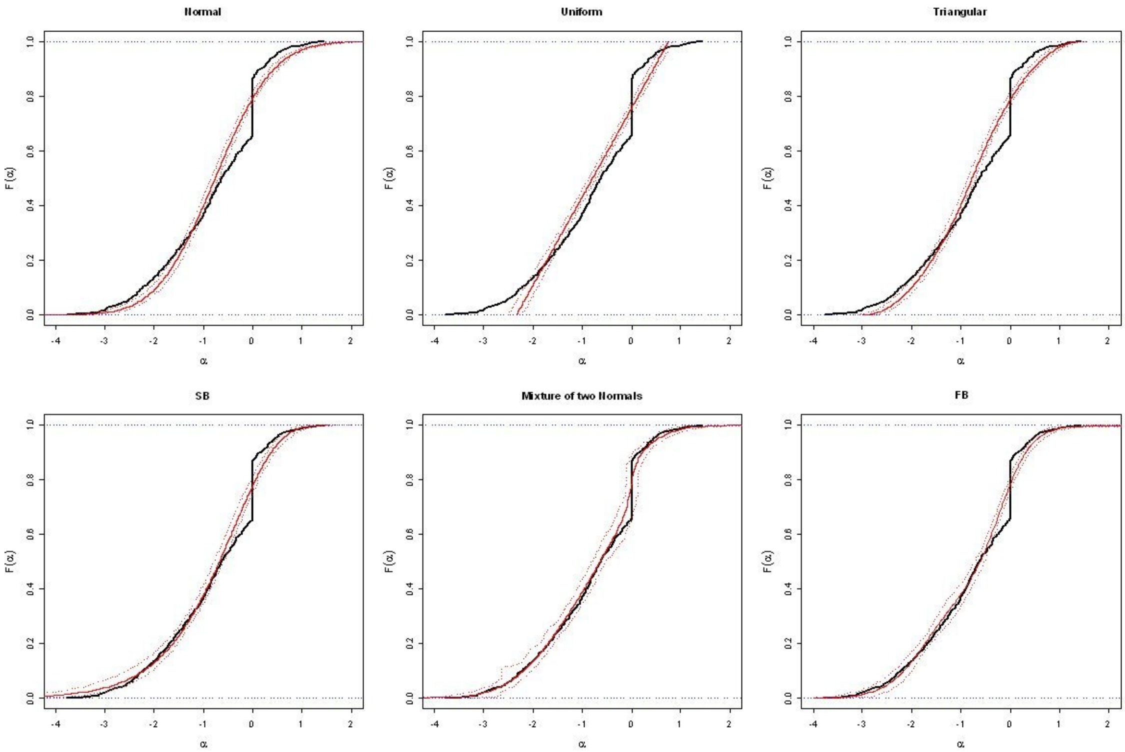

Figure 7: CDF plots for α in models estimated on NM data.

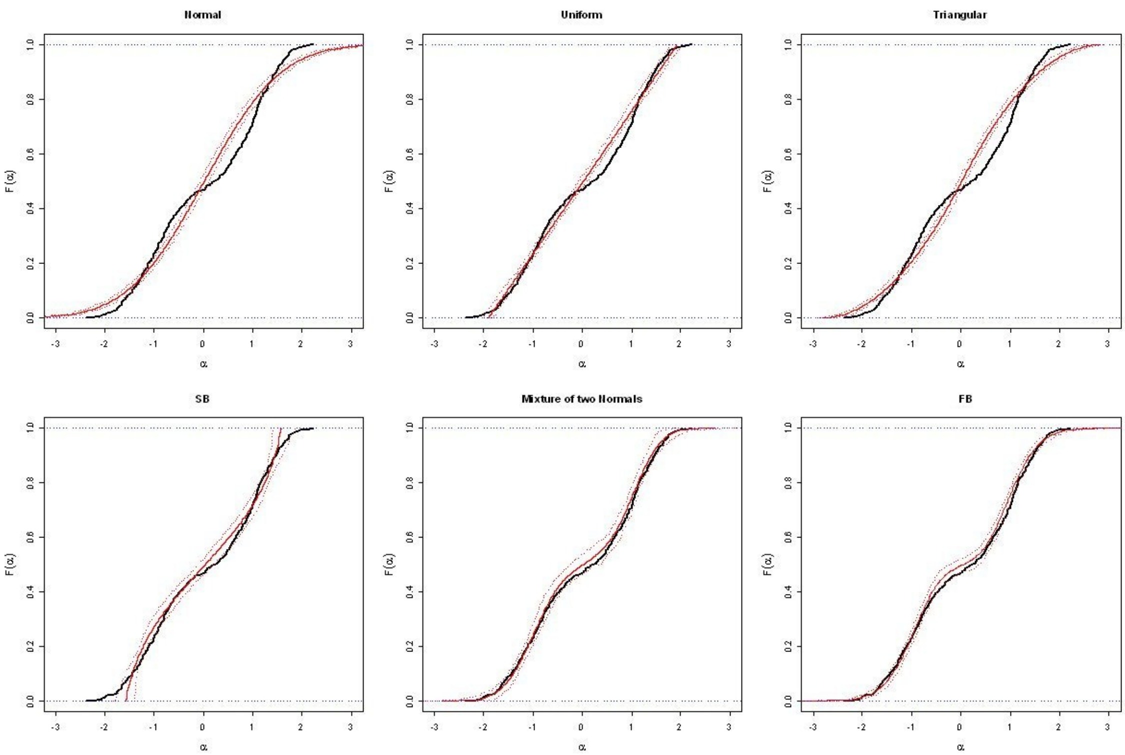

Figure 8: CDF plots for α in models estimated on 2N data.

2N data: For the data generated by a mixture of two Normals, the MOD model M(MOD) obtains the best model fit. This is as expected since the model is the same as the data generating process. The M(FB) and the M(SB) are however very close. As Figure 8 shows, the M(MOD) and also the M(FB) are both able to reproduce the main features of the true 2N distribution. Again, the M(MOD) seems to have higher variance.

U data: For the final dataset, generated with a Uniform distribution, the performance of the various models is very similar. From Figure 9, we note that the M(MOD) again has somewhat higher variance than the M(FB) distribution. In terms of log-likelihood, all models are quite similar.

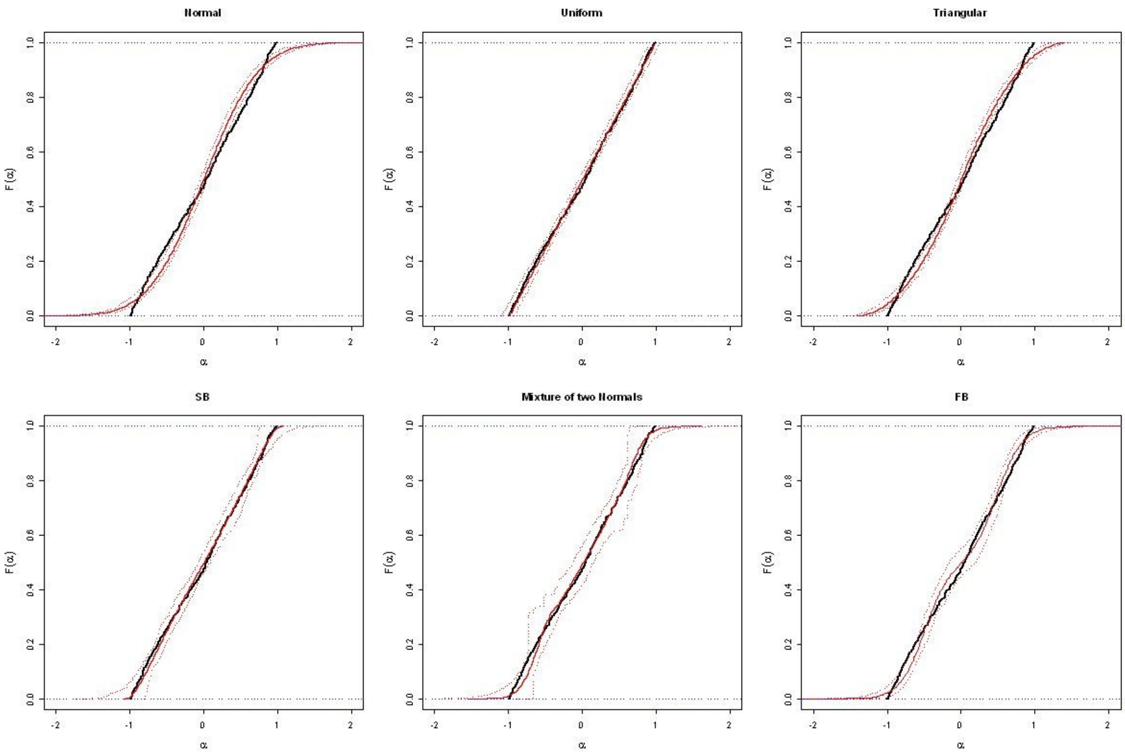

Figure 9: CDF plots for α in models estimated on U data.

4. Experiment on real data

For our analysis on real world data, we make use of data collected as part of a recent VTTS study in Switzerland (cf. Axhausen *et al*., 2008). Specifically, we look at a public transport route choice experiment, with 3,501 observations collected from 389 respondents. The two alternatives are described in terms of travel time (TT), travel cost (TC), headway (HW) and interchanges (CH). With this, the utility function for alternative 1 is given by:

$$U_1 = \delta_1 + \beta_{TT}TT_1 + \beta_{TC}TC_1 + \beta_{HW}HW_1 + \beta_{CH}CH_1 \quad (4)$$

with a corresponding formulation for alternative 2, except for the absence of a constant.

A number of different models were estimated on this data. We first estimated a MNL model, followed by MMNL models making use of Normal, Uniform, symmetrical Triangular and S_B independent distributions for each coefficient. All MMNL models were estimated on the basis of variations in tastes across respondents but constant tastes across observations for the same respondent. In addition, a number of MOD and FB formulations were estimated. For the MOD models, no further improvements could be obtained beyond the use of two points in the mixture, partly due to problems with degeneracy. On the other hand, using the FB approach, models were estimated with up to 6 SNP terms for each taste coefficient. There was no indication that it would not be possible to estimate models with even more SNP terms.

We first look at the achieved likelihoods of the various estimated structures, with a summary given in Table 2. As expected, all mixture models offer significant improvements in model fit over the MNL model, highlighting the presence of significant levels of taste heterogeneity relative to the linear specification of indirect utility. Here, for the more basic specifications, the performance with the Normal, Uniform and symmetrical Triangular distributions is very similar, with better performance being obtained with the more flexible S_B distribution.

Table 2: Model performance on Swiss route choice data.

Model	*Final LL*	*par*	*adj. ρ^2*
MNL	-1667.97	5	0.3106
NORMAL	-1466.73	9	0.3919
UNIFORM	-1467.04	9	0.3918
TRIANGULAR	-1466.75	9	0.3919
S_B	-1439.32	17	0.3999
MOD_2	-1435.47	21	0.3999
SNP_1	-1463.6	13	0.3915
SNP_2	-1460.08	17	0.3913
SNP_3	-1443.29	21	0.3966
SNP_4	-1435.49	25	0.3982
SNP_5	-1429.29	29	0.3991
SNP_6	-1423.68	33	0.3997

Moving on to the MOD and FB models, we can see that, while MOD_2 obtains a better log-likelihood than the model using the S_B distribution, the additional parameters mean that in terms of adjusted ρ^2, the performance of the two models is virtually identical. For the FB models, the adjusted ρ^2 is always below that of the MOD_2 model and the S_B model, but there is a gradual and significant improvement in model fit as we increase the number of terms in the series expansions.

We proceed with a graphical analysis of the implied distributions resulting from the various models. As we are looking at the shapes of the estimated distributions this is much more informative than looking at the estimated parameters. Here, Figure 10 shows the CDF for β_{TT} in the various models, with Figure 11 looking at β_{TC}, Figure 12 looking at β_{HW} and Figure 13 looking at β_{CH}. In each case, the presentation of the FB results is limited to FB_3, FB_5 and FB_6.

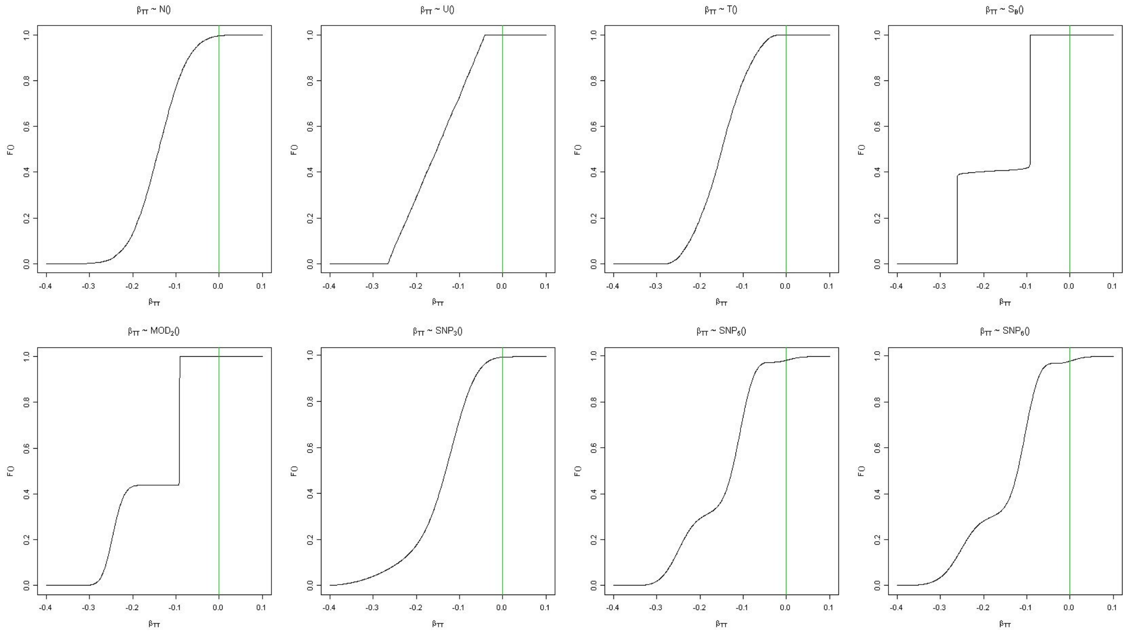

Figure 10: CDF plots for β_{TT} in models estimated on Swiss route choice data.

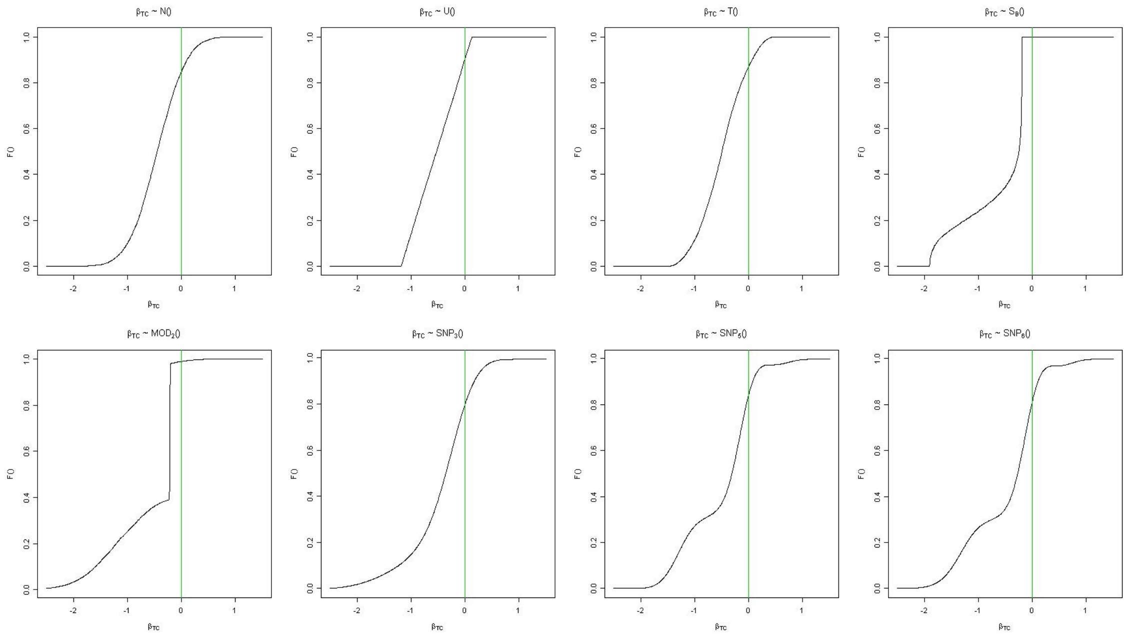

Figure 11: CDF plots for β_{TC} in models estimated on Swiss route choice data.

For β_{TT}, we observe strong similarities between FB_3 and the Normal distribution, while FB_5 and the very similar FB_6 are clearly different. The S_B distribution degenerates to a mass point distribution, while the MOD_2 distribution only becomes degenerate for one mass point. The findings for β_{TC} are quite similar, although this time, the S_B distribution only becomes degenerate for one mass point, along with MOD_2. For β_{HW}, MOD_2 reduces to a Normal distribution, with FB_5 and FB_6 showing some differences. Finally, for β_{CH}, MOD_2 becomes degenerate for one point, while the S_B distribution again turns into a mass point distribution. What we are observing seems to be that the SB and the MOD risk becoming degenerate in ranges where the true density places a lot of mass, even if it is unlikely to be point masses. The FB approach does not have this problem.

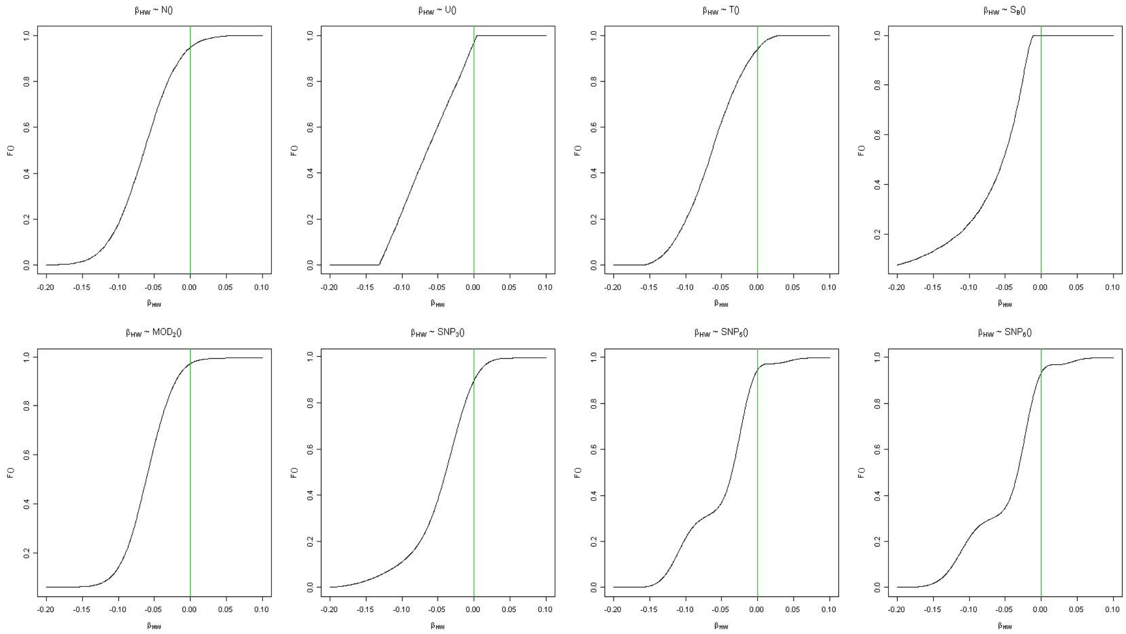

Figure 12: CDF plots for β_{HW} in models estimated on Swiss route choice data.

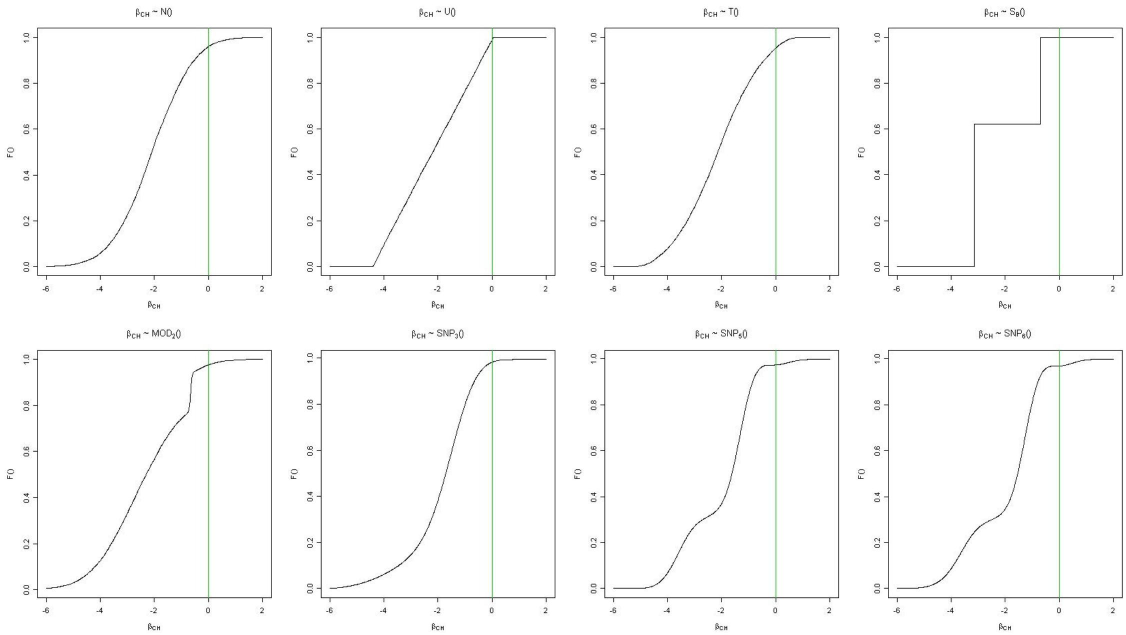

Figure 13: CDF plots for β_{CH} in models estimated on Swiss route choice data.

While the results demonstrate that the advanced approaches are practical and reveal information about the data that would otherwise have been hard to discern, the results are somewhat worrying from a different perspective. All four parameter distributions seem to have two modes and it is hard to accept that this is a true feature of the distribution of preferences in the population. We can think of two potential explanations. The first potential explanation is that the effect is an artefact of the stated preference design. If this is true, then we are in effect measuring the design and not only the preferences which are the object of interest. It would then be prudent to seek to improve the design. We have not investigated this issue. The other potential explanation is that we are seeing a reference point effect (De Borger and Fosgerau, 2008), whereby the size of a parameter is influenced by whether the attribute being valued is larger or smaller than some reference. In any case, it is a real advantage of the flexible approaches that they allow such issues to be discovered. The potential problems here would have been invisible with the standard approaches.

The estimated parameters are presented in Table 3 for the standard models and the MOD_2 while Table 4 presents the estimates for the FB models. Here, δ_1 is constant; the p_1 parameters are used as fixed parameters in MNL, the mean in Normal, boundary to one side for Uniform and Triangular (turns out to be right hand boundary), mean of underlying Normal in S_B and mean of first Normal in MOD_2; p_2 parameters are used as standard deviations in Normal, interval width in Uniform and Triangular, standard deviation of underlying Normal in S_B and std.dev. of first Normal in MOD_2; p_3 parameters give the left boundary for S_B and mean for second Normal in MOD_2; p_4 parameters give interval width for S_B and std.dev. for second Normal in MOD_2; π parameters give mass for first Normal in MOD_2.

Table 3: Model estimation on Swiss route choice data (part 1, asy. t-ratios in brackets).

Model	*MNL*	*NORMAL*	*UNIFORM*	*TRIANGULAR*	S_B	MOD_2
Final LL:	-1,667.97	-1,466.73	-1,467.04	-1,466.75	-1,439.32	-1,435.47
adj. ρ^2	0.3106	0.3919	0.3918	0.3919	0.3999	0.3999
par.	5	9	9	9	17	21
δ_1	-0.0192 (-0.45)	-0.0488 (-0.79)	-0.0417 (-0.68)	-0.0436 (-0.71)	-0.0452 (-0.71)	-0.0558 (-0.86)
$\beta_{TT}(p_1)$	-0.0598 (-11.22)	-0.1405 (-12.04)	-0.0409 (-2.99)	-0.0165 (-0.99)	-0.2417 (-12.25)	-0.2463 (-10.37)
$\beta_{TC}(p_1)$	-0.132 (-7.01)	-0.4484 (-8.59)	0.1301 (3.24)	0.499 (6.37)	0.7224 (2.77)	-0.2124 (-8)
$\beta_{HW}(p_1)$	-0.0376 (-19.31)	-0.0642 (-13.71)	0.0042 (0.61)	0.0337 (3.18)	5.2499 (1.14)	-0.679 (-2)
$\beta_{CH}(p_1)$	-1.15 (-25.21)	-2.11 (-15.94)	0.0584 (0.41)	0.9297 (4.07)	0.2986 (66.61)	-2.6108 (-8.35)
$\beta_{TT}(p_2)$	-	0.0548 (7.39)	-0.2253 (-7.81)	-0.2661 (-7.08)	0.011 (0.71)	-0.0203 (-0.57)
$\beta_{TC}(p_2)$	-	-0.4264 (-9.01)	-1.3133 (-8.99)	-1.9888 (-9.12)	-0.2181 (-1.53)	0.0041 (0.15)
$\beta_{HW}(p_2)$	-	-0.0401 (-7.47)	-0.1359 (-7.5)	-0.1947 (-7.67)	-0.9541 (-1.98)	-0.4684 (-2.11)
$\beta_{CH}(p_2)$	-	-1.2102 (-8.91)	-4.4646 (-10.41)	-6.1639 (-10.28)	0.0007 (0.18)	-1.3447 (-6.02)
$\beta_{TT}(p_3)$	-	-	-	-	-0.261 (-12)	-0.0919 (-8.55)
$\beta_{TC}(p_3)$	-	-	-	-	-1.8974 (-5.09)	-1.1795 (-8.96)
$\beta_{HW}(p_3)$	-	-	-	-	-10.789 (-0.23)	-0.0589 (-11.29)
$\beta_{CH}(p_3)$	-	-	-	-	-3.1556 (-14.14)	-0.6568 (-1.98)
$\beta_{TT}(p_4)$	-	-	-	-	0.1685 (8.58)	0.0004 (0.03)
$\beta_{TC}(p_4)$	-	-	-	-	1.7052 (4.39)	0.587 (6.16)
$\beta_{HW}(p_4)$	-	-	-	-	10.78 (0.23)	0.0296 (4.53)
$\beta_{CH}(p_4)$	-	-	-	-	2.464 (10.94)	0.043 (0.09)
$\pi_1(\beta_{TT})$	-	-	-	-	-	0.4383 (5.37)
$\pi_1(\beta_{TC})$	-	-	-	-	-	0.5883 (9.48)
$\pi_1(\beta_{HW})$	-	-	-	-	-	0.0715 (2.34)
$\pi_1(\beta_{CH})$	-	-	-	-	-	0.8397 (8.66)

Table 4: Model estimation on Swiss route choice data (part 2, asy. t-ratios in brackets).

	FB1	*FB2*	*FB3*	*FB4*	*FB5*	*FB6*
	-1463.6	-1460.08	-1443.29	-1435.49	-1429.29	-1423.68
	0.391521353	0.391323554	0.396594069	0.398159976	0.399066554	0.399730005
	13	17	21	25	29	33
δ_1	-0.051 (-0.82)	-0.0388 (-0.61)	-0.0441 (-1.08)	-0.041 (-1)	-0.0362 (-0.88)	-0.0414 (-0.66)
$\beta_{TT}(p_1)$	-0.1671 (-7.8)	-0.1343 (-8.7)	-0.1448 (-0.34)	-0.1447 (-0.33)	-0.1386 (-0.3)	-0.1447 (-12.43)
$\beta_{TC}(p_1)$	-0.3709 (-8.65)	-0.3693 (-8.64)	-0.5261 (-3.59)	-0.5187 (-3.21)	-0.5121 (-3.02)	-0.5097 (-11.43)
$\beta_{HW}(p_1)$	-0.0588 (-5.02)	-0.0593 (-6.49)	-0.0021 (0)	0.0062 (0.01)	0.0068 (0.01)	0.0149 (1.43)
$\beta_{CH}(p_1)$	-1.5041 (-5.37)	-1.4773 (-6.38)	-2.0936 (-73.2)	-2.0604 (-68.61)	-2.0324 (-67.69)	-2.069 (-11.23)
$\beta_{TT}(p_2)$	0.0714 (6.32)	0.0682 (8.03)	0.1009 (0.42)	0.0983 (0.36)	0.1044 (0.42)	0.1078 (7.5)
$\beta_{TC}(p_2)$	-0.4103 (-9.18)	-0.4794 (-8.63)	-0.6313 (-6.85)	-0.6296 (-6.68)	-0.6227 (-6.29)	-0.6108 (-10.18)
$\beta_{HW}(p_2)$	-0.043 (-7.76)	-0.0579 (-5.74)	-0.078 (-0.15)	-0.0938 (-0.19)	-0.091 (-0.18)	-0.1072 (-6.61)
$\beta_{CH}(p_2)$	-1.3728 (-8.44)	-2.1955 (-7.47)	-1.3169 (-51.61)	-1.1934 (-36.59)	-1.2595 (-42.68)	-1.2923 (-7.9)
$\beta_{TT}(FB_1)$	0.1804 (1.26)	-0.0884 (-0.88)	-0.0551 (-1.3)	-0.068 (-1.42)	-0.3148 (-10.3)	-0.2685 (-2.38)
$\beta_{TT}(FB_2)$		0.1095 (0.9)	-0.3179 (-10)	-0.2491 (-7.28)	-0.4765 (-15.91)	-0.4173 (-3.8)
$\beta_{TT}(FB_3)$			-0.2346 (-7.85)	-0.1306 (-3.71)	-0.2235 (-8.1)	-0.3013 (-2.62)
$\beta_{TT}(FB_4)$				-0.1234 (-3.53)	-0.0115 (-0.42)	-0.0395 (-0.38)
$\beta_{TT}(FB_5)$					0.5322 (25.2)	0.5114 (3.44)
$\beta_{TT}(FB_6)$						0.1453 (1.52)
$\beta_{TC}(FB_1)$	0.1107 (1.62)	0.1455 (2.28)	-1.2582 (-98.99)	-1.2316 (-82.24)	-1.7933 (-167.63)	-0.9804 (-3.03)
$\beta_{TC}(FB_2)$		-0.0905 (-1.18)	-1.4785 (-100.24)	-1.4101 (-82.01)	-1.7686 (-157.62)	-1.3941 (-4.96)
$\beta_{TC}(FB_3)$			0.465 (22.15)	0.3879 (17.55)	0.8431 (53.89)	0.2308 (1.07)
$\beta_{TC}(FB_4)$				0.1474 (7.02)	0.268 (16.79)	-0.0117 (-0.07)
$\beta_{TC}(FB_5)$					-0.3262 (-24.4)	-0.0346 (-0.24)
$\beta_{TC}(FB_6)$						0.3543 (1.93)
$\beta_{HW}(FB_1)$	0.0936 (0.74)	0.101 (0.97)	0.8733 (30.43)	0.8376 (25.92)	0.8871 (27.94)	0.888 (7.76)
$\beta_{HW}(FB_2)$		-0.2015 (-2.15)	0.0444 (1.1)	0.0096 (0.22)	0.059 (1.42)	0.0571 (0.64)
$\beta_{HW}(FB_3)$			-0.4095 (-11.23)	-0.4616 (-12.18)	-0.4907 (-12.4)	-0.5049 (-4.85)
$\beta_{HW}(FB_4)$				-0.0878 (-2.03)	-0.1158 (-2.72)	-0.127 (-1.41)
$\beta_{HW}(FB_5)$					0.0126 (0.33)	0.1476 (1.47)
$\beta_{HW}(FB_6)$						0.1737 (1.87)
$\beta_{CH}(FB_1)$	0.2542 (2.36)	0.3062 (3.32)	0.0312 (0.45)	0.0549 (0.88)	0.0632 (0.93)	0.008 (0.12)
$\beta_{CH}(FB_2)$		-0.2815 (-3.23)	0.0096 (0.21)	0.1855 (5.91)	0.0855 (2.07)	-0.0482 (-0.52)
$\beta_{CH}(FB_3)$			0.0913 (2.26)	-0.0308 (-0.97)	0.0512 (1.28)	0.0227 (0.28)
$\beta_{CH}(FB_4)$				-0.4063 (-15.9)	-0.2555 (-7.32)	-0.2864 (-3.23)
$\beta_{CH}(FB_5)$					0.0043 (0.11)	-0.1206 (-1.45)
$\beta_{CH}(FB_6)$						-0.2296 (-2.81)

In the FB results presented in Table 4, the δ, $\beta(p_1)$ and $\beta(p_2)$ parameters are the same as in the Normal model in Table 3. The $\beta(FB)$ parameters are the terms in the series expansions of the distributions for each coefficient.

On the estimated parameters we note in particular the low standard deviations (p_2 and p_4 parameters) for the MOD_2 model, corresponding to almost point masses. On the FB models we note that most of the terms in the series expansion are quite significant in t-tests, with the exception of the last FB_6 model.

5. Conclusions

This paper has reported the findings of a systematic study using Monte Carlo experiments aimed at comparing the performance of various methods in retrieving random taste heterogeneity in a discrete choice context. Specifically, the analysis has compared the performance of four commonly used continuous distribution functions, the Normal, symmetrical Triangular, Uniform and Johnson S_B, to that of two more advanced approaches discussed in this paper. The first of these two approaches, the FB approach, improves on the flexibility of a base distribution by adding in a series approximation using here Legendre polynomials, while the Normal distribution was chosen as the base. The second approach, the MOD approach, uses a discrete mixture of continuous distributions, where again, in the present study, the base distributions are all Normal.

The simulation study compared the performance of the six resulting models across seven separate case studies, making use of different assumptions for the true distribution of the single random parameter in the model. In each case study, fifty random versions of the data were generated to allow us to gauge the stability of the various approaches. We find as expected that the ability to reproduce an underlying *true* distribution depends on the number of parameters in the estimated distribution. The most flexible distributions are able to approximate a variety of different shapes and they result in higher log-likelihoods. Good performance was also obtained by the models using the Johnson S_B distribution. The latter has, however, the drawback that it cannot be made more flexible. So even though the Johnson S_B distribution may do well in a particular application it is not possible to assess whether it does well enough. In contrast, one may just increase the number of parameters in the two flexible approaches and use a likelihood ratio test to decide when the number of parameters is sufficient.

The performance of the two-parameter distributions is poor in comparison. Even though this could be expected, we consider it illuminating to illustrate how these distributions fail and compare this to the application of more flexible distributions. Many past applications of the Mixed Logit model have relied on such two-parameter distributions. On the other hand, the two advanced approaches discussed in this paper seem to perform very well across all the cases studied here, suggesting that they can approximate well a variety of distributions, ranging from the most trivial (Uniform) to more complex multi-modal distributions.

In the present simulation study, the MOD approach has a slight advantage over the FB approach in terms of model fit. This finding is conditional on the selection of true distributions that we have chosen to investigate. The selection includes a number of cases with point masses which the FB approach cannot accommodate. On the other hand, it seems that the MOD estimates of the CDF have somewhat higher variance than the FB estimates.

For non-smooth distributions, the MOD approach has the ability to become degenerate and have a point mass. The FB approach does not allow for point masses. This may be viewed as an advantage of the MOD approach if one believes in mass-points, a concept that, in an applied discrete choice context, only really makes sense for a mass-point at zero. However, this degeneracy is also a problem for the ability of the estimator to approximate smooth distributions and the estimator must be constrained in some way (cf. Coppejans, 2001). It may be conjectured that the higher variance of the MOD approach is related to this degeneracy problem.

In our application to the Swiss value of time data we have demonstrated that the flexible approaches are practical for real data. We found that all four coefficients tended to have bimodal distributions. This is something that deserves an explanation and we have put forward two potential explanations. The contribution of the flexible approaches that is relevant for the current paper is that they were able to reveal these features of the data that the less flexible approaches did not detect. The Johnson S_B distribution and the MOD did have problems with degeneracy and it was not computationally possible to increase the MOD beyond MOD_2. It is a possibility that this problem is related to weak identification of the distributions in the data. The FB approach did not have problems of degeneracy and there were no computational problems involved in increasing the number of parameters in the series expansions.

The flexibility of either of the two approaches can be increased by estimating additional parameters, in terms of additional terms in the series expansion in the FB approach, or additional distributions in the MOD approach. Here, an important advantage of the FB approach is that it is possible to add just one parameter at a time, while, with the MOD approach, it is necessary to add three parameters at the same time (location, variance and mass). Increasing the number of parameters inevitably leads to increased estimation cost, and issues of convergence to local maxima become more prominent.

Both approaches are not restricted to being based on the Normal distribution, but can use any continuous distribution as the base. Both approaches are also relatively easy to implement, where the FB approach has already been implemented in BIOGEME (Bierlaire, 2003), and where estimation code for the MOD approach is available from the second author on request.

It should also be noted that the potential of these approaches is not limited solely to the estimation of models with flexible distributions. Indeed, as in the present application to the Swiss value of time data, they can also be seen as a diagnostic tool that can be used to get an idea of the shape of the true distribution or to reveal what is in the data; this knowledge can then be used in the choice of an appropriate model. In one of the case studies in the simulation study discussed in this paper, one would, for example, be able to reveal that the lognormal distribution was an appropriate choice without imposing that distribution initially.

In a direct comparison of the two advanced approaches discussed in this paper, we can conclude that they are very similar in their ability to approximate smooth distributions. In general there is no reason to suppose that one approach should be better than the other, since both are able to approximate any distribution arbitrarily well by increasing the number of parameters. Our application to real data did however show that the MOD approach ran problems. These problems may however be related to the data and not the MOD approach itself.

An important avenue for further research is related to development and testing of the two approaches in more complex scenarios, such as in the presence of multiple random coefficients with potential correlation between them. This issue is related to the issue of the degree of model complexity that data will allow. There is clearly a limit in sight where normal-sized datasets will not allow us to identify all we would like to know about heterogeneous preferences.

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A methodology to evaluate the prospects for the introduction of a Park&Buy service

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Abstract

The paper analyses the potential for introducing a Park&Buy service in the city of Pesaro (Italy) along the lines of the pilot project introduced in Siena, Italy, in 2004. It attempts to empirically evaluate the preferences of the parties involved and derives some suggestions on the potential compromise solution via a specifically designed stated preference experiment, drawing from the literature on interactive agency discrete choice modelling. Although various theoretical and methodological issues are still open for discussion, the methodology proves useful in giving insights not only on the parties' preference structure - as normally achieved by discrete choice models - but also on shopkeepers perception of customers' preferences, on the room for bargaining, on each party's influence on choice attributes and on the determinants of the probability of achieving a comprise solution.

Keywords: City logistics; Interactive choice experiments; Discrete choice.

1. Introduction

City centers, especially historic ones, suffer from lack of space to accommodate traffic and parking of private cars. City administrators often restrict motor vehicle access to city centers in order to preserve their aesthetic quality and to reduce congestion and pollution. While these policies support some activities (leisure activities, tourism, etc.), shopkeepers situated within the city center often oppose to traffic restrictions on the grounds that they favor shops and malls equipped with large parking facilities located outside the city boundaries.

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Policies aimed at reducing private car traffic are often accompanied by those limiting or regulating freight vehicle access to city centers. In Europe this set of policies is defined by the concept of city logistics, since its objective is to optimize goods distribution in an urban area.

Various city logistics proposals have been advanced (see e.g. Bestuf, Cityports, CityFreights projects, LT Consultants and BCI, 2002; Egger and Ruesch, 2004; Panebianco and Zanarini, 2005) and a number of pilot projects have been implemented. An interesting one is the Park&Buy (P&B) service implemented in Siena for two weeks in 2004 within the eDRUL project (funded by the 5th Framework Programme)[1]. It aims at improving the accessibility to visitors and tourists to the 750 shops located within the city centre. Due to access restriction, in fact, visitors and tourist, contrarily to residents, can only park their vehicles in the parking lots located outside the city centre. The *P&B* service allows the customers of these shops to have their purchases delivered to the parking facilities or to their hotels.

During the two-week test the parcels of 10 shops located in the centre of Siena were delivered by a transport operator[2] to the parking lot "Il Campo"[3]. The *P&B* service order was processed by the shopkeeper and was forwarded to the e-DRUL Agency (via a web portal or by phone) which notified it to the transport operator and to the customer. When the parcel was delivered to the pick-up point the consumer was informed via as SMS.

The *P&B* service tested in Siena showed two important advantages (Ambrosino *et al.*, 2005a): (a) the efficient management of the freight traffic from the city centre to areas outside the restricted zone; (b) the increased attractiveness of the shops located in the Traffic Limited Zone (TLZ) and, in particular, of those located farther away from the parking lots.

The *P&B* system is similar to other home delivery services provided in France by shops and supermarkets associated to the Nanterre PAD, in Belgium by the Delhaize supermarkest, in UK by TESCO, in Switzerland by the online supermarket LeShop (Egger and Ruesch, 2004), or by other pick-up point organizations such as Tower24 in Dortmund, DHL PackStation in Koln, Cityssimo and E-Box in Paris[4]. This city logistics innovation seems particularly suitable for Italian and European cities centers characterized by TLZs, good public transport accessibility and high commercial attractiveness. Moreover, it is in line with BESTUFS recommendations (Huschebeck and Allen, 2006) stressing the attractiveness of pick-up point services compared to traditional home delivery services and underlining the importance of information and communication technology (ICT).

However *P&B* raises some economic and distributive issues too. For instance, who should pay for the service? Shopkeepers, customers, or both? In which proportion[5]? How quickly should the parcels be deliveded at the parking lot? How frequent should the service be? Should the parcels be delivered on request to other destinations (e.g. home delivery)? And who should pay for that extra-service? Should the service be organized using information technology or not?

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[1] See the website http://srvweb01.softeco.it/edrul/

[2] CO.TA.S. (Consorzio Tassisti Senesi, www.cotas.it)

[3] operated by SienaParcheggi as a business-to-customer (B2C) freight pick-up point

[4] For more information see Egger and Ruesch, 2004or visit www.bestufs.net

[5] In Siena the *P&B* service cost was estimated to be between 3 to 5 € per parcel (including transport and order management cost) but the shopkeepers were willing to pay only 2 € per parcel.

We believe that it would be useful to answer to these questions and to predict if and under which conditions the *P&B* system could be successfully implemented in Italy. It seems to us, indeed, that the technological feasibility of the service is less critical than the lack of willingness of shopkeepers, customers and the city administrators to participate to the project and to share its costs and risks.

Shopkeepers, first and foremost, are the ones who should be actively involved in organizing the service. However, in a city center, there are numerous types of shops (groceries, domestic appliance shops, clothing departments, jewelry stores, bookstores, furniture stores, etc.) and it is quite likely that they would benefit differently from the new service. It is to be expected, then, that they would be differently willing to participate to the project. It sould be noted that the Siena pilot experiment was funded by the City Council and the European Union, but that, in order to be financially sustainable, should be fully supported and properly financed by the local business community.

Customers, who are likely to benefit from the new service, need to actually use it and, at least partially, to pay for it. However, similarly to shopkeepers, different customers will differently benefit from its implementation and, hence, their interest and willingness to pay for it is likely to differ. Whether and how much customers are willing to be involved in the project is a matter which needs to be evaluated empirically.

Finally, city administrators should encourage, promote and guarantee the conditions needed for the service to be successful, including the initial financing of the project and the setup of the regulatory framework within which the new service will take place. The city will benefit from the P&B service as long as the related traffic restraint policies will be accepted and the attractiveness of the city center will be enhanced. Indeed, a successful historical center is likely to raise real estate values and provide higher local tax revenue.

Because there are many different actors which would be involved in the new service and because they have quite different interests, formal and informal bargaining is likely to take place among them. The interacting feature of the bargaining process, although, is quite difficult to be analyzed at the theoretical, methodological and statistical level.

Since the aim of our research is to forecast agents' future demand for *P&B* service and to account for the bargaining process taking place among the main actors deciding if and how to implement it, we based our research on an interactive discrete-choice modelling framework originally conceived by D. Hensher and his associates at ITSL, University of Sidney (Hensher *et al.*, 2007a).

The first part of the paper (Section 2 and 3) is focused on the theoretical and methodological issues involved in the analysis of interactive decision making processes, while the second part (Sections 3 and 4) describes our case study and the descriptive and the econometric results we have obtained, finally Section 5 provides some conclusions and lists our future research lines on this topic.

2. Theoretical and methodological issues in the study of social interaction

Interaction between agents takes place in many ways. At one end of the spectrum, agents interact in decision making as members of an institution (e.g., a family or a firm). They are bound by sentimental or contractual relationships and take some decisions jointly, after formal or informal group discussion. These decisions can be classified as group decisions and can be modelled as group choices. An incomplete list of papers on *group choice modelling* includes Molin *et al.* (1997), Arora and Allenby (1999), Aribarg *et al.* (2002), Gliebe and Koppelman (2002, 2005), Zhang *et al.* (2005, 2006a, 2006b), Dosman and Adamowicz (2006), Puckett and Hensher (2006).

On the other end of the spectrum, there are individual decisions (e.g., individual consumption decisions) which, although taken without consulting other agents, entail an element of social interaction, since they are taken in a social environment (involving, e.g., imitation, image setting, peers' opinions). Relevan literature on *individual choice modelling with social interactions* includes Durlauf (2001), Brock and Durlauf (2001, 2003), Kooreman and Soetevent (2002), Hartmann and Yildiz (2007), Kooreman (1994), Brewer and Hensher (2000) and Paglione (2007).

Most business decisions, indeed, take into account other agents' preferences. Sometimes this is only implicit (e.g. in setting the price for a product a shopkeeper takes into account his clients' preferences), in other cases there is an actual bargaining process taking place via an explicit interaction among the buyer and the seller. During the bargaining process each agent might decide to either cooperate, that is "to play the game" or not to do so, that is "to exit the game".

An agent has an interest in playing the game only if s\he perceives that finding an agreement generates an improvement in her\his welfare compared with the no agreement situation. Each agent might propose a deal to split the gain, while the other agent might accept it, make a counter-proposal or exit the game. Entering a game and leaving it without reaching an agreement might entail a monetary or an opportunity cost.

We assume that a similar relationship exists between the shopkeeper and his customers when the *P&B* service is considered[6]. Such a relationship could be conceptualized as an interaction between two parties which takes the following steps. The shopkeeper designs the service in order to please customers and attract more business. The service will have certain technical characteristics (in terms of frequency of delivery at the parking lot, use of information technology and so on) and certain costs that need to be financed by the two parties[7]. The shopkeeper will propose a certain cost distribution to the customers. The customers might accept the proposal and use the new service or might refuse it.

Taking into account this interaction process is important to enhance the realism of any model describing the potential demand for a new logistic service involving more than one actor, indeed our aim is to develop an operational model that can describe the bargaining area of the agents potentially involved in the *P&B* system, that is shopkeepers and customers, that can estimate the values at stake and that can predict which service set up would be most probably accepted by those actors.

Since the decisions taken by shopkeepers and by their customers determine the success or failure of the *P&B* service, it is useful to analyse how their preferences might interact in determining the acceptability and the success of this service. In this respect a promising research framework is the inter-agency choice modelling, otherwise stated group decision modelling. Within this literature a common representation of the

[6] In the remaining of the paper we abstract, for the sake of simplicity, from the role played by the city administration and from interactions taking place among shopkeepers in deciding how to set up and finance the service.

[7] There is also a potential contribution from public subsidies motivated by improved attractiveness of the city centre and local taxed revenues.

interaction process involving two parties is described by the following equation [Arora and Allenby, 1999; Aribarg *et al.*, 2002; Dosman and Adamowicz, 2006; Zhang, *et al.* 2005, 2006a, 2006b]:

$$U_d^j = \tau_{sk}\beta_{sk}X_k^j + (1-\tau_{sk})\beta_{ck}X_k^j + \varepsilon^j \tag{1}$$

Equation (1) describes the utility that a hypothetical dyad *d*, made up by two agents (the shopkeeper *s* and the customer *c*), derives from choosing an alternative *j* (where *j = 1…J*) as a weighted sum of the utilities of each agent, with the weights represented by the parameters τ and (1 - τ). Notice that even if both agents choose the same alternative *j*, each of them experience different marginal (dis)utilities[8] associated with it, given the fact that each of them has different preferences, represented by the agent-specific β's. The parameters τ and (1 - τ) are the weights that multiply the agents' marginal utilities and represent the relative influence that each agent exerts in the final group choice.

The additive formulation of the systematic component of the utility function of the two agents equation (1) assume cardinal and interpersonally comparable utility functions as theoretically advocated by Harsanyi (1955). This is a crucial assumption discussed at length in public choice literature (see, e.g., Mueller, 1989), with little support in normative economics but, in our opinion, it is still a useful modeling tool given the positive approach adopted in this paper.

Notice also that equation (1) includes the specific assumptions made in most studies (Arora and Allenby, 1999; Aribarg, et al., 2002; Puckett and Hensher, 2006) that each agent has an *attribute-specific influence*, implying that there are as many τ parameter as the number of attributes included in the model.

Drawing from the modelling frameworks proposed David Hensher and his associates at ITSL (Sidney) like the Interactive Agency Choice Experiment (IACE, see Brewer and Hensher, 2000Rose and Hensher, 2004), the Minimum Information Group Inference (MIGI, see Hensher andPuckett , 2006), and the Stated Endogenous Attribute Level (SEAL(Puckett *et al.*2007) we developed a methodology comprising the following 4 steps.

First, a selection of relevant attributes for the *P&B* service is identified by the research group on the bases of literature review and of focus groups discussions involving shopkeepers. These attributes are used to design the *P&B* alternatives to be administered to the shopkeepers and to their customers during a stated preference choice exercise.

Second, during the interview each shopkeeper is asked to make two proposals on the cost distribution and technical characteristics of the service (Table 1): a) the one s\he prefers the most and b) the one s\he deems most preferred by his\her customers. Alternatively, the shopkeeper may decide not to make any proposal if s\he deems it not worth for his\her business. This second step provides us with information on the shopkeeper's preferred alternative and on his\her perception of his\her customers' preferred alternative. It also produces a customization of the choice experiment

[8] The possibility that the β's attached to each attribute represents a marginal utility or disutility depends on the nature of the attributes considered (goods or bads).

similarly to the SEAL methodology[9], whereas in the IACE methodology attribute levels are set and fixed by the analyst.

Table 1: An example of choice tasks submitted during the stated preference exercise.

Under your point of view a Park-and-Buy service (delivering parcels to the parking lot) would make sense for your business? If, yes, which characteristics should it have?			
Attributes	Alternative A*	Alternative B*	None of the two is convenient to me
Cost per parcel to be charged to the shopkeeper	€ 2	€ 3.6	-
Cost per parcel to be charged to the customer	€ 2.2	€ 0.8	-
Maximum delivery time at the parking lot	90’	150’	-
Use of information technology	Yes	No	-
Destinations other than the parking lot	Not available	Available, charging the extra cost to the customer	-
Preferred alternative by the shopkeeper **	-	-	-
Preferred alternative by the customer with no knowledge on shopkeeper’s preference§	-	-	-
Would the client accept the alternative chosen by the shopkeeper? **	-	-	-

Notes: * During the second step A stays for: “This is in my view the optimal solution for my business” and B stays for: “This is, in my view, the optimal solution taking the point of view of my customers”. During the third step A stays for: “Alternative A” and B stays for: “Alternative B”.
** This part of the task is used only during the third stap of the interview.

The third step consists in designing and administering to the shopkeeper 13 choice tasks including two hypothetical profiles that are pivoted orthogonal variations of the *P&B* alternative chosen by the shopkeeper himself during the previous step and the non-choice option.

As a forth step the choice experiment used for the shopkeeper interview is administered to his\her customers. They are asked to choose among the alternatives in the same 13 choice tasks proposed to the shopkeeper without knowing the shopkeeper’s choice. Then the shopkeeper’s choice is revealed to the customers and they are asked whether they would accept or not the shopkeeper’s choice.

This methodology can be thought as an application of an Ultimatum Bargain Game where one player makes a proposal on how to share the surplus of a cooperative interaction with the other player, or in our case how to set up the *P&B* service, while the other player can only accept the proposal or refuse it, ending in this way the game with no gains for both agents.

[9] With no revision of the starting preference on the basis of a second agent counter-proposal as performed within the SEAL methodology.

A further possibility, although we have not implemented it yet, would have been to go back to the shopkeeper, show his\her customers' choices and ask him\her to reconsider his\her choices.

The data collected during the third and fourth step from the shopkeepers and from their customers can be analysed via a nested logit model (Figure 1) where each agent can choose either to participate to the service or not to do so. In the former case the agent can chose between two *P&B* alternatives.

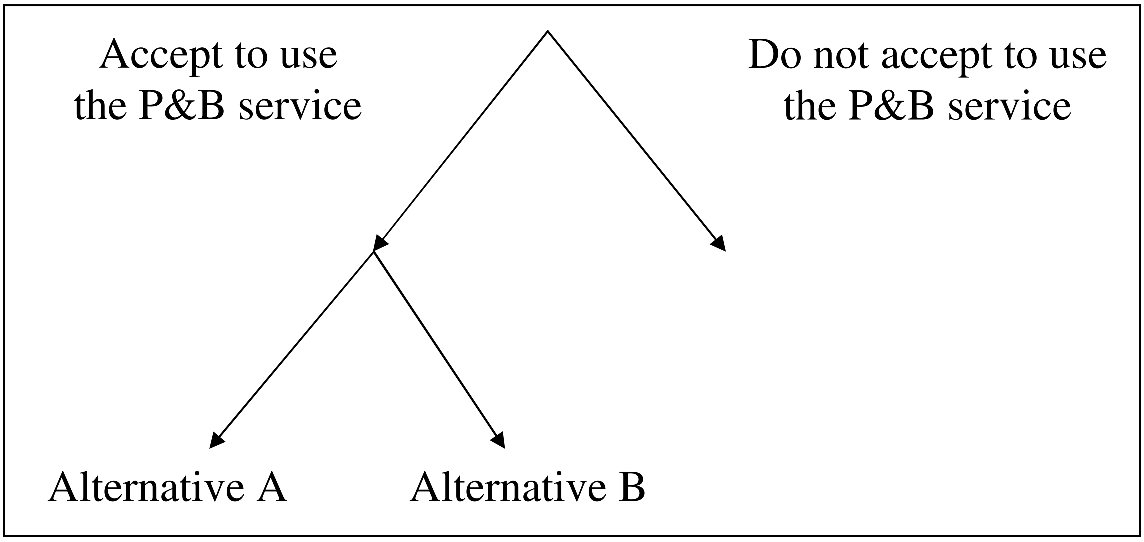

Figure 1: The nested structure of the choice model.

Since there is no actual joint choice, in order to study what the shopkeeper-customer group choice would be we use the initial pass power model developed in the MIGI methodology by Hensher and Puckett (2006). The estimated coefficients of the choice model of each party are used as constant exogenous terms specifying the *initial pass power model*, and are multiplied by the corresponding attribute levels of the *K* attributes of each hypothetical *j* alternative. For each simulated group interaction, the alternative designated as the choice is the combination of the stated choices of the two parties.

In a three-choice set up the model looks as follows:

$$
\begin{aligned}
U_{11} &= \alpha_{11} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{1k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{1k} + \varepsilon_{11} \\
U_{12} &= \alpha_{12} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{1k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{2k} + \varepsilon_{12} \\
U_{13} &= \alpha_{13} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{1k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{3k} + \varepsilon_{13} \\
U_{21} &= \alpha_{21} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{2k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{1k} + \varepsilon_{21} \\
U_{22} &= \alpha_{22} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{2k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{2k} + \varepsilon_{22} \\
U_{23} &= \alpha_{23} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{2k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{3k} + \varepsilon_{23} \\
U_{31} &= \alpha_{31} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{3k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{1k} + \varepsilon_{31} \\
U_{32} &= \alpha_{32} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{3k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{2k} + \varepsilon_{32} \\
U_{33} &= \alpha_{33} + (\tau_{sk} \cdot \beta_{sk})' \cdot x_{3k} + ((1-\tau_{sk}) \cdot \beta_{ck})' \cdot x_{3k} + \varepsilon_{33}
\end{aligned}
\tag{2}
$$

This is the complete power model. When restricting the model to agreement cases, the model reduces to the subset of equations in which alternative *j* is identical for both agents (i.e., both choose 1, both choose 2, or both choose 3). Hensher claims that the focus of group decision making modeling should be on both studying (i) the full set of group preferences; and (ii) the agreement outcomes only. The former specification is particularly useful in investigating potential barriers to agreement (as shown in Brewer and Hensher 2000).

As a generalization of model (1) Zhang *et al.* (2005) proposed a specification of the group utility function termed the *multi-linear group utility function:*

$$U_g = \sum_{i=1}^{n} w_i u_i + \sum_{i_1=1}^{n} \sum_{i_2>i_1}^{n} \left(w_{i_1 i_2} u_{i_1} u_{i_2} \right) + ...w_{i:n} u_1 u_2 ... u_n \qquad (3)$$

Where w_i is member i's weight parameter, and $w_{i_1 i_2}$,…… $w_{1\text{-}n}$ are the intra-household interaction parameters. This model assumes that household utility can be derived by weighting the utilities of the individual household members, and adding interaction effects. The weight w_i can be interpreted as a measure of a member's power or influence over the group decision-making. The interaction parameters $w_{i_1 i_2}$,…… $w_{1\text{-}n}$ moderate the power effect and reflect the group members' concern for achieving equality of utilities. The larger the interaction parameter, the higher the group's collective desire to choose an allocation such that the utilities of all household members tend to be equal. We test if the specification (3) of the utility function of the group is superior to specification (1).

3. Sample description and descriptive results

The city of Pesaro (together with the city of Urbino) is one of the main towns of Marche region, which is located in the centre of Italy. We interviewed 21 shops located in the city centre of Pesaro, specifically: 5 shops selling clothing, 8 groceries, 1 bookshop, 1 footware, 1 optician, 3 shops selling home furnishing, 1 textiles and 1 underwear. The sample used for the econometric analysis reduced to 19 shops due to the fact that 2 of the shopkeepers (the optician and the one selling underwear) stated that they were not interested in the implementation of the *P&B* service.

The analysis of the information stated by the shopkeepers during the second step of the research (which are described in figure 2) shows that they are willing, on average, to accept a cost equal to 0.68 Euro per consignment. 7 of them do not accept any charge, while 2 shopkeepers would accept a 2 Euro charge.

On average shopkeepers propose to charge their customers 1.39 Euro per consignment, ranging from a minimum of 0.5 Euro to a maximum of 3 Euros.

All but one shopkeeper would prefer to use information technology (either computer based or portable cellular phones) to process and monitor the service. 7 of them do not consider desirable to extend the service destination beyond the parking area, while 12 think that home delivery is a desirable feature but that their customers should be charged for the extra-service.

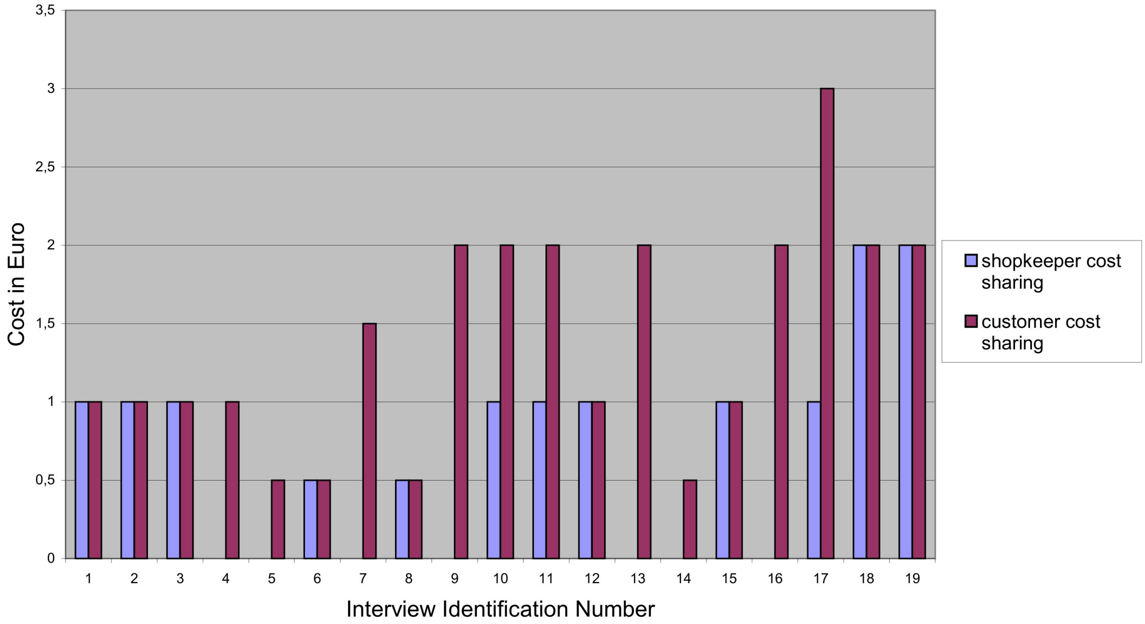

Figure 2: P&B cost sharing according to shopkeepers.

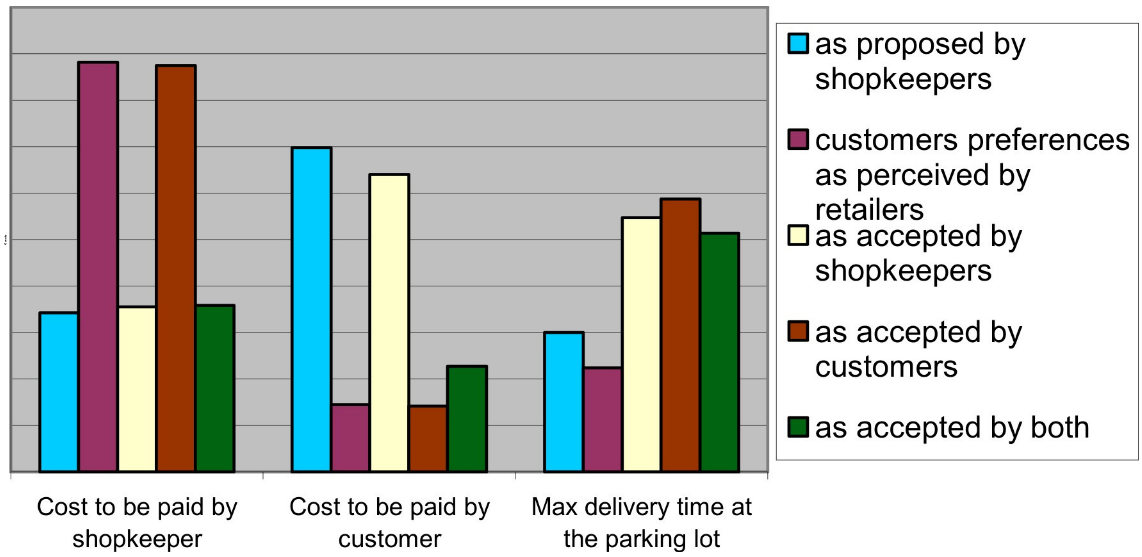

Figure 3: P&B cost sharing and frequency.

The bargaining process between shopkeepers and customers relatively to the *P&B* cost sharing and the maximum delivery time at the parking lot is depicted in Figure 3 showing that:

a) Costs to be borne by shopkeepers. On average, in the first task, shopkeepers stated that they would accept to pay 68 Eurocents per parcel as a contribution to the *P&B* service (first row and first column of table 1, choice task 1) and that their customers would most likely want them to contribute a cost equal to 176 Eurocents (first row and second column of table 1, choice task 1). But in the subsequent choice tasks (generated as orthogonal variations from the first base case), shopkeepers choose alternatives that make them pay on average 71 Eurocents, slightly more than what stated in the first task. How much do customers think shopkeepers should contribute to the *P&B* cost financing? The interviewees stated that they would accept to use the *P&B* service if shopkeepers would pay on average 175 Eurocents, a strikingly similar figure to the one stated by shopkeepers (shopkeepers know their customers well!). In the agreement cases, that is when the same *P&B* scehario is chosen by both parties[10], shopkeepers accept to pay on average 72 cents. The bargaining area for shopkeepers' contribution to the *P&B* cost financing can consequently be estimated to be between 68 and 175 Eurocents.

b) Costs to be borne by customers. On average, in the first task (second row and first column of table 1, choice task 1), shopkeepers stated that customers should contribute 139 Eurocents per parcel for the *P&B* service. They also expect that their customer would most likely want to contribute a cost equal to 29 Eurocents (second row and second column of table 1, choice task 1). The analysis of the choice tasks stated by customers, in fact, shows that they are willing to contribute on average 28 Eurocents (again, shopkeepers know their customers well!). The *P&B* alternatives chosen by both parties are those in which customers pay on average 46 Eurocents. The bargaining area for customers' contribution to the *P&B* cost financing can consequently be estimated to be between 28 and 139 Eurocents.

c) Maximum delivery time at the parking lot. On average, in the first task, shopkeepers stated that a parcel should be delivered at the parking lot within 60 minutes. They also stated that their customers would most likely want a parcel to be delivered in 45 minutes. The analysis of the choice tasks, however, shows that shopkeepers are willing to accept an average time of 109 minutes and customers a surprisingly higher time of 117 minutes. When a *P&B* alternative is chosen by both parties the delivery time is on average equal to 103 minutes. The bargaining area for the delivery timing can consequently be estimated to be between 60 to 117 minutes, as customers appear to be less demanding then it is perceived by the shopkeepers.

4. Econometric results

The stated preference data of shopkeepers and of their customers have been used to separately estimate two different logit models, one for each group, hence the initial pass power model has been estimated.

The shopkeepers' choice model

None of the shopkeepers participating to the SP experiment (19 out of 21[11]) refused to begin the negotiation process, that is chose the third alternative described in table 1. The estimates of the parameters of the binomial logit model based on their choices are reported in table 2.

[10] Out of the 266 tasks (14 tasks times 19 interviews), in 53 of them the customer chooses the same alternative chosen by the shopkeeper without having previous information on the latter's choice.

[11] Two shopkeepers asserted that P&B service was unsuitable for their business, hence they did not provide the necessary starting values for designing the experiment.

Table 2: The shopkeepers' choice model.

Variable	*Coefficient*	*t-statistics*
Alternative specific constant	0.102	0.37
Cost to be charged to the shopkeeper	-3.319	-5.70
Cost to be charged to the customer	-0.640	-1.68
Maximum delivery time at the parking lot	-0.012	-3.60
Use of information technology	0.361	1.27
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	-0.871	-2.23
Extra-cost to be charged to customers for a destination other than the parking lot	0.698	2.15

Notes: N. obs.: 266; LL(B)= -74.03; Adjusted Pseudo R^2 (no coefficients)=0.40851.

The overall performance of the model is quiet good. The most significant parameter is the service cost to be borne by shopkeepers, and, as expected, it has a negative sign. Maximum delivery time at the parking lot has also a negative effect on shopkeepers' utility function. They probably perceived that the quickness of the service would increase the competitiveness of the stores located in the city center. Surcharges for parcels to be delivered at destinations other then the parking lot positively affect shopkeepers' utility function if this extra service is paid by customers, the opposite if the shopkeepers have to pay for them. The parameter of the customers' contribution to the cost of the *P&B* service has a negative sign, most likely because shopkeepers believe that it would reduce their competitiveness, but this estimate has limited statistical significance. Finally the use of information technology is viewed positively, but the estimate of this parameter is characterized by low statistical significance.

The customers' choice model

Since during the SP experiment some customers chose the third alternative, that is they refused both the proposed hypothetical *P&B* services, we decided to use a nested logit in order to model their behaviour. Specifically, we structured the model as tree composed by two branches: a branch, with two twigs, describing the choice between the hypothetical *P&B* services, and a degenerate branch (single twig) describing the choice of not participating to the *P&B* service (figure 1).

The result is a highly significant model according to which customers are particularly sensitive to the *P&B* cost which, according to their preferences, should be paid by the shopkeepers. All the other variables are not significant, including, quite surprisingly, the maximum delivery time at the parking lot.

Table 3: The customers' choice model.

Variable	*Coefficient*	*t-statistics*
Alternative specific constant	6.700	1.87
Cost to be charged to the shopkeeper	3.925	1.93
Cost to be charged to the customer	-3.427	-1.91
Maximum delivery time at the parking lot	0.003	0.45
Use of information technology	-0.829	-1.09
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	1.492	1.47
Extra-cost to be charged to customers for a destination other than the parking lot	0.634	0.87
No-service alternative specific constant	20.867	0.24
IV parameters		
SI	2.45	2.05
B(1|1,1)	2.29	.240

Notes: N. obs.: 266; LL(B)= -15.37; Adjusted Pseudo R^2 (no coefficients)= 0.88389.

The initial pass power model

On the bases of the coefficients estimated for the shopkeepers and for the customers with the models previously described, and following the MIGI methodology, we have estimated an initial pass power model.

For this estimation we used only the tasks where one of the hypothetical *P&B* services were chosen, excluding, thereof, 12 tasks in which customers chose the “non-option”, that is the third alternative in table1. As stated by Hensher and Puckett (2006) the initial pass power model can be estimated considering: a) all the choice tasks, independently of the fact that both parties choose the same alternative or not (complete first pass model), or b) only those choice tasks in which the two parties choose the same alternative (restricted first pass model).

The estimation of the parameters of the complete first pass model, that is the τ_s in equations 2, produced the following results:

According to the model specification, a coefficient τ larger than 0.5 signals that shopkeepers exert a stronger influence then their customers on the value of the attributes characterizing the *P&B* service, while a τ smaller than 0.5 signals a stronger influence of customers. As in Hensher and Puckett (2006), and contrarily to the theory, we consider “unbounded” τ parameters (they are free to exceed the 0-1 boundaries), because we assume that a party might trade off his influence on one attribute with its influence on another one. Hence, the interpretation of the results is the following.

Shopkeepers retain control over their contribution to financing the service, but customers exert an even stronger influence on their contribution. Surprisingly, the quickness of the service is more influenced by shopkeepers rather than by customers. Such a result is consistent with what derived from the previous descriptive and analytical evidence of the data: quickness is not an important attribute for the sampled customers.

Similarly, information technology is a feature deemed more important by shopkeepers than by customers. With reference to whom should pay for the extra-cost of home delivery, the estimates provide a balanced influence on shopkeepers contribution, whereas customers contribution is very much influenced by shopkeepers preferences. Both results appear quite reasonable since the service under consideration is very much in the interest of the customers and, consequently, the parties favour a solution in which the extra-cost is borne by the customers.

Table 4: Complete Initial Pass Power Model.

Mean power measures τ (>0.5 represents relative power to shopkeeper, <0.5 represents relative power to customer)	*Coeficient*	*t-ratio**
Cost to be charged to the shopkeeper	0.808	2.12
Cost to be charged to the customer	-1.060	-4.11
Maximum delivery time at the parking lot	1.163	2.43
Use of information technology	0.979	1.44
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	0.517	0.07
Extra-cost to be charged to customers for a destination other than the parking lot	1.587	2.93
Constant (shopkeeper chooses 1, customer chooses 1)	-0.479	-2.50
Constant (shopkeeper chooses 1, customer chooses 2)	-0.619	-3.39
Constant (shopkeeper chooses 2, customer chooses 1)	-0.712	-2.90

Notes: * The null hypothesis is H_0:$\tau = 0.5$.
N.obs: 254; LL(B)= -100.11; Adjusted Pseudo R^2 (no coefficients)= 0.71.

In order to estimate the restricted version of the initial pass power model two sets of data are available: one including only the agreement choices and one which comprises those tasks where customers were willing to revise their first choice in order to reach an agreement with the shopkeepers. In our interviews both situations are not numerous. Out of 266 tasks, 53 resulted in immediate agreement, while 11 in situations where customers were willing to revise their choice and accept the shopkeepers' choices. Since the data resulting from the first 53 tasks were not enough to estimate the model, this was estimated combining the initial and the subsequent agreement cases.

Table 5: Restricted Initial Pass Power Model.

Mean power measures (>0.5 represents relative power to shopkeeper, <0.5 represents relative power to customer)	Coefficient	t-ratio*
Cost to be charged to the shopkeeper	0.476	-0.11
Cost to be charged to the customer	-0.838	-2.40
Maximum delivery time at the parking lot	1.463	2.48
Use of information technology		
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	0.134	-1.15
Extra-cost to be charged to customers for a destination other than the parking lot	0.733	0.30
Constant (shopkeeper chooses 1, customer chooses 1)	-0.536	-2.20
Constant (shopkeeper chooses 1, customer chooses 2)	-2.446	-4.81
Constant (shopkeeper chooses 2, customer chooses 1)	-2.189	-3.81

Notes: * The null hypothesis is H_0:$\tau = 0.5$.
N. obs.: 64 choice tasks (53 first-agreement cases + 11 second-agreement cases); Information technology variable not considered; LL(B)= -42.24; Adjusted Pseudo R^2 (no coefficients)= 0.50320.

The model could be estimated with all the variables used in the previous models except the use of information technology. The results are similar but not equivalent to the previous ones (those obtained with the complete version of the initial pass power model), demonstrating that the two models have a different meaning.

They indicate that the shopkeepers' contribution is equally influenced by the two parties, unlike the previous result. On the contrary, customers retain a great influence in determining their contribution. The quickness of the service is left to shopkeepers as in the previous model. The contribution to the extra-cost is influenced by customers in the case of shopkeepers' contribution and vice-versa in the case of customers' contribution. Unlike the previous results, customers are less willing to accept the surcharge for home delivery.

The probability of agreement

It is also interesting to estimate how attributes affect the probability of agreement between the two parties. It can be done using the information obtained from the tasks where an agreement (either direct or after concession by the customer) took place.. The alternatives are described by the attributes levels and the alternative chosen by both parties is set to 1. The model contains the same amount of information as the restrictive initial pass power model with the difference that it is specified using the attribute levels as follows.

$$y_j = \alpha_j + \beta' X_j + \varepsilon_j \tag{4}$$

Where y_j is set to 1 when the alternative j is chosen by both parties and 0 otherwise. The results are presented in Table 6.

Table 6: Probability of agreement.

Variable	Coeff.	Std.Err.	t-ratio
Cost to be charged to the shopkeeper	-6.367	3.367	-1.89
Cost to be charged to the customer	-8.508	3.169	-2.68
Maximum delivery time at the parking lot	-0.024	0.008	-2.90
Use of information technology	0.645	0.606	1.06
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	0.909	0.693	1.31
Extra-cost to be charged to customers for a destination other than the parking lot	0.195	0.722	0.27
Constant	-0.454	0.603	-0.75

Notes: N. obs.: 64 choice tasks (53 first-agreement cases + 11 second-agreement cases); LL(B)= -19.36; Adjusted Pseudo R^2 (no coefficients)= 0.50.

It turns out that the increase in the minutes within which the parcel is made available at the parking lot affects negatively and significantly the probability of both parties agreeing on choosing the alternative. Notice the high coefficients attached to the cost to be charged to the customers or to the shopkeepers. They are both negative meaning that an increase in cost has a negative impact on the probability of both parties agreeing on the alternative. Both variables have also high standard errors (because of the conflicting interests among the two parties) resulting in low t-statistics. However, it turns out that the t-statistics (and also the coefficient) for the cost to be charged to the shopkeeper is actually lower than that of the customer, meaning that an increase in the cost to be charged to the shopkeepers affects less the probability of having an agreement then an increase in cost to be charged to the customers. All other variables are not statically significant and can be interpreted as playing a minor role.

Simulative results

In the descriptive results section the levels of the alternative preferred by the shopkeepers and by the customers were identified and discussed. They are summarised in the first three rows of Table 7. The remaining three variables are coded as dummies (meaning that both alternatives use of information technology, alternative A requires extra-cost to be charged to the customers and alternative B to the shopkeepers). How likely is that the alternative A and B so described are accepted relative to one another? The application of the coefficients estimated with the four models (the shopkeepers' choice model, the customers' choice model, the complete initial pass power model and the agreement-only initial pass power model) provides us with an estimate of their relative degree of acceptability.

Table 7: Simulation.

Attributes	Alternative A: Preferred by shopkeepers	Alternative B: Preferred by customers
Cost to be charged to the shopkeeper	0.71	1.75
Cost to be charged to the customer	1.39	0.28
Maximum delivery time at the parking lot	109	117
Use of information technology	1	1
Extra-cost to be charged to the shopkeeper for other destinations	0	1
Extra-cost to be charged to customers for other destinations	1	0
Models:	*P(A)*	*P(B)*
Shopkeepers' choice model	99%	1%
Customers' choice model	0%	100%
Complete initial pass power model	1%	99%
Agreement-only initial pass power model	0%	100%

It turns out that alternative A is highly preferred by shopkeepers, whereas it has no chance of been accepted by customers. The opposite is true for alternative B. This results is obvious since each party prefers his own alternative. But what about the dyad's preferences. The complete and the agreement-only initial pass power model deem definitely more acceptable to the dyad the customers' preferred alternative then the shopkeepers' preferred alternative, meaning that the compromise solution deriving from a bargaining process would most likely be closer to alternative B than to alternative A. But the model cannot tell us neither how close these alternative are to the compromise solution, nor which will be the compromise solution.

Alternative specifications of the group utility function

Because of limited sample size we were able to estimate only the specification of equation 3 , those including the direct interaction terms (all but the one relative to cost to be charged to the shopkeepers).

The model adopting the multi-linear specification of the group utility function (equation 3) is slightly superior to the linear utility model of equation 1. But none of the intra-group interaction parameter proves significant, although their signs are, in general, correct. A positive sign implies that the group utility rises when one party systematic utility improves holding the other party's utility constant (signalling positive group inter-dependence or complementarity). A negative sign implies that the group utility decreases when one party systematic utility improves holding the other party's utility constant (signalling negative group inter-dependence or substitutability). The only interaction term with a positive sign is the quickness of the service, since both party profit from its increase. On the contrary, and not surprisingly, cost variables have a negative sign, signalling conflict. Surprisingly, the information technology interaction term has a negative sign as well.

Table 8: The multi-linear group utility function.

Mean power measures (>0.5 represents relative power to shopkeeper, <0.5 represents relative power to customer)	Coeff.	t-ratio*
Cost to be charged to the shopkeeper	0.854	2.26
Cost to be charged to the customer	-1.117	-3.87
Maximum delivery time at the parking lot	0.718	0.39
Use of information technology	-0.105	-0.74
Extra-cost to be charged to the shopkeeper for a destination other than the parking lot	0.573	0.15
Extra-cost to be charged to customers for a destination other than the parking lot	1.990	3.42
Interaction term relative to the cost to be charged to the customer	-0.340	-2.32
Interaction term relative to the quickness of the service	1.114	0.45
Interaction term relative to the use of information technology	-3.852	-1.52
Interaction term relative to extra-cost to be charged to the shopkeeper	-0.096	-0.92
Interaction term relative to extra-cost to be charged to the customer	-1.869	-2.09
Constant (shopkeeper chooses 1, customer chooses 1)	-0.390	-2.15
Constant (shopkeeper chooses 1, customer chooses 2)	-0.443	-1.66
Constant (shopkeeper chooses 2, customer chooses 1)	-0.437	-1.58

Notes: * The null hypothesis is H_0:τ = 0.5.
N. obs.: 254; LL(B)= -96.79; Adjusted Pseudo R^2 (no coefficients)= 0.72.

5. Conclusions and future research agenda

The paper analyses the potential for introducing an innovative city logistics service in the city of Pesaro (Italy), a P&B service along the lines of the pilot project introduced in Siena in 2004. The idea is to organize a service to deliver the parcels bought in the stores of the traffic-restricted city center to the parking lots where the customers are forced to leave their cars or where their coaches are parked.

In order for the service to be successful, both shopkeepers and costumers need to be willing to use it and to share, at least partially, its costs. Furthermore, the characteristics of the service, that is quickness, use of ICT, destination to be served, etc., should be as much as possible consistent with the preferences of its users.

This paper attempts to empirically evaluate the preferences of the parties involved in the *P&B* service via a stated preference experiment. Since the success or failure of this service is based on the interaction of at least two parties, shopkeepers and customers, group decision theory and group decision making models have been used to design the SP experiment and to analyze the data.

Attribute levels are not pre-fixed by the researcher but set by the shopkeeper, with orthogonal variations on the base alternatives. The same experiment is then administered to his potential customers, without or with previous knowledge on the shopkeeper's choice.

The descriptive and econometric results show that most shopkeepers (19 out of 21) are interested in the implementation of the *P&B* service and are willing to make a proposal on its characteristics and cost distribution. Customers are also interested in the introduction of the new service.

The two parties' preferences about cost allocation, although, are, not surprisingly, quite different. While the shopkeepers' willingness to contribute to the *P&B* costs ranges between 68 and 175 Eurocents, the customers' willingness to pay ranges between 28 and 139 Eurocents. 60 to 117 minutes is the time within which a parcel should be made available at the parking lot. Table 9 represents a summary of the econometric results obtained.

Table 9: Summary of econometric results.

	Shopkeepers.	*Cust.*	*Full PM*	*Re. PM*
Variable	β	β	τ	τ
Cost to be charged to the shopkeeper	-3.319 (-5.7)	3.925 (1.93)	0.808 (2.12)	0.476 (-0.11)
Cost to be charged to the customer	-0.64 (-1.68)	-3.427 (-1.91)	-1.06 (-4.11)	-0.838 (-2.4)
Minutes within which the parcel should be available at the parking lot	-0.012 (-3.6)	0.003 (0.45)	1.163 (2.43)	1.463 (2.48)
Use of information technology	0.361 (1.27)	-0.829 (-1.09)	0.979 (1.44)	
Extra-cost to be charged to the shopkeeper for other destinations	-0.871 (-2.23)	1.492 (1.47)	0.517 (0.07)	0.134 (-1.15)
Extra-cost to be charged to customers for other destinations	0.698 (2.15)	0.634 (0.87)	1.587 (2.93)	0.733 (0.3)

Note: t-stat in parentesis.

Independent discrete choice models, one for shopkeepers only and one for customers only, are estimated. The former indicates that shopkeepers regard their contribution to the service as the most decisive factor. They attribute importance to the quickness of the service as well as to the distribution of the surcharge for destinations other than the parking lot, which they deem should be borne by customers. To some surprise their customers' contribution to the cost of the service enters negatively their utility function, so that they deem it should be reduced as much as possible, most likely because they fear an indirect negative effect on their business.

Customers' choice model is mainly determined by cost allocation. Contrary to the shopkeepers, the cost attributed to them affects negatively their utility function while that allocated to shopkeepers affects their function positively. Furthermore, they believe that the extra-costs of other than parking lot destinations should be borne by shopkeepers.

In order to estimate the influence that their preference structure plays on the bargaining process, two types of initial-pass power models are estimated as proposed in the literature: a complete power model and an agreement-only power model. The former indicates that shopkeepers exert a greater control over their contribution to the financing of the service, the quickness of the delivery (to some surprise), the surcharge attributed to the customer and the use of information technology. Customers exert more influence on the share of their direct contribution only. The agreement-only power model offers a slightly different view. Shopkeepers loose control on their direct contribution, whereas customers retain theirs. It is confirmed that the timing of the delivery is influenced by shopkeepers, whereas customers push for a shopkeepers' contribution to the extra-costs of home delivery and shopkeepers push for customers' contribution.

An enhanced version of the power model allowing the identification of potential altruistic effects did not detect any intra-group interaction effects.

The data collected allowed us also to estimate the determinants of the probability of agreement. The results of our analysis show that the cost of the service, especially for the customers, and the quickness of the service negatively affects the probability of agreement. Information technology, on the contrary, does not seem to play a relevant role.

Finally, a simulation was performed to estimate which of the alternatives preferred by shopkeepers and by customers were more able to succeed. Our analysis showed that the alternative proposed by customers is more likely to be closer to the final compromise solution, or, stated in other terms, shopkeepers seem more likely to concede to customers' desires. However, the methodology is not able to forecast which will be the end result of the interaction process.

To conclude, the paper presents a methodology to evaluate the potentialities of a new city logistics service. Although various theoretical and methodological issues are still open to discussion, the methodology demonstrates to be useful in providing insights not only the parties' preference structure as normally achieved by discrete choice models, but also on the shopkeepers perception of customers' preferences, on the area of bargaining, on each party's influence on the choice attributes and on the determinants of the probability of achieving a comprise solution.

In future research we would like to extend the analysis to different cities both to enlarge the sample size and to verify if there are different perceptions in various parts of the country. A larger sample size should also allow us to estimate different functional forms of equation 3 as well as to estimate a restricted power model with initial pass elements only. More sophisticated discrete choice models will also be estimated.

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Private equity fund investment in the European ferry industry

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Abstract

Over recent years Private Equity Funds (PEF's) have found the European ferry market to represent an attractive investment opportunity. This paper explains the development and working of PEF's, reviewing the pros and cons for this type of investment model. Over the last decade there have been 22 separate transactions completed by PEF's involving the acquisition of 11 different ferry companies throughout Europe. Combined, this amounted to a total investment of €7.7 billion. A series of case studies undertaken by the author relating to the acquisition of individual ferry operators by PEF's offers preliminary understanding of these transactions. The case studies highlight specific characteristics of the ferry market that private equity investors find attractive. Not least among these characteristics is: barriers to entry, long established businesses, the essential infrastructure nature of ferry services, steady cash flows, and high market share. PEF's appear to regard ferry services as displaying characteristics quite similar to other essential transport infrastructure investments such as roads and railways. Based on this analysis, it seems that PEF's view the ferry market as a relatively safe and attractive investment opportunity. Sellers, and regulators of ferry markets (perhaps more especially in the case of subsidized or island 'lifeline' services), need to be conscious of the potential opportunities, as well as the possible disadvantages of PEF investment and ownership. Buyers (i.e. PEF's) also need to be aware of the risks involved (e.g. from over-paying, new regulations etc), as well as the rewards.

Keywords: Private equity fund; European ferry market; Investment.

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1. Introduction

The entry of private equity funds (PEF's) into European ferry markets is a relatively recent phenomenon. Hence this issue has not yet been researched to any significant degree, until now. This paper provides an initial analysis of the activities of PEF's in acquiring ferry companies in Europe.

Firstly, an overview of private equity funds is presented followed by discussion of the pros and cons of private equity fund investment. Then the ferry operators that have been acquired by private equity funds are considered. Through brief case studies with

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emphasis on the various transactions involving ferry lines that have been acquired by PEF's, it has been possible to establish a number of common characteristics. The conclusions outline the main findings, highlighting key issues and questions for further research.

Literature specifically concerning the subject of PEF's acquiring ferry companies is at best limited, which in turn makes this paper quite timely and necessary. The methodology here therefore includes reference to trade/industry press, and industry conference proceedings, as well as relevant academic literature, supported by discussions the author has had with several of the ferry company managers and PEF's involved. The research is thus preliminary in nature, which is understandable given the recency of the PEF phenomenon in terms of acquiring ferry operations. This implies that, over time, further research will be necessary to more fully analyse the longer term impacts and consequences of such investments.

2. Private Equity Funds

Private equity is medium to long-term finance provided in return for an equity stake in potentially high-growth unquoted companies (Price Waterhouse Coopers, 2004). Private equity provides what can be termed long-term, committed share capital in unquoted companies. Private equity funds (PEF's) are unlisted funds that raise capital from institutional investors. That capital is then used to 'shop' for assets that fit the fund's description and aims. PEF's, in other words, use institutional and other investors' capital in order to buy already established firms.

PEF's depend to a large extent on making high financial returns achieved through acquired company profits and thereafter finally when subsequently selling the acquired company on to another buyer at a monetary gain. For each fund it creates, a PEF is paid base fees in return for asset management plus a performance bonus. The general investment characteristics typical to a PEF may therefore be summarized as follows:

- Private equity is medium to long-term finance (i.e. hold equity in acquired business for 3-5 years, then exit)
- Finance is provided in return for an equity stake in unquoted companies
- Institutional investors provide private equity capital
- Potential annual returns range up to 30% for the more successful funds

According to the British Venture Capital Association, almost US$700bn of private equity was invested globally in 2007[1]. The regional breakdown of global private equity investments 2007 was as follows:

- North America 71%
- Europe 15%
- Asia-Pacific 10%

The private equity process is illustrated in Figure 1. The PEF is the 'General Partner' and is linked to the investors who are known as the 'Limited Partners'. Together they

[1] www.bvca.com

create and own the PEF. The PEF then makes specific investments in acquired companies which provide the fund's portfolio of investments.

PEF's typically retain their holding in companies for between 2-5 years then take an exit. The exit can be achieved in any one of a number of ways, for example:

- Repurchase (i.e. selling the shares back to the management)
- Refinancing (i.e. Selling the shares to another investor, even perhaps another private equity firm)
- Trade Sale (i.e. sale of the company's shares to another company)
- Flotation (i.e. the company achieving a stock market listing)
- Involuntary exit (i.e. where the company goes into receivership or liquidation).

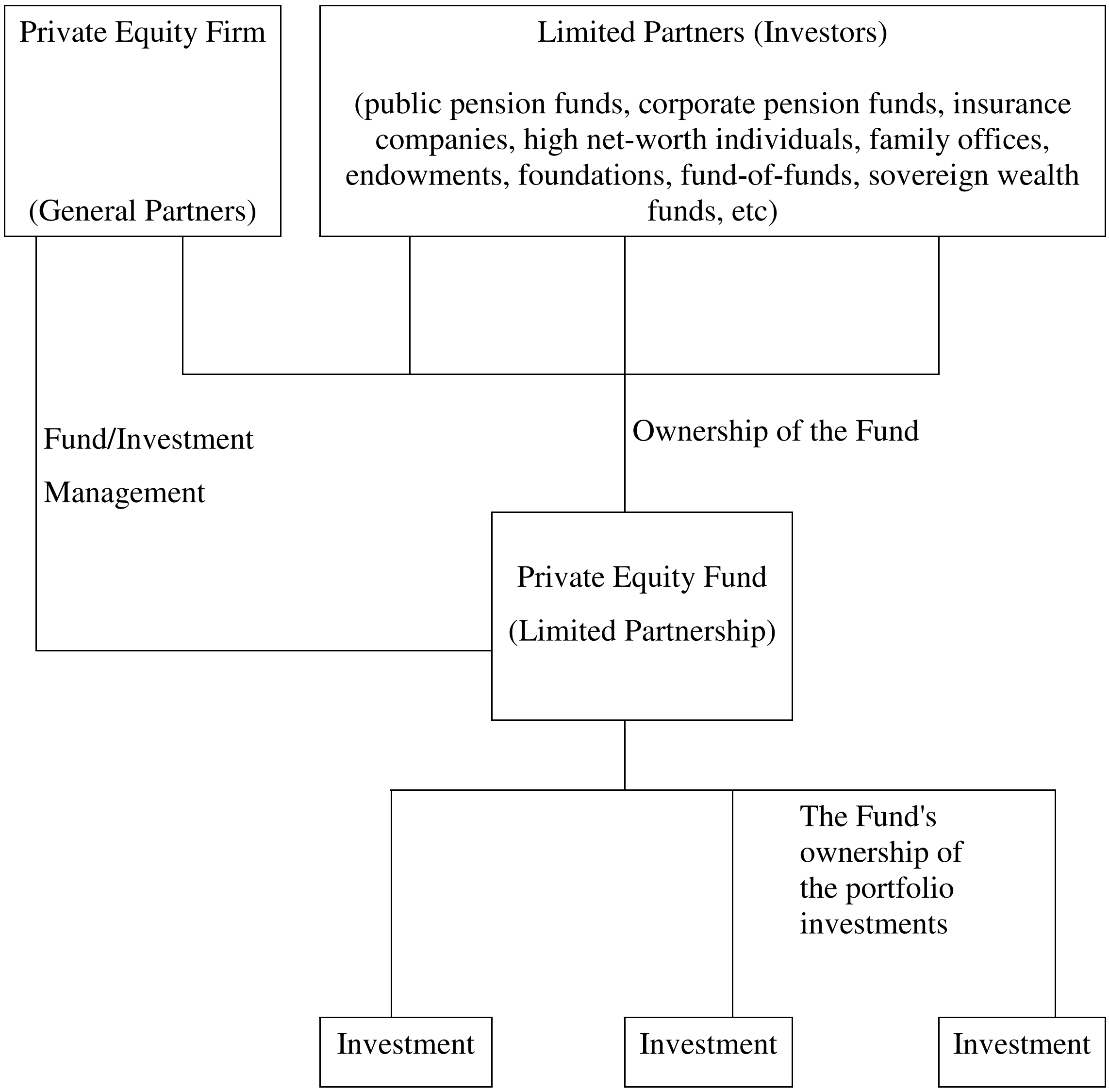

Figure 1: The private equity process (Source: BVCA)

According to Thomsen (2008), there are a number of specific features that make target companies attractive to PEF investors, including:

- A company's strong management
- Exciting development prospects
- Clear plan for value growth
- Meaningful market share
- Further acquisitions a possibility
- Barriers to entry for competitors
- Complex multi-jurisdictional situations

Thomsen stresses the benefit of management retaining independence (that is, existing managers continue to manage the acquired firm) but also emphasizes the need to provide incumbent management with incentives. The PEF focus is on medium to long-term 'value creation', with the prospect of earnings growth sought through the strategic attractiveness of a targeted business supported by the PEF's expertise in change management. Leverage is based on "cheap" financing, with exit planning forming a key part of the strategy. The power of quick and effective execution of decisions and access to a network of high-calibre executives (inside the PEF) are other advantages, according to Thomsen.

Table 1 illustrates some of the differences between private equity and other investor options. PEF's offer good access to capital compared with private ownership, but also allows for capital and competence to be brought together, unlike public equity providers who are less active in the acquired company's strategy. The investment horizon of PEF's is also much longer than the quarterly focus of public investors.

In terms of reporting requirements, the PEF needs frequent information, perhaps comprising monthly management accounts and trends analyses; however this is for internal purposes and is not made public. Conversely, public equity providers and indeed stock exchange regulations generally require frequent disclosure of extensive relevant financial and corporate information which is then in the public domain, thus offering a potential advantage to competitors as well as giving management a more onerous task which diverts their attention from other important matters.

Table 1: Private equity advantages over other investment options.

	Private	*Private Equity*	*Public Equity*
Access to capital	Limited	Good	Good
Contribution	Competence	Capital and Competence	Capital
Investment horizon	Varying	4-7 years	Quarterly focus
Reporting requirements	Annual	Frequent internal/private	Frequent external/public

Source: Adapted from Thomsen (2008)

3. Pros and cons of private equity funds

Private equity is not secured on any assets, although part of the non-equity funding package provided by the private equity firm may seek some security over assets. The private equity firm therefore faces the risk of failure just like other shareholders. The private equity firm is an equity business partner and is rewarded by the acquired company's success, generally achieving its principle return through realising a capital gain via an exit, in addition to receipt of annual profits/dividends extracted during its tenure of ownership.

Conversely, a provider of debt (generally a bank) is rewarded by interest and capital repayment on the loan provided, which is usually secured either on business assets or on directors own personal assets, such as their homes. As a last resort, if the company defaults on its repayments, the lender can put the business into receivership, which may lead to the liquidation of assets.

PEF's tend to adopt a more "hands-on" or pro-active approach with the aim being to add value to the acquired company. In addition to advising on strategy and development, the PEF may have useful business connections to share with its management. The PEF aims to be more like a business partner, someone to approach for helpful ideas and discussion. A hands-on investor is particularly suited to a company embarking on a period of rapid expansion. However, day-to-day operational control is rarely sought by PEF's. In order to provide this support, some PEF's will expect to participate through a seat (or seats) on the board of the acquired company. The director may be an executive from the private equity firm or an external consultant and fees will need to be paid in return for the director's services. In an organizational and administrative sense the private equity firm will expect to:

- Receive copies of management accounts, promptly after each month end
- Receive copies of the minutes of the board of directors' meetings
- Be consulted and involved in, and sometimes have the right to veto, any important decisions affecting the company's business. (This will include major capital purchases, changes in strategic direction business acquisitions and disposals, appointment of directors and auditors, obtaining additional borrowings, etc.)

Some PEF investors may nevertheless have a less active role in the business, more a "hands-off" or passive approach, essentially leaving management to run the business without involvement from the private equity firm, until it is time to exit. They will still expect to receive regular financial information. However, if the company defaults on payments, does not meet agreed targets or runs into other types of difficulties, a hands-off investor is likely to become more closely involved with the management of the company to ensure its prospects are turned around.

According to Stevenson (2008), more private equity is expected to be attracted to shipping in future. Private equity is now targeting an internal rate of return (IRR) of 25-30% which implies the value of invested capital is tripled over a 5-year investment period. Certain shipping sectors are considered capable of providing returns of this level, notwithstanding rather more notorious volatility in areas such as bulk and liner container. As bank debt becomes scarce, so private equity is searching for new opportunities with an estimated US$450 billion of private equity believed to be available for investment in 2008, though this was not all used up. The financial crisis might therefore be expected to result in more private equity interest in shipping, not less, as more low cost investment opportunities arise due to asset write-down's and other business changes.

Key attractions/requirements for private equity investment in target companies include:

- Lower prices (acquired company bargains, more likely in an economic downturn)
- Sustainable cash flows
- A reasonable growth trajectory
- IRR target of 25-30% or more

PEF's, however, are not without their critics. One criticism of PEF's relates to the high salaries paid to some executives. Macquarie, the Australian PEF, is nicknamed "the millionaires factory" because of the very high bonuses it pays staff. In 2005 Macquarie Bank revealed it paid its chief executive Aus$18.5 million in the previous financial year and that another five top executives were paid more than Aus$10 million each (Sydney Morning Herald, July 28th 2005).

This and related matters were considered by the Isle of Man Parliament's (Tynwald) Select Committee[2] during its 2008 investigation of pricing and service-related matters pertaining to the Macquarie-owned Isle of Man Steam Packet Company (Tynwald Court, 2008). Steam Packet, the only ferry company serving Isle of Man, was acquired by Macquarie in 2005, with senior management of the acquired company remaining in place after the takeover. Equity fund managers are just that; they are not ferry company managers and therefore depend on the existing managers to continue to manage the actual business itself. This raises another question, and that is, what added value do equity fund managers bring aside from buying and selling firms and extracting profit? In the case of Isle of Man Steam Packet Company, the select committee found evidence of high prices especially in the freight market, high profits/dividends (relative to other ferry lines in Europe), as well as some apparent limitations with respect to a willingness of the PEF owner to make capital investment in new tonnage and terminal facilities.

Whilst a major advantage of PEF's is that they do not need to disclose inner workings, like public companies, on the other hand this leaves their activities rather difficult to discern (Kuttner, 2007). There is criticism of the standard modus operandi of the funds which is viewed as being to buy in, beef up the chosen investment, and sell out fast at a substantial profit. Thus, PEF's are sometimes accused of selling off firms in pieces, sacking staff, collecting profit, and creating zero wealth, leading to windfall returns for 'financial engineers'. Another accusation is that whereas PEF's do make big investments (in buying up firms) they tend to have little experience in shipping (Brogren, 2007). In this regard shipping is considered to be a very long-term business (e.g. the economic lifetime of a ship can exceed 25 years), whereas at 3-5 years time horizon PEF's are rather short-term by comparison[3]. Perhaps most emphatically, PEF's have been described as "Deal Junkies", constantly looking for a deal, perhaps any deal, at times resulting in what appears to be rather inflated prices being paid for acquisitions purchased in an auction type sales frenzy (Docherty, 2008).

Sanchez & Wilmsmeier (2008) studied ports and terminals bought by PEF's. They found that ports in general made sound returns and represented an attractive proposition for PEF's. Ports are regarded by PEF's as positive and secure infrastructure investment opportunities. To PEF's, ferry operations are also regarded, like ports almost, as

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[2] The author was appointed Advisor to the Isle of Man (Tynwald) Select Committee investigation into Isle of Man ferry services in 2007-8, and subsequently reappointed as advisor in 2009 for a second investigation.

[3] Owners may nevertheless sell vessels in the market and therefore disinvest; whilst not eliminating risk, the latter option will be risk reducing to a greater or lesser extent, depending on the state of the market at a given point in time.

‘essential infrastructure’, in turn implying to some degree a safe investment option compared with certain other sectors.

Once a company has been acquired, the private equity owner may be less interested in making additional investments in expensive assets (e.g. ships, or port facilities). Its primary focus will be on recovering the already significant investment made in acquiring the company. Evidence in relation to Isle of Man Steam Packet Company’s somewhat problematic ship investment/replacement strategy seemed to reflect this, the latter purchasing a 10-year old high-speed craft in 2008 instead of opting for a new or nearly new ship.

If a PEF pays what seems to be an inflated price for a business (e.g. a very high EBITDA multiple), this might in practice be least positive for service users. Equity fund managers will insist on maintaining high profits as that will be essential in order to repay to investors the high initial cost of the acquisition. High profit levels can only really be maintained through high prices to service users, a task easier to achieve in less competitive (i.e. monopolistic) instances.

Private equity fund ownership of ferry lines therefore needs to be considered with a degree of caution, especially with respect to future investment needs in vessels and harbours. The imperative to maintain high and sustained profit levels, essential to repay investing institutions for the high (perhaps inflated) upfront acquisition costs, in addition to hefty management and bonus fees for the PEF’s management, implies considerable pressure will be placed on ensuring a minimum of further capital investment is made (e.g. in ships, terminals etc).

This implies that the PEF may not be able (or willing) to consider long-term aspects commonly associated with investment in ships (e.g. such as ship depreciation over the operating lifetime of the asset). There may instead be a focus on acquisition of second-hand ships or charter, even where newbuilds make more long term sense.

Furthermore, with private equity ownership there is always going to be the possibility of a further sudden disposal of an acquired company. For example, should an operator’s profits fall below a certain level, or if the ‘market’ value were to rise (e.g. through further strengthening of barriers to entry, long-term service agreements etc), that could be the trigger for a PEF to sell on again. Such a scenario may imply companies being regularly bought and sold, perhaps being traded between PEF’s. A key question in this regard relates to whether or not PEF priorities are compatible with, and/or appropriate to, essential island ferry service operations.

4. Ferry operators acquired by private equity funds

Table 2 shows that eleven ferry operators in Europe have either been acquired by or ‘bought into’ by PEF’s (Baird, 2008). Several lines have been bought and sold more than once during the past decade. In all there have been 22 transactions involving an aggregate total investment by PEF’s of almost €7.7 billion. Geographically, four of the operators serve UK routes, six serve Mediterranean Sea trades, and one is active in the Baltic Sea.

The earliest noted activity of PEF’s in the European ferry market dates back to 1995 when both Condor and Wightlink, respectively serving the Channel Islands and Isle of Wight, sold some of their shares. Wightlink has been sold three times to various PEF’s, while Condor has been sold on between four different PEF's. This reflects the fact PEF's tend to look for an exit after 2-5 years, perhaps even less. Red Funnel Ferries has been sold on to three PEF's while Isle of Man Steam Packet Company was sold twice during 2003-2005.

The proportion of equity held by PEF's varies between ferry operators. In the early period up to 2000, PEF's tended to take only a minority stake in ferry companies. However this practice has since changed and PEF's are now generally taking a majority or even 100% ownership, with some exceptions.

Table 2: Private Equity Fund acquisitions/investment in the European ferry industry, 1995-2008.

Operator	*PEF Buyer*	*Year*	*Price Paid (€million)*	*Equity share (estimated)*
Wightlink	Cinven	1995	160	Min Holding
Wightlink	Royal Bank of Scotland	2001	270	35%
Wightlink	Maquarie Bank	2004	350	Maj Holding
Condor Ferries	3i	1995	50	33%
Condor Ferries	ABN-AMRO	2002	225	Maj Holding
Condor Ferries	Royal Bank of Scotland	2004	360	Maj Holding
Condor Ferries	Maquarie Bank	2008	390	Maj Holding
Red Funnel Ferries	JP Morgan	2001	105	Min Holding
Red Funnel Ferries	HBOS	2004	145	49%
Red Funnel Ferries	Prudential	2007	300	Maj Holding
Moby Lines	Efibanca/MPS	2000	5	4.3%
Moby Lines	Equinox	2004	20	14%
Moby Lines	Clessidra	2005	50	30%
Isle of Man Steam Packet	Montagu Private Equity	2003	210	100%
Isle of Man Steam Packet	Maquarie Bank	2005	315	100%
Grandi Navi Veloce	Permira	2004	522	80%
Grandi Navi Veloce	Investitori Associati	2006	700	87%
Scandlines	3i / Allianz	2007	1,560	
Superfast Ferries	Marfin Investment	2007	500	90%
Blue Star Ferries	Marfin Investment	2007	500	85%
UN RoRo	Kohlberg Kravis Roberts	2007	910	100%
SNCM	Butler Capital Ptnrs	2006	35	38%
		Total	7,682	

Source: Cruise & Ferry Info: ShipPax, Halmstad, Sweden.

Figure 2 illustrates recent private equity activity in the European ferry market, showing in matrix form the logo of each ferry line, and the logo of the respective private equity buyer, together with the relevant year of sale/acquisition.

In the next section of the paper each of these acquisitions is analysed individually in more detail. The aim is to identify and explore some of the key factors pertaining to each acquisition, and to highlight any aspects common to the decision-making process of PEF's and their investments in the ferry sector. The analysis builds on, updates and augments earlier research undertaken by the author (Baird, 2008a).

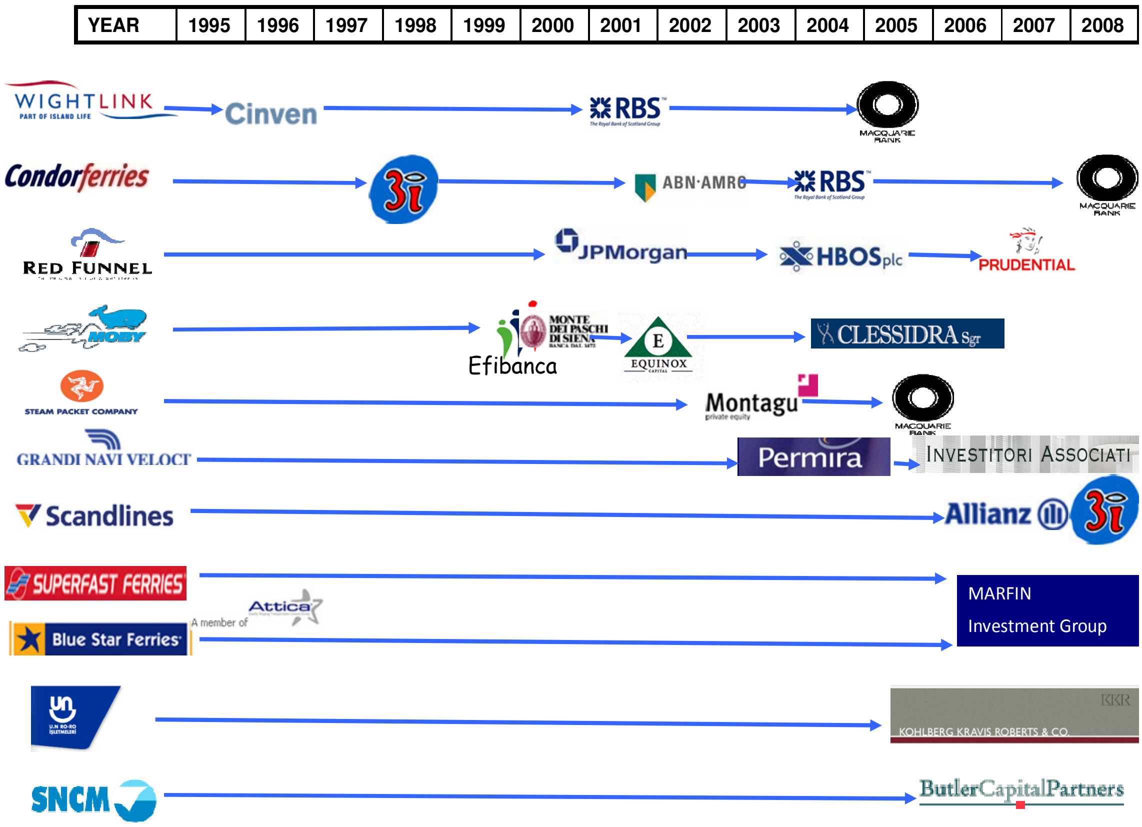

Figure 2: Ferry operators acquired by private equity funds, by year of transaction.

5. Case studies

5.1. Wightlink

Wightlink is a long-established firm (160 yrs old). The company has a significant market share of about 40% of the UK-Isle of Wight ferry market. Wightlink has control over key terminals on the British mainland at Portsmouth and Lymington, and on the Isle of Wight it owns the port of Fishbourne. The company's revenue in 2007 was estimated at €77m with EBIT of €16m. The fleet consists of 11 ships with an estimated re-sale value of about €100m. Annual traffic carried in 2007 amounted to 5.7m passengers, 1.2m cars, and 150,000 coaches/lorries.

Wightlink was formerly part of the ex-British Rail ferry company Sealink which was sold to Sea Containers during the mid-1980's (Cruise & Ferry Info, May 2003). The company was then sold by Sea Containers to venture capital company Cinven Ltd in 1995 for €160m. In 2001, Wightlink was purchased by the private equity division of Royal Bank of Scotland (RBS) in a management buy-out, with the management retaining 65% of the business and leaving RBS with 35% in return for a total investment of €270m. In 2003 Goldman Sachs was appointed to advise on the further disposal of Wightlink. Several international PEF's were among the bidders looking to acquire the company. In 2004 Wightlink was acquired by Macquarie Bank of Australia for €350m. The company's strong market share, long established routes, and consistent revenue and profit stream made it an attractive proposition in the eyes of PEF's.

In 2006 there was a call for an Isle of Wight fares investigation by the local Member of Parliament (Cruise & Ferry Info, October 2006). It was claimed that the main operators (Wightlink and Red Funnel) had increased fares in excess of inflation. It was also claimed that a new pricing structure including price increases was introduced following the acquisition by Macquarie. The need to raise prices seems to be related to the increasing purchase price paid for the business by subsequent owners (with EBITDA remaining relatively constant) and the need to make a return on investment. Wightlink has since embarked on a fleet replacement programme (several of its ships were rather elderly and needing replaced), with new ferries ordered from low-cost yards in Croatia and the Philippines for delivery between 2008-2010. This added capital investment may be expected to motivate the PEF owner to seek increased returns.

5.2. Condor Ferries

Condor Ferries took over operations of the then British Channel Island Ferries service between the UK and the Channel Islands of Jersey and Guernsey in 1994. The company secured a 6-year 'franchise' awarded by the Channel Islands government to operate ferry services (albeit no subsidy is paid). This franchise provides Condor with a dominant market position for the transport of passengers, cars and freight by sea.

In 2007 the company achieved estimated revenues of €102m with an EBIT of approximately €25m. Condor's fleet comprises 5 ships with a total estimated re-sale value of approximately €70m. Annual traffic flows in 2007 were 940,000 passengers, 198,000 cars, and about 80,000 trailers.

UK venture capital group 3i retained a one third stake in Condor for several years until 2002 when the company, then part of the Commodore Group, was sold to a management buy-out backed by ABN-AMRO Capital for €225m. In 2004 a controlling interest in Condor was bought by RBS for €360m, the purchase closely following the award of a new 6-year operating concession to 2009.

Amid speculation in early 2008 that RBS wished to sell the company, the governments of Guernsey and Jersey published a joint sea transport policy stating that neither island would look for new operators until the end of 2013 unless the market or current operator fails (Cruise & Ferry Info, March2008). This effective monopoly position served to enhance the sale potential somewhat. Following the extended operating agreement, in mid 2008 Macquarie Bank acquired Condor for €390m.

While the resale price of Condor has continued to rise, traffic volumes and EBITDA appear to have remained relatively constant and the assets more or less unchanged. The increase in (perceived) value appears to be more related to the contract with government to serve the islands which effectively ensures that a barrier to entry for competitors exists.

5.3. Red Funnel Ferries

Red Funnel Ferries is another very long-established firm (150 yrs old) with a significant market share of about one third of the UK-Isle of Wight market. The company has control of key ports and routes between Southampton city and the island.

In 2007 Red Funnel had estimated revenues of €65m and EBIT of €16m. It has a fleet of 6 ships which have a re-sale value estimated at about €65m. Annual traffic flows amount to 3.0m passengers, 555,000 cars, and 103,000 coaches/trailers

Like Condor Ferries and Wightlink, Red Funnel has also had a succession of PEF owners over recent years. Formerly owned by ex state-owned Associated British Ports (at one time a listed company and now itself owned by a PEF), Red Funnel was sold to a management buy-out backed by JP Morgan International Capital in 2001, the latter paying €105m. As with other sales the new owner left the existing Red Funnel management in place. In 2004 Bank of Scotland Corporate Banking (HBOS) purchased Red Funnel in a €145m deal giving it a 49% holding. In 2007 the infrastructure fund of insurer Prudential Group paid an estimated €300m for Red Funnel. Prudential said it was attracted by the high quality of the business, growth potential and strong management (Cruise & Ferry Info, July 2007).

The management of Red Funnel, much like some other ferry operators acquired by PEF's, has therefore worked their way through several different owners in the space of only a few years. An issue raised by one former senior manager concerns the 'EBITDA multiple' paid for the operator (Docherty, 2008). In Red Funnel's case, the first PEF owner paid 5 x EBITDA, the second paid more than 10 x EBITDA, and the third paid closer to 20 x EBITDA.

In the ferry company management's mind, this raised the question of how a PEF came to value an acquisition, and also why subsequent valuations increased so much whilst at the same time EBITDA, and traffic volumes and revenues, remained more or less constant. In other words, how can a company continually be worth more when at the same time its traffic flows and net profit remain constant?

5.4. Moby Line

Moby line is an established ferry company that has been operating between Italy and Sardinia/Corsica for almost 20 years. The company has a significant market share across the routes it serves. In 2007 operating revenue was estimated at €180m with EBIT of €15m. Moby operates 14 ships, a mix of old and new, with an estimated re-sale value of about €300m. Annual traffic flows amount to some 4.0m passengers plus an unknown number of cars and freight trailers.

The participation of PEF's in Moby Lines has taken a rather different format compared with other operators. This has mostly involved the sale of minority shares in the company with PEF's providing capital for Moby's business expansion. In 2000, Monte Paschi Ventures Banca and Efibanca took a 4.3% holding in Moby. These investors supported the implementation of the first stage of Moby's strategy to become the leading operator on the Sardinia-continent trade by transforming the business model into a low cost operation. In 2004, the PEF Equinox took a 14% share in Moby. This was followed in 2005 by the sale of 30% of Moby for €50m to PEF Clessidra (ShipPax Correspondents, December 2006). These minority capital injections paved the way for investments in additional vessels (new and second hand) and also in the subsequent acquisition by Moby of a competing carrier, Lloyd Sardegna, in 2007. In this sense the investments by PEF's have been used by Moby primarily to augment its operations and to strengthen its market position.

It is envisaged that Moby will eventually look for a public listing which will allow some of the PEF investors to take an exit. From the perspective of PEF investors in

Moby, the value of a shipping line is considered to be not only in the steel (i.e. ships). The value includes assessment of a mix of factors such as existing charter-in and charter-out contracts, the order book and purchase options, the management, the freight contracts, and risk management (Scorza, 2007). Looking at net asset value (NAV) is an important aspect, but according to Clessidra this needs to be accompanied by a wider analysis of the company and its operations and markets in a holistic sense. However the role of the PEF investor still remains largely passive, allowing the management to continue to manage the operation.

5.5. Isle of Man Steam Packet Company

The Isle of Man Steam Packet Company (SPC) is reputed to the oldest continuously operating shipping company in the world, its service dating back almost 200 years. The company enjoys a dominant market position being the only provider of ferry services between the UK mainland and the island, which lies in the middle of the Irish Sea. The Isle of Man government rents the port facilities at Douglas only to SPC for its use under what is known as the 'Linkspan User Agreement'. In an extension to the Agreement in 2007, this was further extended to 2020 with an option to take it to 2026.

No subsidy is paid to SPC, and no tender is/was used to select the operator, unlike many other island trades, and even for non-subsidized services such as the Channel Islands. The company's revenues in 2007 were estimated to be €61m with EBIT of €22m. On a return on sales basis this made the SPC one of the most profitable ferry operators in Europe. The company's 3 ships in 2007 had an estimated re-sale value of about €35m. A larger high-speed craft (second-hand conversion) was acquired in 2008 at a cost of approximately €25-27m including modifications. Annual traffic flows in 2007 amounted to 556,000 passengers, 166,000 cars and 38,500 trailers.

SPC was acquired by Sea Containers during the mid-1990's for an unknown figure, although as the company was in some distress at the time it is thought to be below €20m. In 2003 SPC was sold to Montagu Bank for €210m. Montagu thereafter quickly sold the company on to Macquarie Bank for €315m in 2005. Both PEF owners allowed the same management to continue.

In its 2008 investigation of SPC, the Isle of Man Parliament (Tynwald) Select Committee raised a number of issues to do with SPC's finances and operations (Tynwald Court, 2008):

- The lengthy and unusual User Agreement was contrasted with the more common tender process used by other islands to secure ferry services;
- Pricing was considered excessive, particularly for freight;
- The very high acquisition prices paid by PEF's for SPC, relative to assets, meant earnings would need to be maintained at high levels, which in turn implied a need for high transport prices;
- The Department of Transport needed to consider its role as regulator, more especially as it seemed to be acting rather like a partner to SPC;
- It was not certain that the private equity model (in this instance) was entirely compatible with long-term essential island ferry service provision.

There was in addition some evidence that the PEF owner was constraining the company's ability to invest in new or replacement ships, or to make investments in port facilities. This suggested a drive on the part of the PEF to minimize costs and maximize EBIT. Given the shipbuilding cycle, variations in vessel prices over time, and the long-term nature of ship investment, this raised the question of whether or not the shorter timescale of PEF ownership (e.g. 2-5 years) was compatible with that of the shipping industry in general.

The somewhat inflated sale price of SPC, reflecting in large part the economic worth of the long-term User Agreement with the Government, was considered to be least positive for service users. In the case of SPC this was more especially related to freight customers. Equity fund managers may insist on maintaining high profit as that will be essential in order to cover the high initial cost of the (leveraged) acquisition. In the case of SPC, high profit levels can best be maintained through high freight rates, this being possible in large part due to the absence of competition in the freight market, the UA giving SPC an effective monopoly.

However, this also implies that the Isle of Man freight transport logistics sector is to a large extent paying the price for the high/inflated SPC purchase price paid by Macquarie, and before that by Montagu. Of course, this also means that the real cost of the UA is being met by the Isle of Man economy, its producers and consumers.

On the issue of fleet renewal, the aborted SPC attempt in 2007/8 to acquire *Spirit of Ontario*, a nearly new high-speed ferry that was available for purchase at around half the newbuild cost, appeared to be due to the fact SPC would only offer to charter the vessel rather than buy it. This approach was possibly due to pressure at the time from its owner for SPC not to purchase the ship. Similarly, it is believed that fast craft builders offered SPC new and attractive vessel options but SPC has been prevented from purchasing a more expensive newbuild because its owner, the PEF, has a focus on maximising short and medium term returns.

Instead of acquiring a new or nearly new fast craft, SPC subsequently received permission from its owners to acquire a second-hand (10-year old) vessel previously used by the US Navy and to upgrade it to an acceptable standard at a total cost of about £20 million (i.e. about half the price of a new vessel). It is possible that a similar degree of pressure is placed on SPC by the bank not to invest in shoreside/terminal facilities, given the findings of the Select Committee on the quality of passenger terminal provision.

In early 2009 the Select Committee was re-convened for the purpose of investigating further the financial accounts of SPC, implying some disquiet amongst local politicians at the PEF model adopted in this instance.

5.6. Grandi Navi Veloce (GNV)

GNV, which stands for 'Grand Navi Veloce' (translates as 'big fast ships') was established by the Genoa-based Grimaldi Line in 1991, although the Grimaldi family has been involved in shipping for generations. The company has a significant market share on its key routes based in Genoa and connecting Sicily, Corsica, Sardinia, Malta, Spain and North Africa. The fleet in 2008 consisted of 10 ships, most of which were wholly-owned. Annual traffic flows amount to 1.3m passengers, 433,000 cars and 2.47m lane metres (i.e. approx 200,000 x 12.6metre freight units). In 2007 GNV's estimated revenues were €267m achieving an EBITDA of €60m.

The company's policy since start-up has been to introduce one brand new vessel almost every year (actually 8 new ships were introduced over an 11 year period). By

2003 GNV was encountering some difficulties with its debt repayments, estimated to be in excess of €350m (Scorza, 2007a). Moreover, while sales were constantly growing, there was little improvement in EBITDA. This led to the sale of 80% of the company to PEF Permira in 2004 for €522m, an earlier plan to float the company on the Milan Stock Exchange having failed. The Grimaldi family became minority shareholders but still led the management of the company.

In 2006 Permira took an early exit through the further sale of GNV to Investitori Associati (as lead PEF together with 2-3 other smaller PEF investors participating), the latter paying €700m for an 87% holding. Some seven investment funds had been in competition to acquire GNV. One of the other attractions of GNV was the fact it had acquired 4 new well-designed RoPax ferries (with options for a further 4, subsequently exercised) at very competitive prices from Italian shipbuilder Apuania (a total cost estimated at €450m for all 8 ships) just prior to a dramatic rise in newbuild material costs. Indeed, by late 2008 Grimaldi Holdings as it had then become, had sold three of the 8 newbuildings and long-term chartered a fourth, resulting in significant gains for the new owner Investitori (Cruise & Ferry Info, December 2008).

5.7. Scandlines

Until 2007 Scandlines was owned jointly by the Danish Ministry of Transport and Deutsche Bahn (DB), the German state-owned rail company. In operation for over 105 years, Scandlines maintain a wide range of services on the Baltic Sea, mainly between Germany, Denmark and Sweden.

The company has a significant market share on all its routes. In 2007, revenue was €547m and EBIT a healthy €76m. Scandlines has 17 ageing ships, most of which are owned, and with a sale value estimated at about €300m (2007). It also owns 5 of its strategic ports. Annual traffic flows during 2007 was 18.5m passengers, 4.0m cars and 1.0m trucks.

In 2006 the state owners decided to sell Scandlines via an auction. At the beginning of the auction industry press considered an approximate price of €400m would be sufficient to acquire Scandlines. Scandlines themselves disclosed that interest from buyers was ‘phenomenal’ (Cruise & Ferry Info, January 2006). But as several private equity bidders became involved, the initial price estimate was soon bid upwards to some €800m. Eventually in 2007 it was announced that a joint venture bid of two PEF’s, Allianz and 3i, had acquired Scandlines for a figure of €1.5 billion, which is about four times higher than the initial estimate. A third shareholder, the shipping company DSR of Rostock, was included in order to operate the business on behalf of the two main PEF shareholders.

According to Thomsen (2008), the key factors that made 3i and Allianz purchase Scandlines were:

- Stable infrastructure-like assets
- Good underlying growth drivers in freight and passenger traffic
- Good mix of passengers, freight and retail sales (border liquor stores etc)
- Opportunities to expand ferry services and related services
- Steady cash flows
- Opportunities for regional market consolidation
- Network of short crossing routes offering high potential for related sales

The acquisition has not done too well because the current financial crisis has resulted in reduced demand, for travel and goods transport, and this affects ferry operators just like others in the shipping and transport sectors. After years of double-digit growth, Scandlines experienced an overall decline in its transport volume in 2008 and a significant decline in profitability (Krieger, 2009). On its nine Baltic Sea services, the number of passengers declined by 3% to 17.3m. Car, truck and rail traffic also fell.

Scandlines attributed the decline to the financial crisis and the high price of oil. Tourist traffic slowed down markedly on the company's routes. As a result of falling demand, Scandlines terminated its service between the Danish ports of Arhus and Aabenraa and the Lithuanian port of Klaipeda. It also reduced its services between Rostock and the Danish port of Gedser as well as between Rostock and the Latvian port of Ventspils. The company said that declining demand for industrial and consumer goods in 2009 would continue to slow down freight traffic with the Baltic States and would also affect the Scandinavian services.

5.8. Superfast Ferries/Blue Star Ferries

Superfast Ferries was established by the Greek Panagopulous shipowning family during the mid 1990's when it started fast RoPax Trans-Adriatic services between Patras in Greece and Ancona in Italy. From that beginning the company expanded its concept further in the Adriatic, then the Baltic Sea and the North Sea. This means the company has a relatively recent history compared with most other acquisitions of ferry lines by PEF's. The Superfast parent company, Attica, which was listed on the Athens Stock Exchange, subsequently established another line, Blue Star Ferries to serve the domestic island trades in Greece.

Both Attica subsidiaries enjoyed a significant market share on their main respective routes. However these routes are highly competitive and are fully commercial operations (i.e. without subsidy or government contracts). The fast speed of the vessel also resulted in continuous pressure on costs, principally fuel expense. For the few years prior to its disposal, Attica strategy centered on disposal of some vessels at a time when the market for such tonnage was still quite high, and with few shipbuilding slots, also prior to the point when the fuel price started to increase significantly. The resultant high prices obtained for some of ships resulted in significant gains leading to reasonable profits and dividends being maintained during tough trading conditions.

In 2007 the PEF Marfin Investment Group (MIG) paid approximately €500m for a 90% holding in Superfast Ferries. During the same period MIG had acquired a majority ownership of sister company Blue Star Ferries (85%); although the price of the latter acquisition is not known it is considered to be approximately €300m, which means MIG paid about €800m for all the Attica ferry interests. Subsequently both lines were merged into Attica.

Prior to its disposal in 2007, Attica had revenues of €316m and an EBITDA of €70m. Its fleet comprised 13 ships with a total re-sale value estimated at around €500-600m. Annual traffic carried (2006) was 4.0m passengers, 580,000 cars and 298,000 trailers.

5.9. UN RoRo

UN RoRo based in Istanbul was established in 1993 by Turkish trucking interests. The basic idea was to develop a new 'Motorway of the Sea' link between Istanbul and

Trieste thereby avoiding the highly problematic road transport journey through the various countries of the former Yugoslavia (Torbianelli, 2000). Over the past 15 years or so UN RoRo has managed to secure a significant market share (37%) of the traffic previously moving by road (Cruise & Ferry Info, November 2007).

The company had purchased a fleet of nine modern RoRo ships by 2007 with further vessels on order. The fleet is entirely based around the highly successful standard Flensburger RoRo design of 195m long 3,000+ lane-metre 21-knots vessels. UN RoRo has established its own terminals in Turkey at Pendik and another at Ambarli, conveniently located away from urban areas and avoiding more expensive traditional docker working practices, the latter an essential aspect in development of the Japanese coastal ‘Motorways of the Sea’ since the 1970’s (Baird, 2000).

UN RoRo’s revenue in 2007 was estimated to be about €130m with EBIT of €10-15m. The company’s 9 ships had an approximate re-sale value estimated at €250-300m. Annual traffic flows are around 100,000 trailers based on a daily service on what is a 52-hour voyage (Buchanan, 2007).

The largest shareholder, trucking owner Ulusoy, was opposed to the takeover by US-based PEF KKR in 2008. Ulusoy subsequently started a competing Ro-Ro service under the name Ulusoy Sea Lines, with orders placed at Flensburger for similar vessels to those used by UN Ro-Ro.

One of the first actions of KKR was to raise freight rates by €130 per trailer within a few months of acquiring the line. UN Ro-Ro claimed this was necessary because of the rising bunker prices. But some truckers were said to have realized that although they were happy to get a good price from KKR for their shares, the inevitable consequence of a PEF taking control is a focus on profitability and this will generally mean raising prices (Cruise & Ferry Info, January 2008).

Debt financing for the acquisition was arranged by Turkish banks Garanti Bankasi and Turkiye Is Bankasi. Reflecting the experience with several other PEF deals, a large number of professional advisors were involved in the transaction, aside from KKR and UN Ro-Ro, including[4]:

- Norton Rose LLP together with Özel & Özel acted as the legal advisors for U.N RoRo Isletmeleri A.S.;
- Morgan Stanley acted as the financial advisor;
- White & Case LLP and Simpson Thacher & Bartlett acted as the legal advisors for KKR;
- Finsbury Group, Kekst and Company and Bersay Communication acted as PR advisors to KKR;
- Deloitte acted as financial advisors for KKR;
- The currency conversion was made through www.oanda.com.

5.10. SNCM

SNCM is a very long established company (158 yrs) serving the government-subsidized routes between south-east France and Corsica. The company has a significant market share, albeit in some decline over recent years.

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[4] http://investing.businessweek.com/research/stocks/private/snapshot.asp?privcapId=36571630

In 2007 the company's revenues amounted to €190m, with EBIT € negative. SNCM has a fleet of 10 ships with a re-sale value estimated at approximately €250m. Annual traffic flows in 2007 were 1,079,308 passengers, 358,000 cars, and approximately 100,000 trucks/trailers.

For a long period there had been conflict between the French state and the trade unions representing crews and other SNCM workers. This coincided with rising financial losses. The European Commission investigated increasing subsidy levels and the impacts on private competition, mainly on rival Corsica Ferries. Substantial changes were recommended and subsequently the French state took the decision to dispose of SNCM.

A consortium comprising the PEF Butler Capital with public transport specialist Veolia successfully bid for SNCM in 2007. However the bid was conditional as it involved a pull-out clause in the event that SNCM was not awarded the new 8-year concession contract for Corsica routes. SNCM eventually won the tender and with it a state subsidy amounting to €97m/year.

Butler Capital at the outset acquired a 38% holding in SNCM for €38 million, with Veolia taking a slightly lesser stake. In order to address public interests, the French state retained a 20% holding in the company. To appease the employees, a share of around 8% was allocated to the trade unions. Butler Capital subsequently took an exit in 2008 through selling its shares to partner Veolia for an undisclosed sum, with the other minority shareholders remaining as before.

The strategy of Veolia is to use its extensive transport management expertise to rapidly turn the company around (through efficiency savings) so that it will generate a profit. The role of Butler Capital in this instance was to help finance the initial purchase (privatization) of SNCM but then to take an exit at the earliest possible opportunity, which has been achieved.

6. Conclusions

The entry of PEF's into the European ferry market is a relatively recent phenomenon. It is still early days but already some results and trends can be detected.

To begin with, it is evident that PEF'S tend to focus on companies in the ferry sector that have the following characteristics:

- Established ferry services/essential 'infrastructure' (e.g. serving islands and/or 'Motorways of the Sea' type services)
- Protected or semi-protected markets/barriers to entry (e.g. via control of strategic ports, and/or through government contracts to maintain 'lifeline' type services)
- Significant or dominant market share

A number of common features have been identified relating to the majority of transactions. These have been separated into five different aspects and are summarized as follows:

1. PEF's tend to pay high prices to acquire ferry lines

With few exceptions, purchase prices paid by PEF's to acquire ferry companies tend to be a high multiple of EBITDA, and several times greater than net asset value (i.e. net worth of the ships). The auction of a ferry operator appears to help further raise the end price achieved due to intense competition in the market between PEF's.

2. PEF's have an immediate/intense focus on profits/dividends (ROI)

PEF's need to ensure the acquired business generates a profit. The PEF will look for substantial dividends annually. This is necessary to repay investors, not least because such acquisitions tend to be highly leveraged arrangements (i.e. based on loans as well as equity). There therefore seems to be a tendency to increase ferry service prices in order to raise profits.

3. PEF's leave ferry managers/partners to operate the business

The PEF is led by 'financial engineers' not maritime business managers. The existing ferry company managers will therefore tend be retained, with few changes. The PEF holding a majority of shares will nevertheless generally control the board of directors and seek regular management meetings with a strong focus on financial performance. However, a PEF may also bring with it an experienced transport operator as joint venture partner; this seems more likely where the management and operational efficiency of an acquired ferry company can be significantly improved (e.g. the case of former state-run operations, such as Scandlines and SNCM).

4. PEF's have limited focus on newbuildings/terminals/route development investments

Once a PEF has made a significant investment in the acquisition of a ferry operator, it will not be too keen to spend further large amounts of money on new assets. Hence there is less focus on buying new ships, or making expensive outlays in terminal upgrades, or in start-up of new routes. The key emphasis for the PEF is to sweat the existing assets and routes, for which a premium will normally have been paid.

5. PEF's tend to look for an exit after 2-5 yrs

PEF's require an exit through a further sale of the acquired ferry company typically after a period of between 2-5 years from the time of the initial acquisition. It is important for the PEF that the re-sale value increases over the time of ownership. The current financial crisis and general economic conditions will inevitably put pressure on valuations. More limited takeover activity in the past year or so suggests PEF's are waiting a little longer than usual in order to exit at a time when markets are more stable. This may have implications for re-financing of leveraged deals (e.g. where bullet loans used by PEF's to acquire a firm become due for repayment).

There is clearly a need for further research in this developing area. Some important questions to consider include:

- Do PEF's leave lines in better condition after sale?
- Are there better sources of finance?
- Shipping is generally regarded as a long-term investment, PEF's are not; does this matter?
- And, what happens after the global financial crisis?

Finally, there is the matter of whether the PEF entry into the ferry business will last. To a large extent this depends on whether or not PEF's continue to enter into attractive deals and don't find themselves overpaying for businesses (Reinikainen, 2007). And, of course, whether they can maintain positive financial returns on an annual basis is something that is going to be testing during times of economic downturn.

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Ship scheduling and routing optimization. An application to Western Mediterranean area*

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Abstract

The objective of the paper, knowing the number of ports and ship fleet, is to optimises maritime transport routing of a containership, based on demand scheduling to each port of call ,using the expert system approach with owner utility function (McFadden D. 2000). All that need the operative cost of ships employed and their technical characteristics. The problem solution will be given, for each ship of the fleet, by routing of the ships , container movement for each port of call and transport cost. This paper proposes the use of a methodology based on an expert system computation program with a random utility function of a shipowner operating in a maritime network mapped by geographical information system GIS (Catalani M. 2001).

Keywords: Maritime; Networking; Route; Feeder; Optimisation.

1. Introduction

The current trend for giant ships, as can be seen from the constant growth in size of ocean-going container ships, has led the shipping companies which own these ships, known as deep-sea craft, to select a limited number of stop-over ports where they can concentrate large amounts of merchandise. All this involves significant investment on the part of big deep-sea shipping companies in ever larger ships, which, by stopping at few ports, make it possible to cover a wide-ranging market, making use of local feeder services (Frankel E. 2005). In this way, it is possible to serve port terminals where one direct stop-over would not be economically advantageous or even practicable for geographical, technical, or commercial reasons, (distance from the main trade routes, shortage of infrastructures, shallow waters, modest quantities of containerisable cargo, etc.). The feeder service therefore, in the maritime container transport scenario, is a logistic activity where the main merchandise carrier is substituted, for a certain portion

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of the run, by one or more secondary transporters (Ronen D. 1983). With the progressive growth of the feeder service, increasing importance has been given to efficient planning of logistic activities and the resources used, as in this sector too, competition will be increasingly based on the quality of the services offered, especially punctual and frequent delivery. At the moment, container ships are being designed as container carriers of over 11,000 teus called Malacca-max, named after the eponymous Maltese straight (Frankel E. 2004). This would lead to a fall in freight if old ships are not "scrapped" at the same time. The main aim of this paper is to put together an optimisation model for maritime routing, able to automatically manage a sea route optimizing the relative routine over short sea services (Catalani M. 2001). A secondary, but no less important aim is to calculate the parameters of the function to be used in the optimisation process, based on an investigation carried out at a number of shipping companies working in the area of feeder redistribution in the Mediterranean. A random parameters model or mixed logit model (Mcfadden D. and Train K. 2000) based on agent Bayesian approach has been elaborated. The final objective is also to map the feeder service by GIS (geographic information system) with the technical, logistic and operative data of a line (Catalani M. 1998).

2. The line operators in the Mediterranean

The main large shipping lines working in the Mediterranean, with their subsidiaries, are mainly Maersk, Hanjin, CP Ships, Neptune Orient Line and P&O NEDLLOYD (the latter two merged into a single society). There are also the Global Alliances (Grand Alliance, The New World Alliance, United Alliance, and CHKY Alliance). At the moment the hold capacity on the charter market is slightly higher than what the various ship owner groups offer (Sturmey, S.G.1967 and Frankel E. 2005).

It is interesting to note how the main line operator, i.e. the Danish group Maersk - Sealand, can call upon a capacity almost double that of the second largest shipping company, the Italy-Swiss colossus MSC – Mediterranean Shipping Company. Going on the available data Alphaliner 2003 it is possible to group the characteristics of the feeder services into two macro sectors: *Deep sea services and short sea services*:

- *Deep Sea services*. For this service there are 106 operators, with 664 ships amounting to 2,337,505 teus. Same with 62 direct services with 277 ships amounting to 507,689 teus and others with 34 handling services with 301 ships to a total of 1,378,816 Teus.Lastly10 services which do not call at Mediterranean ports with 86 ships to a total of 451,000 teus.
- *Short Sea services*. For this service there are 105 operators to a total of 233 ships, of which 60 are feeder services (common + dedicated) to a total of 122 ships, equal to 88,034 teus of total capacity; 45 "Short Sea" line services with a total 111 ships at 61,933 teus.

The average size of deep sea ships in direct service from the Mediterranean amounts to around 1,800 teus, while the ships that work in transhipment (one port of call) have an average capacity which is higher by 4,500 teus. The remaining ships which currently run in the Mediterranean, operating mainly on the Northern Europe-Far East routes and which do not call at any port in the Mediterranean have an average capacity of 5,500 teus. The 3/4 of the world fleet operating "pendulum" services along the East-West and North-East routes serve the Mediterranean market including one or more ports of call of the Mediterranean Hub in their "port rotation" (Meersman H., van de Voorde E., Vanelslander T. 2005). In the current scenario, with regard to the Mediterranean line services, previously referred to as "Short Sea" services, they tend to combine traditional volumes with pure feeder transhipment cargo, including one or more intermediate stopovers in the transhipment hub in the schedule. In this case the average capacity varies from 500 to 900 teus (Frankel E. 1995).

3. Med port rotation

The main cost elements of a voyage is *daily charter rate* of the feeder ship (depending on the size, speed and type of the ship being chartered and the length of the voyage), *expenditure* at the various ports of call (variable from port to port and depending on the number of ports visited, as well as the size of the ship), *bunker costs* (depending on the speed of the ship and the length of the voyage) and *insurance costs* (depending on the size, age and the place where the ship was registered) (Evans JJ., Marlow PP. 1990 and McConville J. 1999). Profits, however, depend on the number of teus carried during the journey and the tariff negotiated with the Shipping Line for the transport based on the FIO (free in–free out) for each stretch. This tariff is normally determined from an analysis of running costs for the service and the operating margin fixed by the operator himself. At the moment, the feeder charters in the Mediterranean are very much influenced by the excess of supply, and the profit margins per unit transported are minimum (Jansson, J.O. and Shneerson B. 1987). The ideal structure of a feeder service will include in their "port rotation" a limited number of ports in the same geographical area, whose combined import and export volumes are able to maximise the use of available capacity. Such a system depends on feeder services that connect a Hub port with a maximum of 4 regional ports. A more complex structure is one that has 3 ships doing *"butterfly"* services, with trips of 21 days, operating on a double loop centring on the Hub port. The three ships do two stop-overs per week at the port of transhipment with one stop-over per week in each regional port included in the port rotation. This structure keeps up the weekly frequency, and with it the connections required, serving two different geographical areas at the same time, requiring 21 days' rotation. A typical example is the Adriatic–Middle Eastern services with the hub at Gioia Tauro or Taranto. In this case, the Adriatic loop is completed in around 9.5 days, while the Eastern loop takes around 11.5 days (Frankel E. 2002).

The incidence of the transport cost on the final price of the merchandise transported varies significantly depending on the commodity categories transported; the degree of this incidence depends on the total value of the load transported. More detailed figures show the existence of cost variability for the various countries of origin of the products. In fact the merchandise has different prices even if the unit value of the cargo constitutes an important variable for an operator. Its oscillation can alter the potential market, especially for merchandise with a low unit value and very wide supply (Engelen S., Meersman H., van de Voorde E. 2006). However, purely as an example, the IMF estimates that for the single stretches, the average cost is equal to around 6 % of the value of the world total. It appears greater for the developing countries (around 10 %) than for industrialised nations (5 %). On the contrary while the cost of door-to-door transport can be estimated at around 20%, even allowing for the possibility of very anomalous situations. Knowing the incidence of transport on the unit cost of the cargo contributes to identifying the centres of highest cost. Furthermore, in all phases of the cycle, the transport intermediaries (shipping agents and forwarding agencies) need to be considered with the their costs; their incidence on the total door-to-door cost is around 8-10 %.

4 Transport costs and performance indicators

The running cost of a voyage assessed from the point of view of the affreighter (charter or feeder-operator) chartering the ship from a ship-owner is made up of the following variables with chartering, insurance, main and auxiliary fuel, berthing, port dues and general expenditure (Russo F. 2001):

$$\left.\begin{array}{l} Rc = C_{chart} * T_V + C_{ins} * T_V + C_{IFO} * \\ * IFO * T_S + C_{MDO} * MDO * T_V + \\ + \sum C_{bi} * T_{pi} + \sum C_{pi} + C_{ge} \end{array}\right\} \quad (1)$$

where:

Rc = running cost of transport
T_v = total voyage time as steaming, manoeuvring, operation and idle times (days)
C_{chart} = chartering price of ship ($/day)
C_{ins} = voyage insurance price ($/day)
T_s = route timing (days)
C_{IFO} = main fuel pricing ($/mtons)
IFO = main fuel consumption (mtons/day)
C_{MDO} = auxiliary fuel pricing ($/mtons)
MDO = auxiliary fuel consumption (mtons/day)
T_{pi} = timing at ports (days)
C_{bi} = berth dues ($/day)
C_{pi} = port fees (variables from port to an other)
C_{ge} = general expenditure (maintenance etc.)

When the running cost of a voyage is known, a particularly significant element is the relationship between this cost and the teus actually carried by the ship. Described as C_u, the unit cost will be:

$$C_u = \frac{Rc}{teus} [\$/Teu)] \quad (2)$$

This is the most common economic indicator in the seagoing container transportation sector and also the most significant from the point of view of an operator carrying out a feeder service, as it provides an average value for the cost sustained in transporting a single *teu*.

The daily unit cost C_{ud} is obtained by dividing the C_u for total days:

$$C_{ud} = \frac{C_u}{days}[\frac{\$}{Teu * days}] \quad (3)$$

A transport productivity index Φ is calculated from the relationship between time sailing and the duration of the voyage as a whole (sailing time plus time in port):

$$\Phi = \frac{Ts}{Tv} \quad (4)$$

At last an other important indicator is the coefficient of ship utilisation defined by the ratio between the number of transported container and ship's capacity.

5. Expert system and mixed logit integration

The aim of this paper is to analyse a model able to minimise the running costs in an open multi-port system served by a fleet of vessels. The model used is based on the expert system code (Catalani M. 2001) interacting with a utility function approach. In particular, it will be possible to optimise the routing knowing the handling of containers in any port of call for each ship. The input data used to calibrate the utility function consists of many variables: distance, ship size, fuel cost, coefficient of ship utilisation. The model includes only a few components of the running costs. The expert system code will allow the calculation of the optimal loading plan of the ships involved on this route. The sum of the running cost of all ships will lead to the definition of the "Routing Plan''. The output of the code will provide the route which optimise parameters of utility function. This takes on particular importance in the case of small and medium-sized ships running short routes as a feeder service in the Mediterranean area (Buxton 1971). This case leads us to consider the behaviour of an owner who must allocate ships operating in a multi-port system and minimise the running cost. All that needs to be considered in terms of the operative cost of ships employed and their technical characteristics (Frankel E. 1997). Generally speaking, this approach is partially defined in the literature (Jansson JO., Shneerson B. 1987), but it can be very complex if we consider the large number of variables involved. In our case, we have a port system (nodes) interconnected by routes (links) constituting the maritime network served by a fleet of vessels. We must consider the possibility for each ship to transport containers to each port along the route, minimising overall running costs (Zerby, J.A. and Conlon, R.M. 1982). The solution to the problem is calculated for each ship of the fleet from: the timing and routing of the ships, container movement for each port of call and running cost. The software that was created to analyse maritime networking route returns optimal routing optimisation according to previous variables declared in the utility function. The aim is to optimise the utility function according also to the distances matrix (distances values between several ports) and containers O-D matrix (matrix origin - destination of containers flow between several ports). The distance matrix and containers O-D matrix and all parameters of function utility ,as said, are used by software to plot and design optimal routing.

This exhaustive methodology entails a computer search of a large number of possibilities to find the optimal solution, which becomes difficult if the number of ports, variables and ships increases considerably. In contrast, this paper proposes the use of a methodology based on an "expert system". This method allows us to find solutions in a limited domain with the same results as those obtained by human experts. The advantage of this choice, with computerised calculations, allows us to "grasp" the know–how of maritime logistic experts. The program, which will solve the problem of routing for a liner with many ports of call, requires the following operative phases:

- identification of the route and ports
- knowledge acquisition in terms of container traffic
- formulation of logical rules for cost structure
- code of optimum problem solution

As regard the employed methodology for utility function solving it uses a mixed logit model such as McFadden D. and Train K. 2000. This is one of the most complete models developed by McFadden D. (1996), Train K.(1998), Ben Akiva M. - Wolker J. (2002).

The utility function uses only a few cost variables due to the limit of computer program with a large extension of variables. The econometric model application reflects the choice of freighters who operate in the Mediterranean area. In reality there fifty-nine chartered feeder ships which main running costs are: time charter, insurance, bunker and port fees. The charterer operates time by time with different feeder ship sizes. The Bayesian procedure in mixed logit model considers charterer choices (repeated) among j sizes of feeder ships in each T time periods (Allemby G. 1997) and (Train K. 1998). The perceived utility from alternative j in period t becomes (Train K. - Sonnier G. 2003)[1]:

$$U_{njt} = \beta'_{n} x_{njt} + \varepsilon_{njt} \tag{5}$$

Where $\varepsilon_{njt} \cong$ iid extreme value and $\beta_n \cong N(b,\Omega)$. The vectors of variables x_{njt} and parameters β_n extended to K. Conditional on β_n the probability sequence of choices being the product of standard logit formulas (Train K, 2003):

$$L\langle y_n \mid \beta_n \rangle = \prod_t \frac{e^{\beta'_n x_{ny_{nt}} t}}{\sum_j e^{\beta'_n x_{ny_{nt}} t}} \tag{6}$$

[1] Train K. and Sonnier G. 2003'' *Mixed logit with bounded distribution of partworths''*. The methodology, the papers and the manual to implement the procedure described in this paper are available on Train's website at http://elsa.berkeley.edu/~train.

Successively the parameters are defined by c_n, = $T(\beta_n)$, where T is a transformation that depends only on β_n and is weakly monotonic.

The distribution of c_n, is determined by the transformation. Utility is specified as:

$$U_{njt} = T(\beta_n)' x_{njt} + \varepsilon_{njt} \tag{7}$$

The chartered probability choice sequence given β_n, as Train K. and Sonnier G, 2003 is:

$$L(y_n|\beta_n) = \prod_t \frac{e^{T(\beta_n)' x_{ny_{nt}t}}}{\sum_j e^{T(\beta_n)' x_{njt}}} \tag{8}$$

The overall explication of the formulas (5,6,7,8), the code and the papers, as said, are available on Train website.

6. Routing networking analysis

The paragraph 6.1 shows an example relating to the times and the costs of a typical voyage of a feeder ship, operating on a routing service in the eastern Mediterranean area (Sturmey, S.G.1967 and Buxton, I.L. 1971). The charts show the standard composition of data supplied by a feeder operator (charterer) on behalf of the line. The capacity of the ships examined varies from a minimum of 400 teus (1 teu as a standard capacity of 14 tons) to a maximum of 1000 teus. The average capacity is equal to 650 teus per ship. The database used includes the following division:

- scheduling of the journey, rotation, activity for stop-over, arrival and departure times from each port in the rotation;
- ship profile and container details of unloading /loading per port;
- round trip costs;
- port dues.

The analysis of the data shown in the following figures must be understood as purely descriptive of the model for costs which was used by the application below, and should not therefore be identified with the true situation. It needs to be pointed out, in any case, that "stevedoring" costs are not normally included, i.e. the shifting of containers in port, but only the costs of transport based on the FIO agreement (Free In – Free Out) between the feeder operator and the main line owner of the container.

Table 1 shows the schedule of a feeder ship. In it, we show the schedule number, the port of call with relative dates of arrival, the start of operations, and departure with container movement such as unloading and loading.

Table 1: Ship's scheduling Med area.

MED / SERVICE Current Schedule					
Schedule No. 3125					2001
026				Moves	
Ports	Arrival	Start ops	Departure	Disch	Load
1			15 09 (08:00)		199
2	17 Mon 09 (06:00)	17 09 (08:00)	17 09 (16:00)	94	55
3	18 Tue 09 (06:00)	18 09 (07:00)	18 09 (16:00)	62	110
4	19 Wed 09 (08:00)	19 09 (09:00)	19 09 (19:00)	74	121
1	21 Fri 09 (02:00)	21 09 (03:00)	21 09 (21:00)	265	
SHIP DETAILS					
Intake					400 Teus
Vessel capacity					281 Teus
Deadweight					4.100 Tons
Speed					15 Knots

Source: MCT, Shipping companies.

Table 2 shows the ship profile representing the weight condition of the ship at departure from each individual port, defined in metric tonnes and teus, full or empty. Specifically, in Table 2 we show the names of ships, the port rotation list, and the quantity of containers loaded and unloaded.

Table 2: Ship profile determination.

M/v HH					voyage N.26				
TEUS Port Rotation	LOADING			DISCHARGING			SHIP'S PROFILE		
	Full	Empty	WGT	Full	Empty	WGT	Full	Empty	WGT
1	280		3.727				280		3.727
2	70	14	1.091	139		1.796	211	14	3.022
3	110	31	1.663	80	8	945	241	37	3.740
4	132	35	1.791	86	11	1.340	287	61	4.191
1				287	61	4.191			
TOTAL TRIP	592	80		(teus full / empty transported during voyage)					
Legenda: 1,2,3,4 = ports									
Note: Ship profile represents condition of cargo in every ports in WGT, Teus Full or Empty - Loading / Discharging									

Source: MCT, Shipping companies.

Table 3 shows a summary of the overall subdivision of the main components of total round trip costs with the distance travelled, average speed, fuel consumption, manoeuvring, operational steaming, time charter cost, insurance, bunker and mooring fees, and cost per mile in $.

Table 3: Summary of round trip costs.

Ship name	Voyage n°		Miles travelled	Average Speed (miles/hour)	Consume (tons)		Total (mt)	Daily Consumption (mt)
					Main (mt)	Aux (mt)		
1	26		1.530	14,71	62,76	4,30	67,06	10,21
			Steaming d h m	Manoeuvring d h m	Operation d h m	Idle Times d h m	Total (days)	
			04/ 8.00	00/ 3.23	01/ 3.45	00/ 22.34	06/ 13.42	
		US $ TC x day	TC (US $)	Insurance (US)	Bunker (US $)	Port dues (US $)	Mooring dues (US $)	Total (US)
		5.188	34.091,59	201.40	6.194.,94	11.734,25	321,52	52.543,70
		US $ / mile	mile / mt	Cost subdivision %				
				Time charter	Insurance	Bunker	Port Charges	
		4,05	22,81	64,9%	0,4%	11,8%	22,9%	

Legenda:
TC = Time Charter
Mt = Metric Tons
Main = Fuel main motor (tons)
Aux = Fuel auxiliary motors (tons)
D h m = Day, hours, minute
Steaming = Navigation time
Manoeuvring = Port manoeuvring
Operation = Handling time
Idle Times = Off port time

Source: Shipping companies.

Table 4 shows the details of the fees paid at each port. Generally we have different dues for different ports.

Table 4: Port fees.

RECAP - port dues			
Ship Name	Voyage	Port	US$
1	26	1	1.201,55
2	26	2	1.458,32
3	26	3	3.800,11
4	26	4	1.274,28
---------------------	------------------------	-----------------	-----------------------------

Source: MCT, Shipping companies

Table 5 shows detailed container movements in the loading/unloading ports. As we can see, the details of containers transported on each link of routing are given here with indication of size, WGT, full or empty.

Table 5: Detail of containers transported on routing.

Pol	Pod	LOADING								DISCHARGE								Mvs
		20 F	40 F	TEUS	WGT	20 E	40 E	TEUS	WGT	20 F	40 F	TEUS	WGT	20 E	40 E	TEUS	WGT	
1	2	49	45	139	1.796													199
1	3	33	17	67	784													
1	4	36	19	74	1.147													
1	1																	
Total		**118**	**81**	**280**	**3.727**													
2	3	3	5	13	145		4	8	16									149
2	4	1	2	5	48	6		6	13									
2	1	36	8	52	869													
Total		**40**	**15**	**70**	**1.062**	**6**	**4**	**14**	**29**	**49**	**48**	**139**	**1.796**					
3	4	7		7	122	1	2	5	10									172
4	1	47	28	103	1.474	24	1	26	57									
Total		**54**	**28**	**110**	**1.596**	**25**	**3**	**31**	**67**	**36**	**22**	**80**	**929**		**4**	**8**	**16**	
3	1	68	32	132	1720	7	14	35	71									195
Total		**68**	**32**	**132**	**1720**	**7**	**14**	**35**	**71**	**44**	**21**	**86**	**1317**	**7**	**2**	**11**	**23**	
																		265
Total										**151**	**68**	**287**	**4.063**	**31**	**15**	**61**	**128**	

Legenda:
20 F = Container 20' feet (full) — 20 E = Container 20' feet (empty)
40 F = Container 40' feet (full) — 40 E = Container 40' feet (empty)
WGT = Weight Cargo tonn — Mvs = Moves discharging/loading containers
POL = Port of loading — POD = Port of discharge

Source: Shipping companies.

From ships data base elaboration, more generally, from data base the total trip routings number are 140 and the main considerations deriving from the overall aggregated data analysed are:

- the number of voyages carried out by the same ship in the reference month varies from 1 to a maximum of 5.
- the cost of chartering the ship is equal to 64.07 % of the cost of the voyage.
- the bunker cost amounts to 11.27 % of the total cost.
- the port costs are 24.08 % .
- the insurance costs, however, account for the remaining 0.58 %.
- the average daily bunker consumption is around 11.61 tons per day while at sea.
- the average cruising speed is around 15 knots.
- the average navigation cost is US $ 6.55 per mile.
- the ship does 15.83 miles per bunker tonne

6.1. Routing optimisation application.

Based on data base available from feeder operators with different feeder ships size in the Mediterranean area, and after mixed logit calibration by maximum likelihood simulation of the utility cost function parameters, an application of a Train K. code (see note pag. 6) with coefficients transformation of the above data has been attempted. The results of the application, with statistical data analysis, are shown in the Table 6.

Table 6: Estimâtes coefficients of normals transformations.

Variables β	coefficients	t-statistics
Ship Dimension (TEU)	1.0	1.8
Movement level	10.0	2.1
Distance	1.0	1.1
Running cost	0.5	1.9
Simulated log likelihoods	-62.8915	

It is clear that the ship utilization coefficient is statistical significant because t-value is greater than +/- 1.96 unlike ship dimensions variable and distance variable. All that needs more investigation. It is essentially an exemplification of a proposed routing based on an expert system (Russel S.J. and Norvig P. 2003). The proposed model makes use of a calibration model of McFadden's utility function as above. Essentially, the cost function calculation method (utility) uses a mixed logit model calibrated using a sample of 59 feeder ships operating in the Mediterranean, and chartered by the operator himself. The routing under examination takes into account the following ports:

- Istanbul
- Izmir
- Marmaris
- Pireus
- Saloniki

In these ports there are some containers for the same routing which must be transported. The variables that come into play in this problem, in addition to the distances between the ports, are also those concerning the cargo to be loaded onto the ship. Theoretically, to identify the best route able to optimise the merchandise distribution costs, it is necessary to assess an important number of combinations of different container flows combined with different pathways (Erichsen S. 1971*)*.The criterion proposed is based on the following assumptions: we assume that we are in port with the ship empty; we have to decide which containers to load and how many (containers with the same destination are considered to be "equal") and we must select the next node to be chosen. We can use one criterion and evaluate the best route. We can then change criterion and redo the calculation procedure. Finally, we will compare the best routes, as many as the number of different criteria and call this solution the relative best one. Here we define the following criterion, which includes:

- the routing with 5 links .With the increase in the number of stretches, there will be a relative excellent closer to the real excellent. With a sufficiently high number of stretches, there will be an absolute excellent, but the calculation of the excellent will be particularly difficult.
- the utility function as explained(Cascetta E. 2001)

Figure 1: GIS mapping of the network.

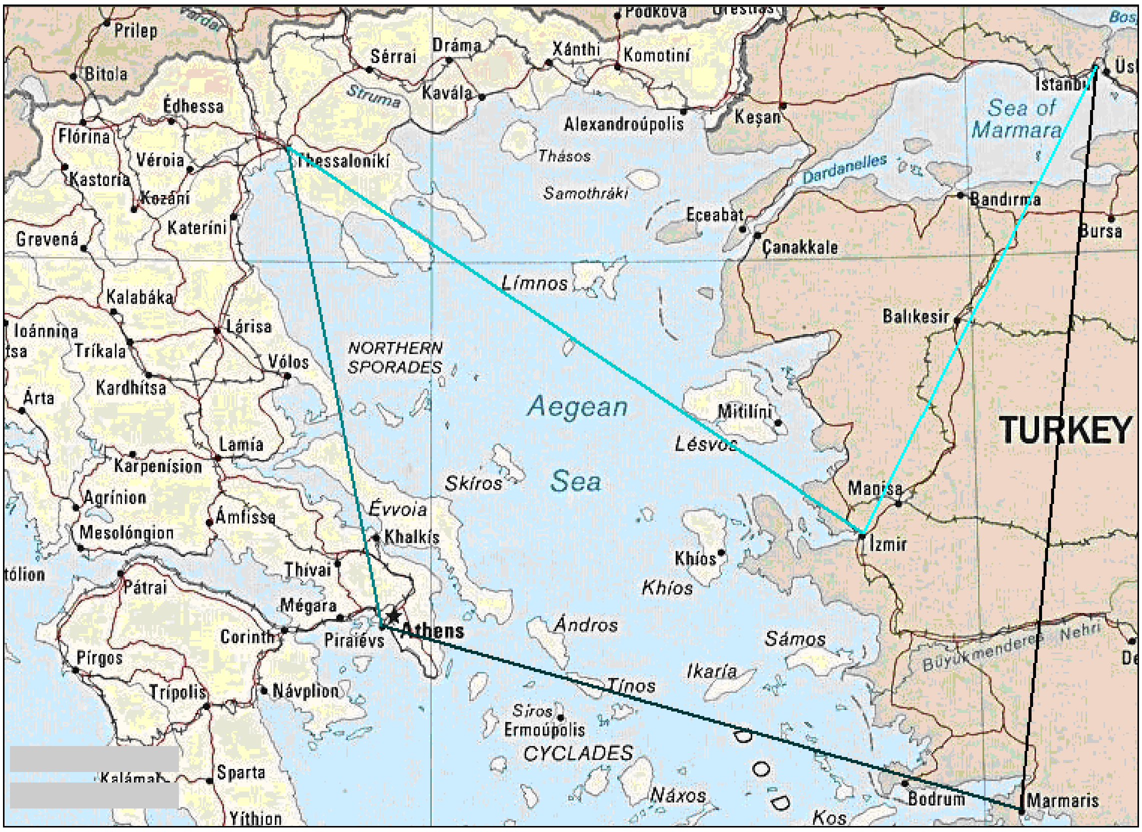

Figure 2: Routing optimisation output.

This graphic representation of the area has been mapped using a geographic information system (GIS) with the Aegean and Marmara seas and the Greek and Turkish coastal areas (Affum K. J., Taylor M.A. 1998). The map in the Figure 1 shows the five ports involved in this study.

Figure 2 shows the best routing based on the previously identified parameters. The map shows the overall routing with different shades of colour to illustrate it better. The routing of the ship is: Istanbul, Marmaris, Pireus, Saloniki, Izmir, Istanbul.

7. Conclusion

The model proposed in this paper is an example of how to implement an application based on an expert system strategy plus a mixed logit calculation of parameters to be used in the routing optimisation code. The model must be considered also as an extension of the paper presented at the 9th WCTR from the author (Catalani M. 2001). The high level of data based on the feeder service allows us to implement many real models .Nevertheless the difficulty of code implementation has limited our ability to consider a higher number of variables than mixed logit calibration will allow. For a good calculation response, we will need all the parameters affecting routing cost which need to be taken into account such as ship size, voyage frequency, distance covered, total cost, cost per mile, bunker, chartering pricing etc . Nevertheless, the expert system application must be considered as a prototype to maritime transport.

The model has a high flexibility parameter that allows the updating (when cost factors are added or changed) or the adaptation (when the application has to represent different contexts) of the routing problem. The obtained results reflects the size of data base. So if I modify the surveyed variables it is possible to obtain a better results with a goodness fitting of data with statistical significance.

In the model proposed, the value of the routing link equal to 4 or 5 was fixed (for a simple representation of the routing diagram), but more realistically, to simulate route planner behaviour, an extension to 6 – 7 is needed. As specified, all this significantly increases the complexity of calculation .

Finally, the application of output shows a net differentiation regarding the traditional planner ships' assignment to the port system. It is particularly evident that the main routing link does not start with the nearest link, in terms of distance, from the departure port. The network is emphasised also distance, container movement and handling at ports. The trade-off between vessel size and the number of ports present in the network is evident. This analysis is substantially useful in the interaction of new modes of planner fleet capacity within the network. Despite the limitations that can be found in a symmetric maritime network geographical area of study, the application is interesting for route planning operations because it integrates the traditional optimisation approaches. Lastly, it will be possible in the future to experiment on specific area characterized by the presence of frequent storms, the approach proposed. This can be applied for example in the Tyrrhenian sea, in Med area, where the need to avoid the storm area by high speed ferries, in winter time, is a rule. In this case the advantage for shipping companies and passengers (high sea negative condition) must be quantified with different utility function variables.

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Safety of the navigation in congested maritime area. The case of the Messina strait

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Abstract

In the last decade a relevant expansion of traffic by sea occurred, not only on the long distances, but also on the middle-short distances; on coastline urban areas and particularly on neighboring urban areas, but separated by the sea, the increase of the flows often involves greater risks of accident for the navigation (Lewison, 1978; Merrick et al., 2001; van Dorp et al., 2001). The risk of maritime accident results particularly high for the ro-ro ships. This papers clarify some aspects concerning the concept of risk and safety at sea dealing with some literature models. An application is proposed to the Messina Strait context that is the crossroad of elevated flows of traffic along two directions. The navigation safety in the Messina Strait has been analyzed with the support of a micro-simulation approach.

Keywords: Risk; Safety; Micro-simulation.

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1. Introduction

In the last decade a relevant expansion of the traffic by sea occurred, not only on the long distances, but also on the middle-short distances; on coastline urban areas and particularly on neighboring urban areas, but separated by the sea, the increase of the flows often involves greater risks of accident for the navigation (Lewison, 1978; Merrick et al., 2001; van Dorp et al., 2001).

An accident can be defined as an undesirable event that provokes damages to humans, to goods and to the environment; the main factors that can determine an accident are:

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- external conditions, namely conditions of rough sea or conditions of reduced visibility;
- functional breakdown, as malfunction of technical equipments;
- errors of navigation, namely errors of manoeuvres, inadequate understanding of the situation, negligence, violation or deviation from the procedures, from the rules and from the instructions;
- errors committed by other ships.

The risk of maritime accident results particularly high for the ro-ro ships; they have an inclination to the accident, because they operate in congested navigable waters, adjacent to the coast, moving at medium-high speed.

The first part of the paper is meant to clarify some aspects concerning the concept of risk, underlining how the management of the maritime traffic through the navigation rules and advanced control systems can contribute to enhance safety in the sea.

In the second section of the work, the attention is addressed to some literature models for the analysis of safety in the sea, quoting the most common cases of accident (stranding, collision). The main models analyzed for safety analysis are Inoue (2000), Kristiansen (2005) and Yip (2008). The preferred model for our study context is Kristiansen (2005) because the Messina Straits should be considered as a large maritime area with long permanent routes; whereas Inoue and Yip consider restricted area as port waters. An application is proposed to the Messina Straits context that is the crossroad of elevated flows of traffic along two directions (Calabria-Sicily and Ionian-Tyrrhenian seas). The navigation safety in the Messina Straits has been analyzed with the support of a micro-simulation approach. The whole matter describes an interesting scheme for the evaluation of safety, also related for scenarios with more intense future traffic.

2. Safety analysis approach

The hazard in *active* form is connected with any transport activities taking place in the territory, when from such activities can derive dangers for the safety of transport users and not users and damages to the integrity of the environment. The defence towards this type of risk can be practiced by undertaking one of the followings actions:

- planning of long term interventions on the transport systems (construction of new safer transport structures, use of modern monitoring equipments, policies supporting less dangerous transport modalities, etc.);
- prevention: short-term or in “real time” control management of transport in order to avoid, in every condition, the overcoming of a maximum threshold of admissible risk;
- emergency: actions meant to know with timeliness the characteristics of the accident, the helping needs, and other necessary actions suitable for limiting the damages to people and things and to overcome the phase of danger.

The *hazard* is a condition in which exists a *potential cause of damage*. There is a *hazard* when a system (or an activity), under certain conditions, can provoke unwanted consequences. *Safety* denotes a situation in which the level of risk is low and acceptable, both economically and socially. Analytically, the literature of the sector induces to assume the risk equal to the product among the vulnerability V of the area involved in the risk, its exposure N and the probability P that the risky event could happen:

$$R = V \cdot N \cdot P = M \cdot P \quad (1)$$

in which M is the measure of the magnitude, given by the product of vulnerability and exposure.

The process of analysis and evaluation of the risk (fig.1), according to Kristiansen (2005), can be articulated in different phases, the first one results in the definition of the system object of study that, in a maritime context, includes the description of the geographical area (specific routes and ports), of the environment (conditions of the sea, weather report, visibility), of the ships (number, capacity, dimensions and technical description) and other contextual elements (traffic and activity that can cause dangerous situations).

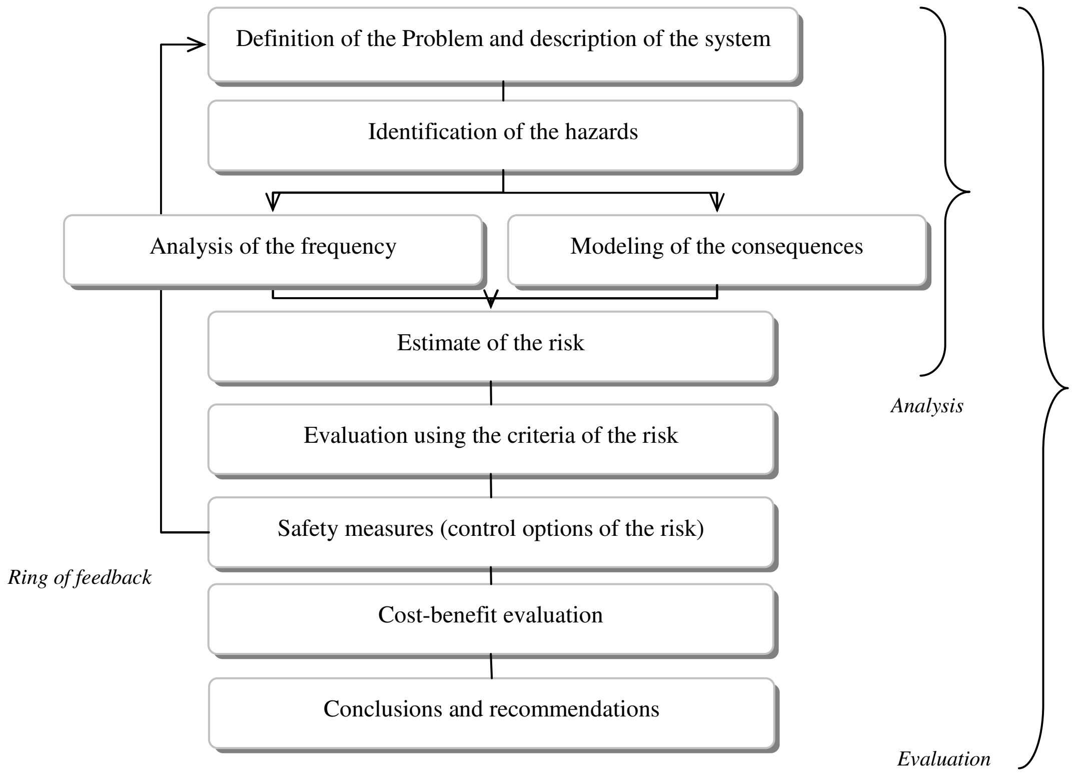


Figure 1: Process of the analysis and the evaluation of the risks (Kristiansen, 2005, p. 209).

Subsequently it is necessary to identify the possible events and possible conditions that could make the risk increase. It is possible therefore to carry out the analysis of the risk and to identify it quantitatively and qualitatively. An analysis of the frequency can be made in order to evaluate the probability that the event could happen; this analysis could be better realized through the use of the statistic data and the historical series regarding the frequency of the above quoted events. Contextually, through the modeling of the consequences, the real effects of the risks can be evaluated. After the evaluation of the frequency and the consequences of every risk, it is possible to measure the total risk. To reduce the risks to an acceptable level, it is necessary to introduce some safety measures in the system (e.g. the realization of a system of evacuation on board). The analysis is concluded with the cost-benefit evaluation, in order to analyze if the benefits following the adoption of some safety measures are compatible with the costs connected to their realization.

This formulation allows to underline the opportunity of interventions for the reduction of the risk; the interventions can be addressed (fig.2) to reduce the probability (or frequency) the cause could happen (at the origin of the event) and to limit *M*, the damages connected to a possible cause, to restrain the consequences of the event. Fig.2 shows the results on risk level: from R_1 to a lower level R_i (interventions of prevention or protection).

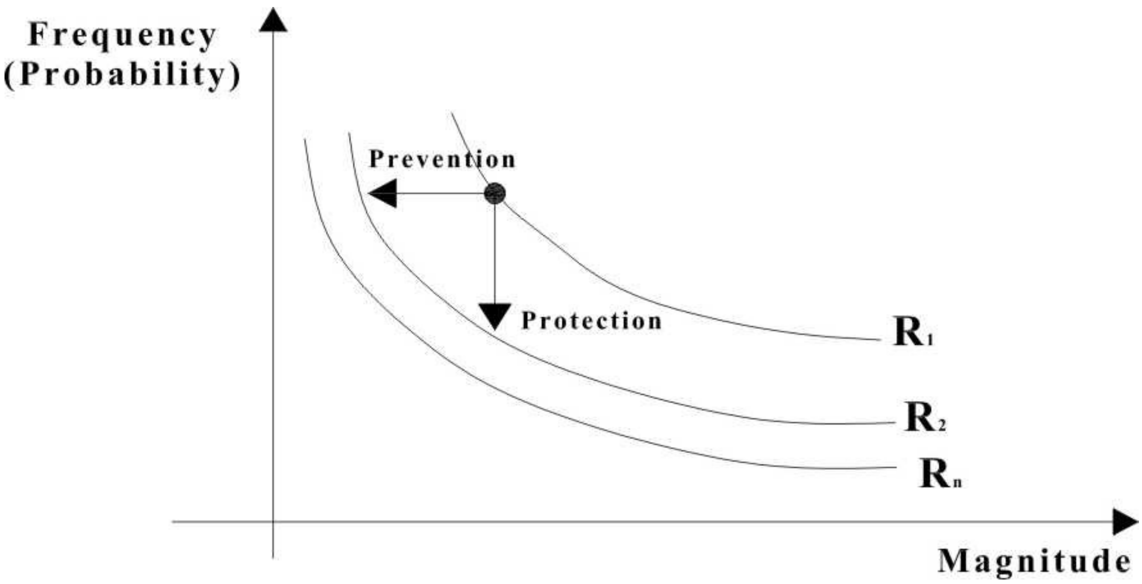


Figure 2: Reduction of the risk through the activity of protection or prevention.

3. Models of Kristiansen

An analytical approach to the evaluations of the accident risk in the sea is proposed by Kristiansen (2005, Ch. 6). The expected number of accidents for a ship in the time unit and for a specific maritime route, can be valued with the following expression:

$$N_a = \lambda \cdot Q \tag{2}$$

where:

N_a is the expected number of accidents on the route per time unit;
λ is the average rate of accidents per passage of a ship on the route;
Q is the number of passages per time unit.

Considering a route as a sequence of more maritime sections and in the hypothesis in which among two following sections the navigation and topological characteristics are constant (fig.3), the expected number of accidents inside a line *m* between two sections can be expressed as:

$$N_{am} = \lambda_m \cdot Q_m = P_{am} \cdot Q_m \quad (3)$$

where:

N_{am} is the expected number of accidents in the time unit inside the line *m;*
P_{am} is the probability that an accident happens in correspondence of the line *m.*

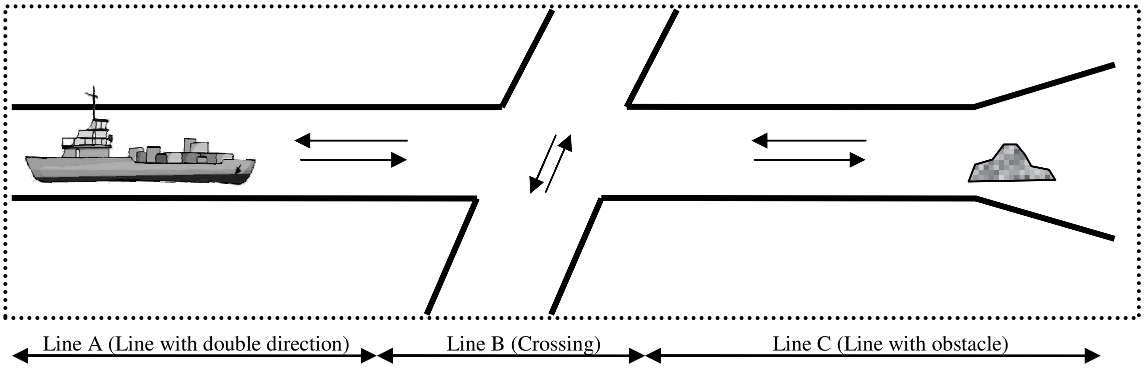


Figure 3: Example of subdivision of a route in homogeneous sections.

If *u* stands for the type of accident, the expected number of the *u* type accidents in the line *m* can be expressed as:

$$N_{am,u} = P_{am,u} \cdot Q \quad (4)$$

where:

$N_{am,u}$ is the expected number of *u* type accidents in the time unit inside the line *m;*
$P_{am,u}$ is the probability that a type *u* accident happens in correspondence of the line *m.*

The total number of accidents for time unit for the whole trip, can be express as:

$$N_T = \sum_m \sum_u P_{am,u} \cdot Q_m \quad (5)$$

Therefore the problem is the definition of the probability P_{am}.

The model proposed for the evaluation of the accident probability is based on the assumption that the ship is in movement (and therefore potentially connected to a possible situation of danger), that is unexpectedly involved in a risky event that causes the loss of control, and that it is not possible to intervene readily, provoking an accident/collision.

The probability of an accidental event considering such assumptions, is expressed through the product of two probabilities that reflect the transition from the state of normal functioning to the accident:

$$P(A) = P(C) \cdot P(I/C) \quad (6)$$

where:

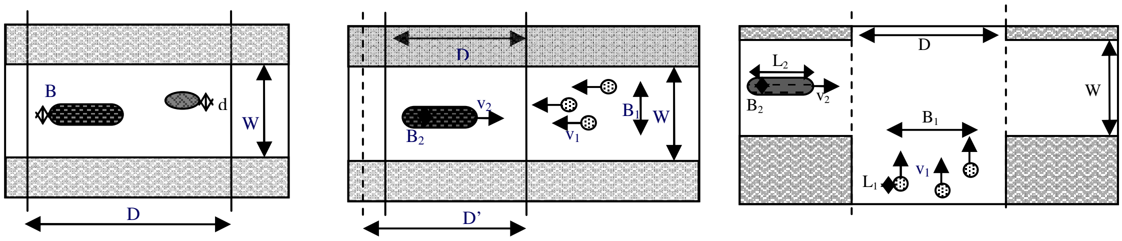
P(A) is the probability of an accidental event per passage;
P(C) is the probability to lose the control of the ship per passage;
P(I/C) is the conditional probability to have an accident after loss of the ship control.

An alternative form is:

$$P_a = P_c \cdot P_i \tag{7}$$

where the subscripts denote accident (a), loss of control (c) and impact (i).

Some analytical formulations are proposed for the calculation of such probabilities in the case of stranding and collision, differentiating among head-on collision, crossing and overtaking (fig.4).



a) Grounding *b) Head-on collision* *c) Crossing collision*
Figure 4: Modeling of a maritime accident.

3.1. Case of grounding

In the case of grounding (fig.4a), the probability that an uncontrolled ship hits an obstacle depends exclusively on the dimensions of the section and on the width of the ship:

$$P_i = \frac{B + d}{W} \tag{8}$$

where:

W is the average width of the fairway;
d is the cross-section of the obstacle (e.g. rock, island, etc.);
B is the width of the ship.

The probability P_i that a ship, losing the navigation control, hits against another ship present in the same sea area is calculable through the following analytical formula:

$$P_i = \frac{B_1 + B_2}{W} \tag{9}$$

in which B_1 and B_2 are the widths of the two ships simultaneously present in the sea area.

In a seaway with a number of obstacles the conditional probability P_i is given by the union of the cross-sections of the obstacles; in this case:

$$P_i = \frac{B}{W} + \rho \cdot D \cdot d \tag{10}$$

where ρ is obstacles density (obstacles/area-unit) and D is the length of the fairway. If the ships' width is small relative to the fairway width W, it is possible to assume:

$$P_i = \rho \cdot D \cdot d \tag{11}$$

The probability of losing the navigation control P_c can be estimated on the basis of observation of traffic, counting of accidents and estimating P_i for a specific fairway. For example, on the basis of a number of ships accidents and of a number of passages detected in a time period, it is possible to evaluate:

$$P_a = \frac{N_a}{Q} \tag{12}$$

Assuming P_i =1, it is possible to derive P_c through the following expression:

$$P_c = \frac{P_a}{P_i} \tag{13}$$

In alternative, if is known the accident frequency for distance unit μ_c, it is possible to estimate P_c as:

$$P_c = \mu_c \cdot D \tag{14}$$

3.2. Case of collision

Contrary to the grounding, the collision represents an impact among two moving objects; therefore, it is possible to distinguish different types of collision (head-on collision, transversal collision or collision due to an overtaking manoeuvre).

The probability of head-on collision (fig.4b) for a single ship in the considered sea area in the observation time, considering the probability of losing the control P_c, *is*:

$$P_a = P_i \cdot P_c \tag{15}$$

P_i is the impact probability for incoming traffic, obtained by the product of the stated sea area for the traffic density:

$$P_i = \rho \cdot A = \rho \cdot D \cdot d = \rho \cdot (B_1 + B_2) \cdot (v_1 + v_2) \cdot D / v_1 \tag{16}$$

where B_1, B_2, v_1 and v_2 are respectively width and speed of the two ships, D is the length of the section and ρ is the traffic density (average number of ships entering the fairway within a time period), equal to:

$$\rho = \frac{Q_1 \cdot T}{(v_1 \cdot T) \cdot W} = \frac{Q_1}{v_1 \cdot W} \tag{17}$$

Q_1 is the arrival frequency of meeting ships and T is an arbitrary time unit of reference.

The probability of losing the navigation control P_c can be estimated on the basis of observation of traffic as the grounding case. Some Japanese investigations (Fujii, 1982) give $P_c = 2 \cdot 10^{-4}$ (1/passage).

In the case of ships passing through a maritime intersection (fig.4c), the impact probability among two groups of ships is:

$$P_i = P_{i1} + P_{i2} = \rho_m \cdot A_1 + \rho_m \cdot A_2 = \rho_m \cdot (B_1 + L_2) \cdot D \cdot \frac{v_1}{v_2} + \rho_m \cdot (B_2 + L_1) \cdot D \tag{18}$$

$$P_i = \frac{Q_1}{v_1 \cdot v_2} \cdot \left[(B_1 + L_2) \cdot v_1 + (B_2 + L_1) \cdot v_2 \right] \tag{19}$$

where ρ_m is the density of the crossing ship, A the exposed area, B_1, B_2, L_1, L_2, v_1 and v_2 are respectively widths, lengths and speeds of the two groups of ships, Q_1 is the frequency of the group 1 ships arrival to the intersection. Assuming that the two groups of ships have identical characteristics, the expression is greatly simplified:

$$P_i = 2 \cdot (B + L) \cdot \frac{Q_1}{v} \tag{20}$$

As in the case of head-on collision, the probability of impact P_a and the number of collisions N_a can be calculated through the following expressions:

$$P_a = P_i \cdot P_c \tag{21}$$

$$N_a = P_a \cdot Q \tag{22}$$

The case of the overtaking, finally, concerns two ships moving to the same direction but with different speeds. It is similar to the case of head-on collision except for the relative speed formulation. If it is assumed that a ship is exposed to a uniformly distributed traffic moving to the same direction, the impact probability is obtained by:

$$P_i = \frac{(B_1 + B_2)}{W} \cdot \frac{(v_1 - v_2)}{v_1 \cdot v_2} \cdot D \cdot Q_1 \tag{23}$$

4. Analysis of the navigation safety in the Messina straits

The analysis of the navigation safety in the Messina Straits has been made at first on the base of historical series referring to the accidents happened in the last years in the examined area; then it has been calculated the potential risk assuming the models adopted in the previous section.

4.1. Statistic analysis on historical bases

The Messina Straits has been a context of numerous accidents in the years. During the last 50 years there have been 44 collisions, some of them have had serious consequences.

From a statistic point of view, this means that every year, in the area of Messina Straits the average of 0,84 accidents take place (Securmed, 2007). If we analyze the last 22 years (1986-2007), characterized by conditions of traffic more similar to the present ones, we obtain an average of 0,32 accidents/year.

Furthermore, knowing that within one year, in the Messina Straits there are about 120.450 in transit ships and that the average number of annual accidents happened is equal to 1 (approximate for excess), the estimated probability of accident P_a is $0{,}83 * 10^{-5}$.

For the estimation of the reliability and the analysis of the risk connected to a system, it is often applied the Poisson probability distribution. If assumed that a standardized interval t (time or space) is divided into n under-intervals whose value is $\Delta\tau = t/n$, when the number n of under-intervals increase, that is $\Delta\tau$ getting to zero, the probability to observe X events in the period t can be calculated with the variable of Poisson whose function of probability is:

$$P(X = x) = \frac{\lambda^x}{x!} \cdot e^{-\lambda} \tag{24}$$

If assumed that the number of accidents per year is defined according to a Poisson distribution with an average λ=0,32, the probability to have an accident per year is equal to 0,23; in other words, assuming that the risk doesn't change in the years, it is therefore sorted out that the probability to have an accident is equal to 23,2%, that denotes a significant risk. It can be observed that P(X=2)=0,03; P(X=3)=0,003.

4.2. Application of the Kristiansen models

The risk of collision in the Messina Straits has been estimated beginning from the models of Kristiansen proposed in the previous section. It has been carried out the representation of that model developing a representative network of the study area, with 5 nodes, located in correspondence with Reggio Calabria, Villa St. Giovanni, Messina, Rada S. Francesco and Tremestieri ports, and 24 network nodes, situated in correspondence with the intersection points among the different routes (fig.5). As concerns the representation of the services of maritime transport, it has been referred to the morning rush hour (07.30-08.30) of a working weekday, considering the number of departures from every port towards the various destinations and calculating therefore the risk in this condition. Such value has been extended then to the whole day through a coefficient α obtained by the relationship between the number of runs affected in the rush hour and those effected within the whole day, getting a value of α equal to 12,05.

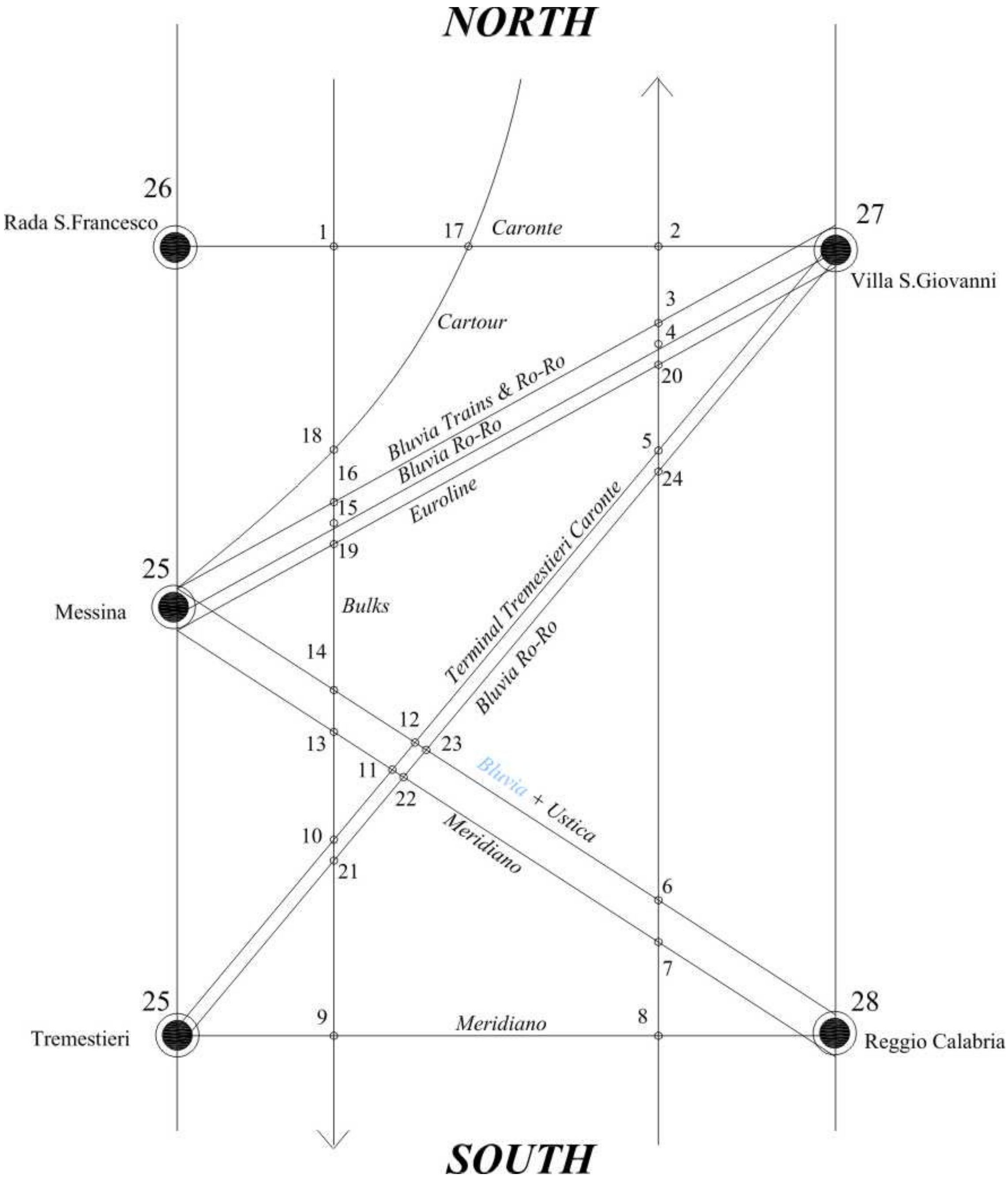


Figure 5: Network of Messina Straits.

The accident risk analysis has been handled for different scenarios:

- present situation;
- scenario 1: hypothesis of fully working Vessel Traffic Service (VTS);
- scenario 2: hypothesis of increase the transport demand in the Straits;
- scenario 3: composition of the scenarios 1 and 2.

Present situation

The risk of accident is connected to the mutual position of the ships; in particular dangerous situations are to be recognized as head-on collision, crossing and overtaking. The total number of accidents per time unit for the whole trip N_a, can be expressed as the product of the probability that an accident type could happen at the passage from the section *m* and the number of passages of the ships in the time (*Q)* added for all accidents types and for all maritime sections in the study area.

The risk of head-on collision characterizes the connection among the ports of Messina Straits in relationship with to the frequency of the runs: the greater is the number of the ships coming from the direction (*Q*) opposite the examined ship, the greater is the risk of collision.

The probability to lose the control P_c, comparing the available values in literature (Kristiansen, 2005) has been assumed equal to be $2*10^{-4}$; in the case of some of the busiest routes (Messina-Reggio Calabria and Messina-Villa S. Giovanni) this value has been subsequently reduced ($1*10^{-5}$), since in the case of Messina Straits, the attention of the ship master is greater because of the reduced capacity of movements, due to the elevated traffic density.

From the application of the proposed theoretical models, it has been found out that the traffic density is higher along the Messina-Villa S. Giovanni route (0,09 ships/km²), with an expected number of collisions per passage equal to $1,00*10^{-2}$; the lowest value has been recorded in correspondence with the Tremestieri-Reggio Calabria route ($2,12*10^{-3}$), because the number of ships coming from the opposite direction is lower. In conclusion, the expected number of head-on collisions in one year is equal to 0,036.

The situation of the crossing point represents the risk that a ship collides with one moving to a perpendicular direction. Assuming the loss of control Pc equal to $1*10^{-4}$, on the base of some literature studies (Kristiansen, 2005), it has been calculated a risk due to the intersection between the navigation routes equal to 0,031 collisions/year on the Messina-Reggio Calabria route, 0,024 collisions/year on the Messina-Villa S. Giovanni route, 0,0075 collisions/year on the route of Rada S. Francesco-Villa S. Giovanni, 0,0079 collisions/year on the Tremestieri-Reggio Calabria route, 0,048 collisions/year on the Tremestieri-Villa S. Giovanni route and 0,012 collisions/year on the route of Messina-Salerno; the potential risk due to the intersection among the merchant ships along the Ionian-Tyrrhenian direction and the ships crossing Messina Straits is higher and equal to 0,089 collisions/year per direction. In conclusion the expected value of accidents per crossing point is estimated equal to 0,312 collisions/year.

The condition of overtaking takes place when the ships are navigating along the same direction but with different speed. Assuming the probability to lose the control P_c equal to $2*10^{-4}$, as suggested in some literature studies (Kristiansen 2005, p. 144), it has been calculated a greater probability of risk along the Ionian-Tyrrhenian route (0,004 collisions/year for direction), followed by the Messina-Reggio Calabria route (0,0029 collisions/year). The expected number of accidents estimated for overtaking in the Sicily/Calabria way is 0,0049 collisions/year and in the whole area of the Straits is equal to 0,0129 collisions/year.

The total risk of accidents in the area of the Straits is finally obtained by the sum of the risks for the three typologies of accident for all the examined routes; it has been obtained a value equal to 0,36 collisions/year, very similar to the average value of 0,32 collisions/year really found out with reference to the last 22 years.

Scenarios analysis

Scenario 1 hypothesized that the VTS, a monitoring and traffic control system designed to improve the safety and efficiency of navigation, safety of life at sea and the protection of the marine environment, is fully working. The variable influenced by the hypothesis of functioning of the VTS system is the loss of control P_c. In the simulation, in fact, it has been reduced of 50% on every route, because, since the traffic has been constantly monitored by radars and communication units, the possibility to lose the control should be reduced to the least.

In this hypothesis, the expected value of head-on collisions is equal to 0,018 collisions/year, a value of 0,156 refers to accidents due to intersection among the routes and 0,004 collisions/year are due to overtaking, for a total of 0,18 collisions/year, that represents the halved value compared with the risk of collisions obtained for the present situation.

In a second scenario the hypothesis was about an increase of the 30% of the maritime traffic between Calabria and Sicily, considering the increasing integration level between the cities of Reggio Calabria and Messina, and of 50% in the direction Ionian-Tyrrhenian, in virtue of the important role of the Mediterranean and the straits area, in particular the role of the port of Gioia Tauro, center of commercial exchanges with the European Countries and transit for the goods coming from the Asian Countries.

In the considered case, the parameter that differs in comparison with the present situation is Q, the number of ships per time unit. From the analysis, it was derived that the expected number of head-on collisions is equal to 0,061 collisions/year, the accidents due to the intersection of the navigation routes are equal to 0,561 collisions/year and overtaking events are equal to 0,012 collisions/year; in total it has been calculated a risk of 0,634 collisions/year, almost double in comparison with the present situation.

The third scenario is an overlap of the previous two; it is contextually hypothesized that the VTS system is operative and the increase of the transport demand. It has been calculated a risk of frontal collision equal to 0,030 collisions/year, 0,281 collisions/year due to intersection among the routes and 0,006 collisions/year due to overtaking, for a total of 0,317 collisions/year.

4.3. Comparative framework

In the application of the Kristiansen models to the Messina Straits it has been stated that the total functionality of the VTS system has a great influence on safety; in fact the possibility of the considerable decreasing of the loss of control P_c of a ship during the navigation, implies a consequent reduction of the potential number of annual collisions.

The difference in the number of annual collisions between the present scenario and the scenario with VTS system is underlined in the fig.6. In comparison with the probability of the risk estimated for the present condition, it has been observed a variation of the risk equal to -50% in the scenario 1, +77% in the scenario 2 and -11% in the scenario 3. In the last hypothesis, the introduction of the VTS system compensates the increase of the maritime traffic in the Strait and the risk is however lower than the one estimated in the present situation.

It is important to notice that the component of greater risk is that connected to the numerous crossing points; therefore a strategy to reduce the risks of accidents can be that of reducing the number of routes in the Straits area.

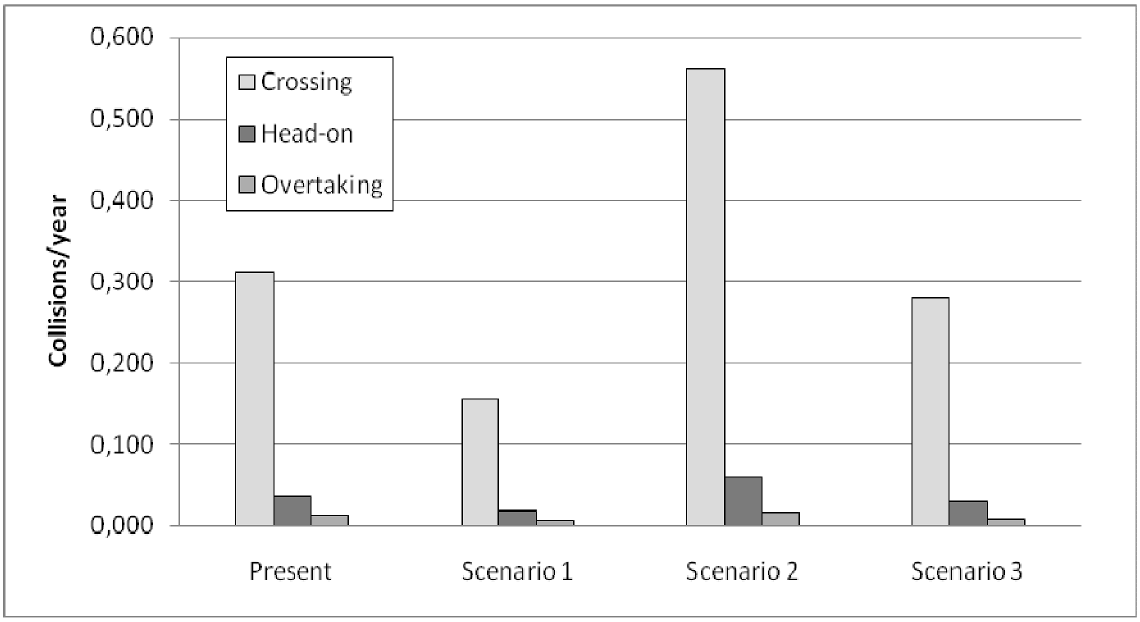


Figure 6: Comparison among scenarios.

5. Simulation of the maritime transport system in the area of Messina straits

The analysis of the mobility phenomena on a maritime network is possible with the aid of simulation instruments (Cascetta, 2001; Gattuso and Rinelli, 2004). These are very important because they allow to obtain various indicators of transport system performance, but also to analyze the effects produced on such indicators by alternative system configurations (project scenarios).

Using the model as a study tool and the results of the investigation on the mobility (calculations, O/D investigation) as a database, it is possible to evaluate consequential effects of planning interventions, as the variation of the flows on the single lines, the variations of the route times for the different connections, the impacts on the costs supported by the community, also in terms of externality.

As concerns the simulation of the maritime transport system in the area of the Messina Straits it has been resorted to a micro-simulation approach. After the construction of the network it has been implemented a specific model that allows to simulate the flow of the ships and the mutual interactions in the area of the Straits, beginning from behavioral hypothesis on the single vectors and on the navigation rules.

For the construction of the network 6 basic port nodes (3 on the Calabrian coast, 3 on Sicilian coast) have been individuated plus other two representing the directions of the North-South flows. The lines correspond to segments of the routes followed by the ships that operate in the Straits (fig.7). The network is made up of 17 nodes and 43 lines with 162 km of lines in total.

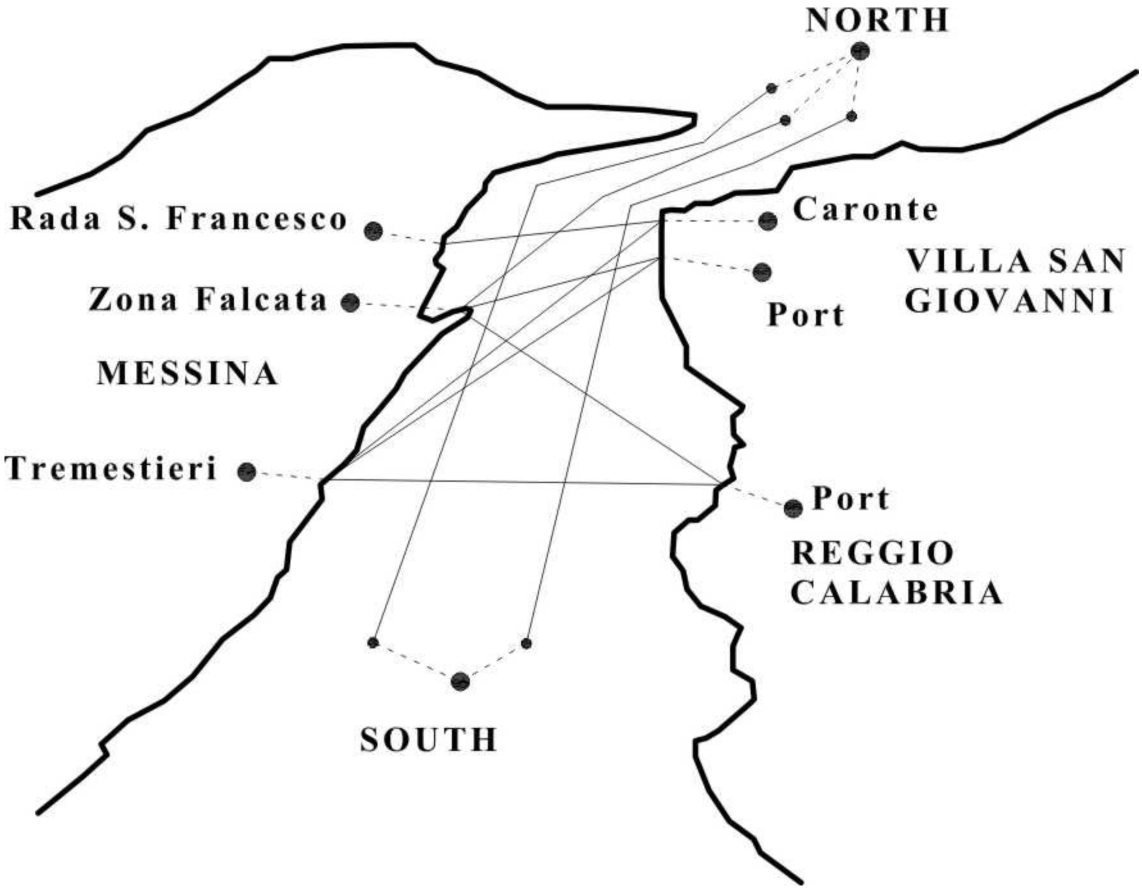


Figure 7: Network of Messina Straits.

It has been built an O/D matrix considering the flows in terms of runs/day which take place along every origin/destination couple.

According to the investigation, the line with the greatest number of crossings is the route which links the port of Villa St. Giovanni with the port of Messina; along this maritime line there is the company Bluvia with two typologies of ships (ferries and ro-ro ships) for a total of 151 runs/day. Among the ports, those mostly congested are Messina Zona Falcata with 226 runs/day and the port of Villa S. Giovanni with 222 runs/day, Villa S. Giovanni Caronte with 142 runs/day and Messina Tremestieri with 136.

The micro-simulation, that has been carried out using a specialized software (AIMSUN), allows to represent and to analyze the intersections among the navigation routs like road intersections under uncontrolled conditions (in absence of traffic light regulation), assuming as the only element of regulation the obligation to give way to the ships coming from the right, as specified in the ColReg 72.

The different typologies of operative ships are defined in fig.8, each of them with its own characteristics (length, width, speed, etc.).

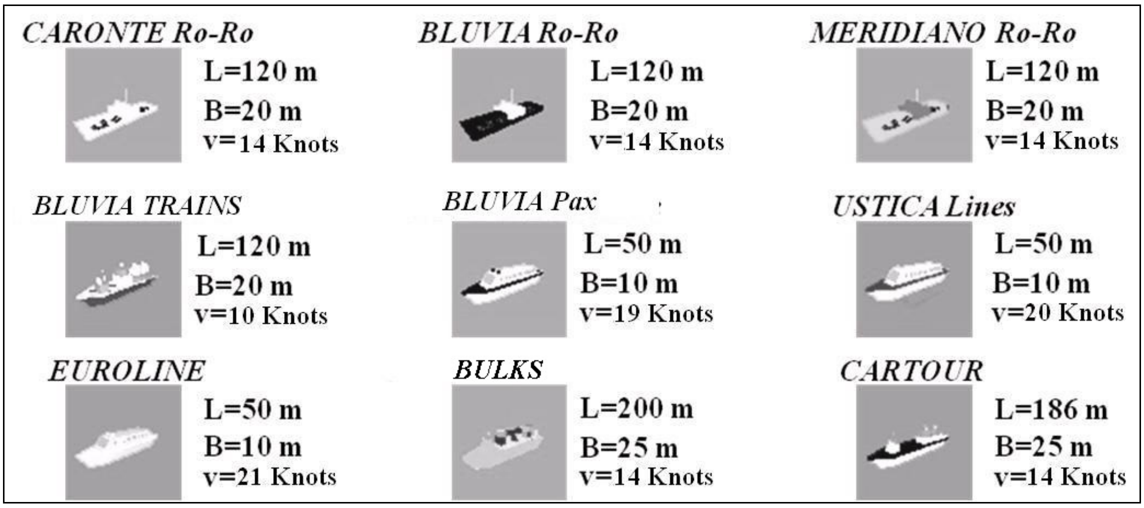


Figure 8:– Characteristics for ships.

For the present scenario it has been considered the official timetable (period: May 2007) given by the navigation companies which operate on the Messina Straits.

The simulation produced different performance indicators as flow, density, speed, trip time, total trip time, total distance and delay experienced by the fleet. These results offer some interesting data in order to evaluate the performance of the maritime services in the Messina Straits.

Considering the increasing trend of traffic between Sicily and Calabria, threes future scenarios and their consequent results have been recognized and simulated. The assumed scenarios correspond to an increase of 30%, 50% and 100% of traffic between Sicily and Calabria.

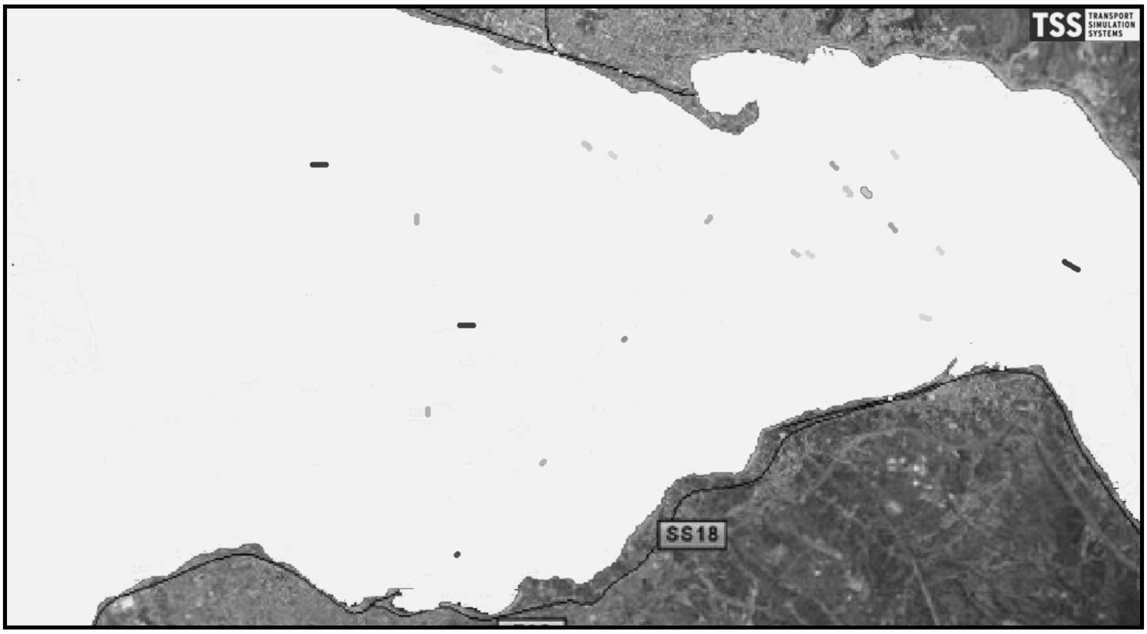


Figure 9: Interactive simulation

From the video simulation it is possible to notice how the increasing traffic during the day creates a considerable number of interactions among the ships and this influences the safety factor. Fig.9 shows the situation that would occur in the rush hour (7:00-

8:00) considering the hypothesis of doubling the flows between the two regions. At 8 o'clock in the morning it has been recorded the contemporary presence of 21 ships on the network.

The density of the ships in the Straits area is a very important parameter that can modify different factors such as the level of control (P_c) and the visibility. To quantify the vehicular density it has been considered a particular area, that is the same as in the simulated network, equal to about 80 km². During the simulation it has been calculated the average density in the rush hour (7:00-8:00) for the different four scenarios; the density increasing is in direct proportion with the increasing of the flows (respectively 0,100, 0,125, 0,150, 0,300 ships/km^2).

Then it has been considered the corridor with the most intense traffic, that is between Villa St. Giovanni and Messina, calculating the density on a reference area of about 15 km^2 (fig.10).

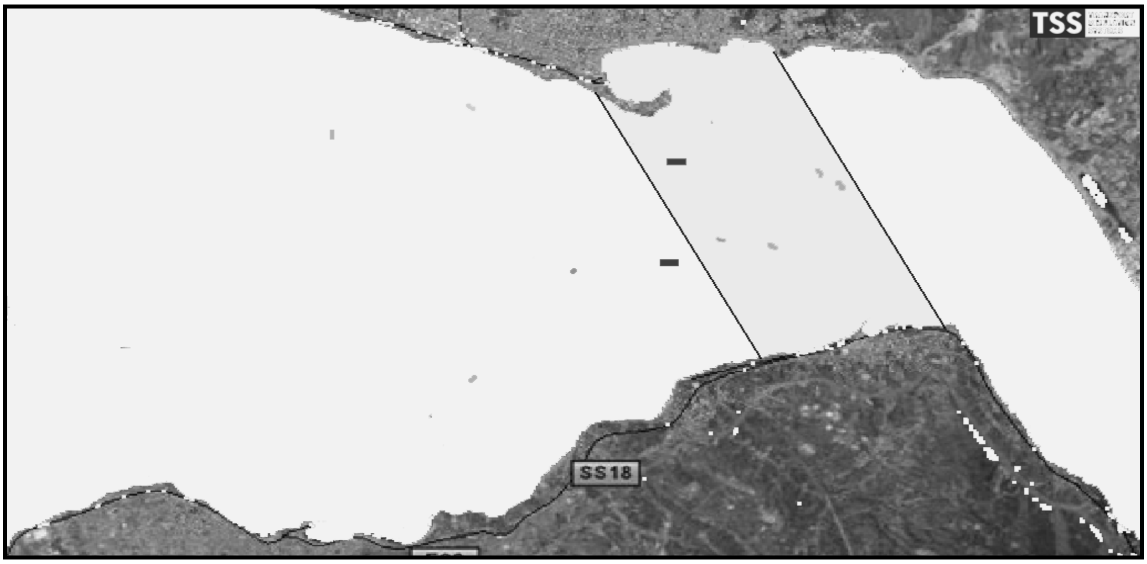


Figure 10: Corridor Messina –Villa S. Giovanni.

The density values are very high (respectively 0,26, 0,34, 0,40, 0,53 ships/km^2) and this represents the critical element of this route. Comparing these values with those resulting from the whole area in which the network has been built, it has been inferred that about 50% of the ships are concentrated in the Messina-Villa S. Giovanni corridor.

The peaks of density have been recorded in the morning time band (from 7:00 to 10:00) and in the afternoon (from 14:00 to 17:00).

The day delay suffered by the fleet is the effects of congestion amounts to 2 hours, at the present situation, in comparison with the total trip time in absence of interferences (about 200 hours). The delay for the users can increase in some particular conditions as bad meteo climate or very moved sea.

Then the simulation of the rush hour (7:00-8:00) has been carried out observing the number of times that the vehicles are found in a potential situation of collision (intersection, frontal passages, overtaking). For the calculation of P_a the values derived by the analytical model of Kristiansen have been adopted for the different routes and typologies of collision. It has been considered a P_a value, for every typology of interaction, as the average value of all the values calculated for every route and typology of collision (tab.1).

Table 1: Values of P_a.

Interaction	P_a *(coll/event)*
Crossing collision	$69{,}00 \cdot 10^{-7}$
Head-on collision	$6{,}37 \cdot 10^{-7}$
Overtaking collision	$5{,}87 \cdot 10^{-7}$

Once obtained the P_a value, it has been estimated the expected number of collisions/year; the results for the present scenario are similar to those obtained with the analytical model of Kristiansen (2005). Fig.11 proposes a synoptic diagram of the results for the different scenarios.

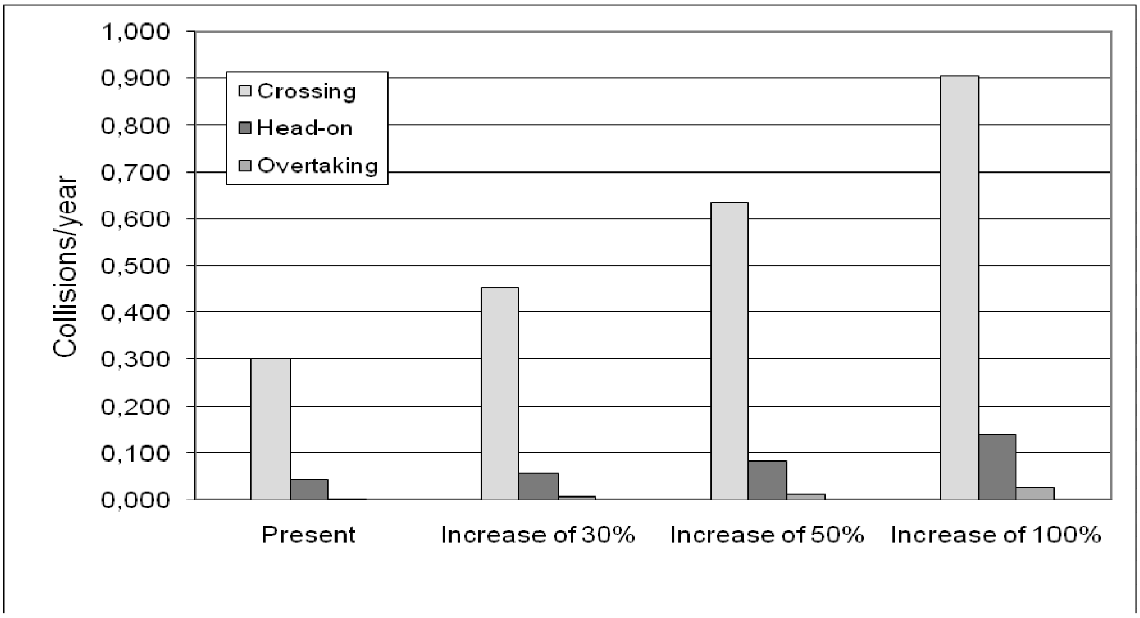


Figure 12: Risk of annual collisions for different levels of maritime traffic.

5. Conclusions

In this work some analytical models have been applied for the analysis and the evaluation of the frequency in the case of maritime transport systems; a specific application has been carried out with reference to the area of the Messina Straits, characterized by maritime transport services of middle-high frequency, and therefore with a high degree of risk, simulating both the present situation and some alternative scenarios, coming to the conclusion that the management of the safety control through instruments of navigation control could involve an effective reduction of the risks of accident, both under the present conditions of traffic, and in the case in which the integration between the cities of Messina and Reggio Calabria contributes to increase the number of daily movements.

The operation of the maritime transport system in the Straits Area has been simulated through a microscopic approach, exploiting the calculation of synthetic indicators.

The study shows that, from the safety point of view, the conditions of the maritime transport services in the Straits area, do not have an optimal configuration; unfortunately this is mainly due to the numerous intersections among the various routes followed by the ships; in fact many points of intersection in limited areas like the one of Messina Straits imply elevated collision risks. By analyzing the connections between Calabria and Sicily it has been recognized the area corresponding to the corridor between Messina Zona Falcata and Villa S. Giovanni as the area with the highest risk.

The use of a fully working VTS system could affect meaningfully safety aspect; in fact by decreasing in a consistent way the possibility of control loss of a ship during the navigation, it has consequent reduction of the risk of collision. A reduction of the risk of accidents could be obtained through the simplification of the net too, or through a reduction of the number of routes in conflict.

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